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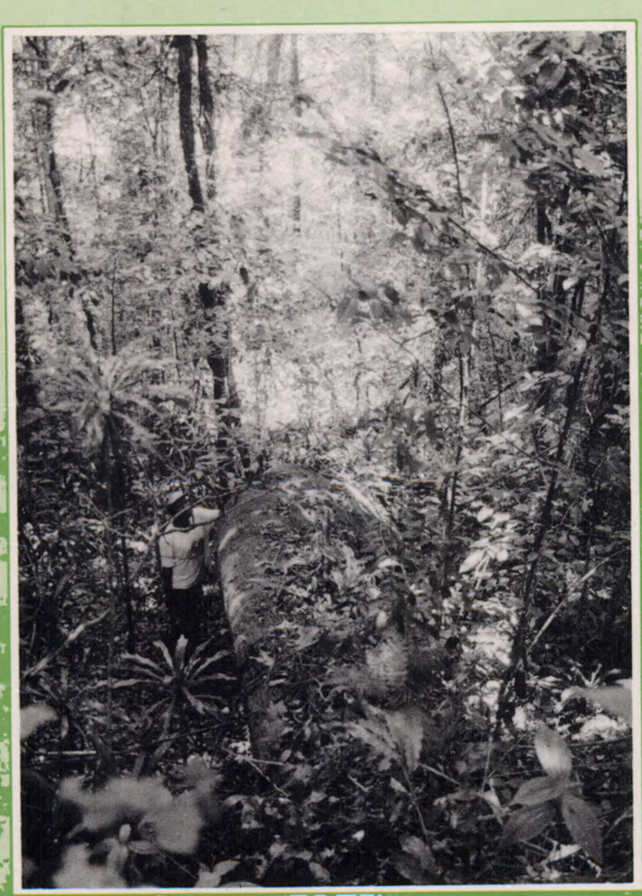
The IUCN Tropical Forest Programme

Forest Conservation in The East Usambara Mountains Tanzania

Edited by
A.C. HAMILTON and R. BENSTED-SMITH



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Forest Conservation in the East Usambara Mountains Tanzania

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IUCN – The World Conservation Union

Founded in 1948, IUCN – The World Conservation Union – is a membership organisation comprising governments, non-governmental organisations (NGOs), research institutions, and conservation agencies in 120 countries. The Union's objective is to promote and encourage the protection and sustainable use of living resources.

Several thousand scientists and experts from all continents form part of a network supporting the work of it's six Commissions: threatened species, protected areas, ecology, sustainable development, environmental law, and environmental education and training. Its thematic programmes include tropical forests, wetlands, marine ecosystems, plants, the Sahel, Antarctica, population and sustainable development and women in conservation. These activities enable IUCN and it's members to develop sound policies and programmes for conservation of biological diversity and sustainable development of natural resources.

The IUCN Tropical Forest Programme

The IUCN Tropical Forest Programme coordinates and reinforces activities of the IUCN members and Secretariat which deal with tropical moist forests. The Programme focuses on the conservation of species and ecological processes, and on investigating and promoting sustainable use of the resources of these forests.

The Programme includes international and national policy initiatives and strategies as well as field projects addressing selected problems in managing the world's most biologically significant tropical forests. These selected projects put the World Conservation Strategy into action by reconciling the requirements of conservation with national development and the needs of people living in forest areas. Special emphasis is given to the development of compatible uses for buffer zones around national parks and reserves.

IUCN develops its positions and policies on the basis of the concerns and information communicated by members, trends identified by monitoring activities, and the feedback from numerous field projects. Data on species of plants and animals, and on tropical forest sites which are important for biological and ecosystem conservation, are held by the World Conservation Monitoring Centre in Cambridge, UK.

This series of publications from the Tropical Forest Programme, in conjunction with regular meetings, enables IUCN to communicate policies and technical guidance to governments, major international institutions, development planners, and conservation professionals. The Programme works closely with development assistance agencies, governments and NGOs, to ensure that conservation priorities are adequately addressed in their activities.

The Tropical Forest Programme receives generous financial support from the Government of Sweden. It is coordinated by Jeffrey Sayer at IUCN Headquarters in Gland, Switzerland. Mark Collins is responsible for tropical forest monitoring at the World Conservation Monitoring Centre.

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The IUCN Tropical Forest Programme

Forest Conservation in the East Usambara Mountains
Tanzania

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IUCN – The World Conservation Union
Forest Division, Ministry of Lands, Natural Resources and Tourism
United Republic of Tanzania

1989

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Published by: IUCN, Gland Switzerland and Cambridge, UK, in collaboration with the Forest Division, Ministry of Lands, Natural Resources and Tourism, P.O. Box 426, Dar-es-Salaam, Tanzania and funded by the Norwegian Agency for International Development (NORAD)

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Citation: Hamilton, A. C. and Bensted-Smith, R. (eds) (1989). Forest Conservation in the East Usambara Mountains, Tanzania. IUCN, Gland, Switzerland and Cambridge, UK. 392 pp.

ISBN: 2-88032-965-5

Printed by: Man Graphics Ltd, Nairobi, Kenya

Design and Layout by: Communications Unit, IUCN Regional Office for Eastern Africa, Nairobi, Kenya

Cover design by: James Butler

Photographs by: Petri Heinonen (PH), David Pratt (DP) and Alan Hamilton (the remainder).

Cover photo: Submontane forest, Kwamsambia Forest Reserve, 980 m.

Available from: IUCN Publications Service Unit,
219c Huntingdon Road, Cambridge, CB3 ODL, UK. or
IUCN Regional Office for Eastern Africa, Nairobi, Kenya

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Section A

Formal Report of the IUCN/Forest Division/NORAD Project in the East Usambara Mountains 1986 – 87

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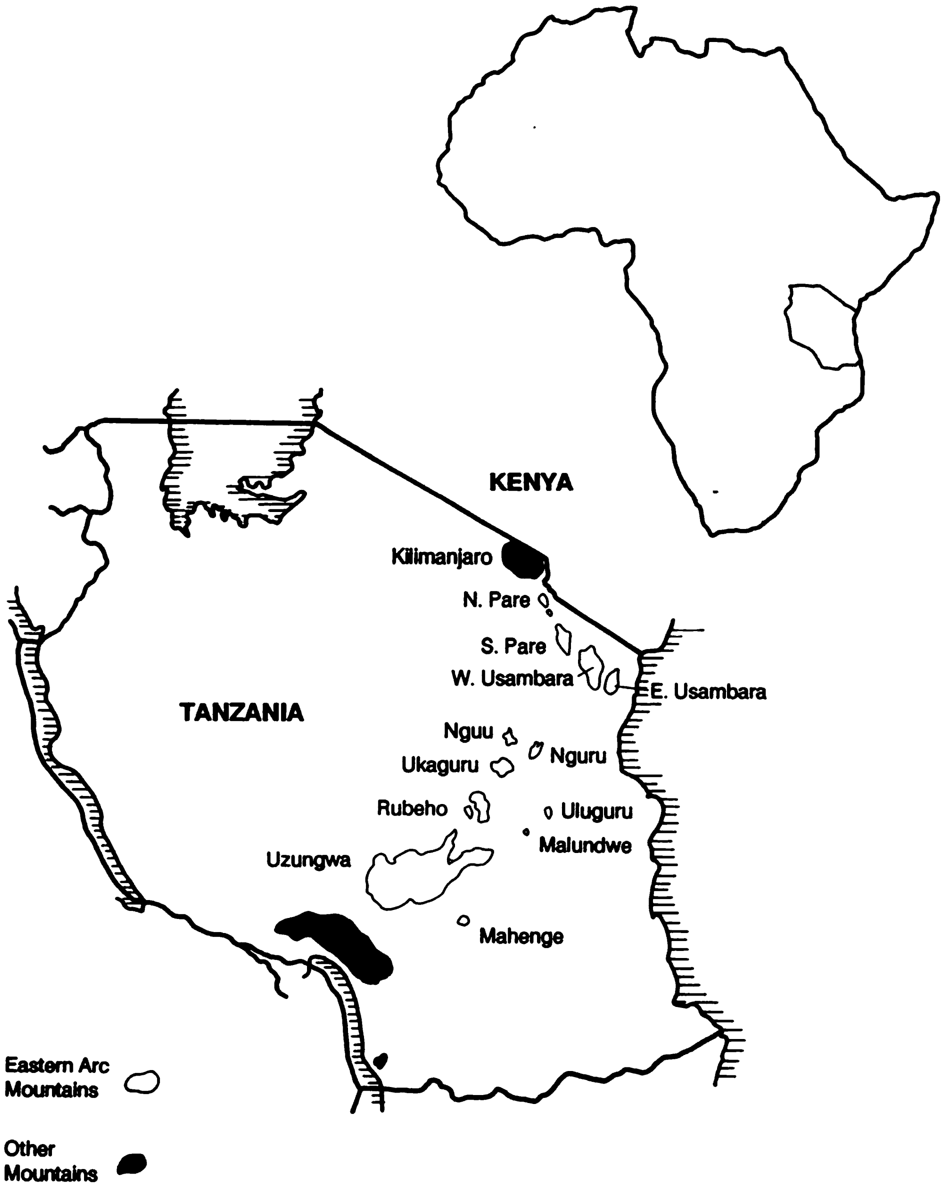

Figure 1.1 Location of East Usambara Mountains within Tanzania.

1. Conservation of the East Usambara Forests

by A.C. Hamilton (Forest Botanist)

Contents

1. Purposes of the IUCN forest work

The main purposes of the work described in this report are to assess the values of the forests of the East Usambaras and to make recommendations for their management. Figs. 1.1 & 1.2 show the location of the East Usambaras within Tanzania; some geographical features are described in Chapter 2. The work is closely related to the Amani Forest Inventory and Management Plan Project (AFIMP) being undertaken by the Forest Division with the help of the Finnish International Development Agency (FINNIDA). The IUCN role is to provide information and advice for the new management plan.

The East Usambara forests lie in an agricultural landscape and their future will be much influenced by the attitudes and activities of the farming community. IUCN and the Tanzanian Government have recently initiated an EEC-financed project to help farmers use the land in a productive and sustainable way, with the further purpose of providing assistance for forest conservation. A subsidiary aim of the present work is to provide information and recommendations useful to this project.

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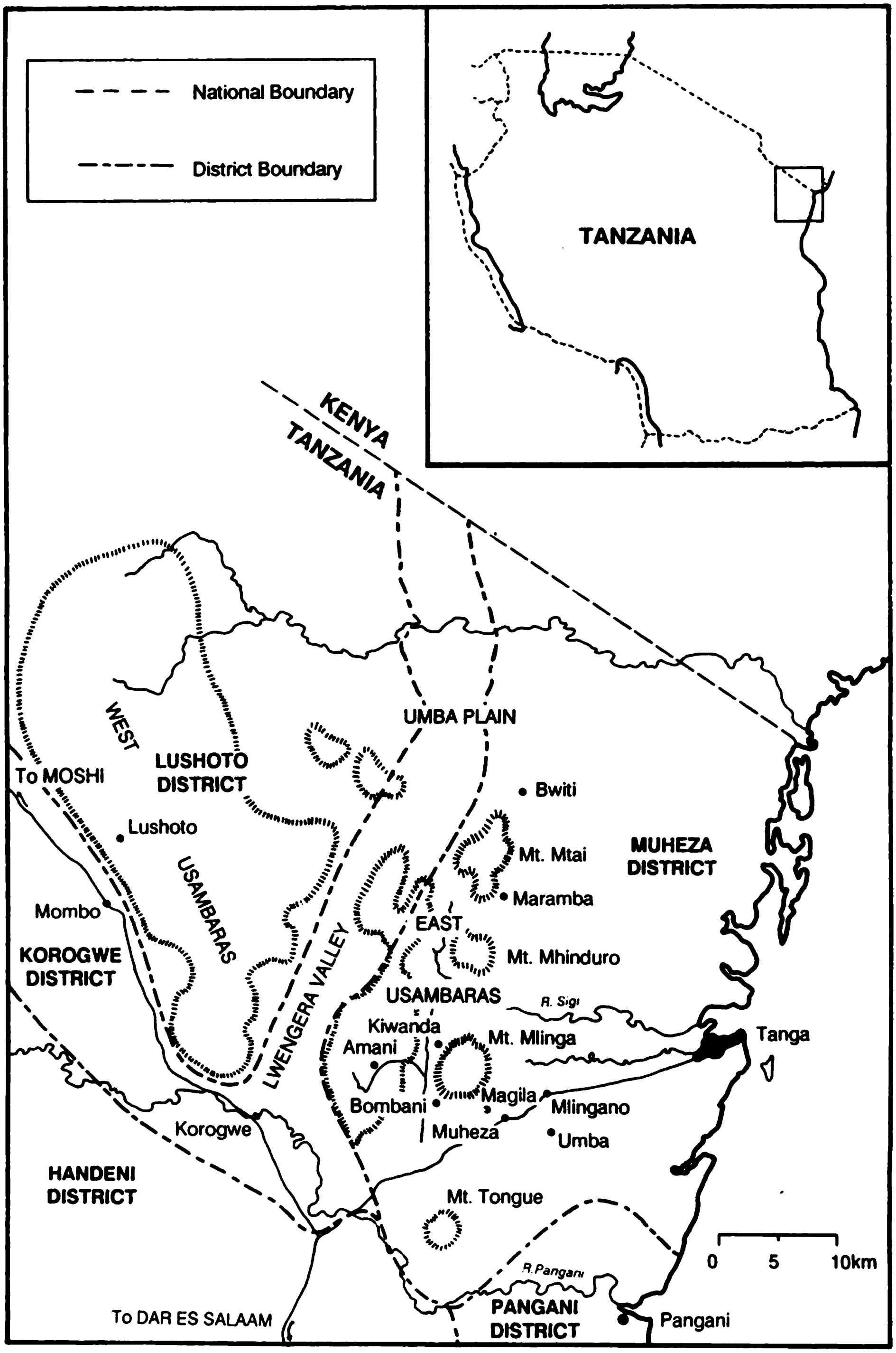

Figure 1.2 Location of the East Usambara Mountains within Tanga Region.

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In greater detail, the objectives are:

- to reinforce the Forest Division/FINNIDA inventory, especially as regards tree identification. Botanists working for IUCN were seconded to help with the inventory from the Tanzanian National Herbarium (Tropical Pesticides Research Institute) and the Silvicultural Research Centre (Tanzania Forestry Research Institute). These were Mr. S. Kibuwa and Mr. C.K. Ruffo, assisted by Mr. R. Abdallah and Ms. C. Mmari respectively.
- to undertake inventories of the rest of the flora and fauna. These were to be carried out by scientists working under the direction of a Forest Botanist, who was required to ensure that all work would be useful for conservation purposes and who was also required to collate previous information. The Forest Botanist was asked to investigate personally forest types on very steep slopes ('inaccessible areas'), which would not be covered by the Forest Division/FINNIDA inventory. He was also requested to carry out intensive surveys of large plots in examples of forest types, to provide more detailed biological records.
- to carry out a study of catchment properties on the East Usambaras, so as to determine which patterns of forest and land utilization are compatible with sound watershed management. This work falls under the direction of a Catchment Specialist, Dr. M. Bruen of the University of Dar es Salaam.

2. Growing awareness of the value of the forests

The government has been aware of the value of forests on the East Usambaras as protectors of the environment (climate, water, soils) since the 1930's (Chapter 5). In 1976 most forest reserves on the East Usambaras were placed in the special category of 'Catchment Forests' in recognition of their environmental importance. Management of such forests aims primarily at protecting catchments, with conservation of genetic resources and the production of timber as secondary objectives.

Although a few botanists and zoologists have been aware of the outstanding biological value of the East Usambara forests for many years, a wider awareness among biologists has only developed during the last ten years. The urgent need for conservation of the forests was stressed at a meeting of the Association for the Taxonomic Study of the Flora of Tropical Africa (AETFAT) in Uppsala in 1966. The theme of the Fourth East African Wildlife Symposium, Arusha, in 1978 was "Ecological Islands and their Conservation", with special attention directed at the East Usambaras. The organisers of this conference, Dr. W.A. Rodgers and K.M. Homewood, carried forward the task of informing and alerting the scientific world further by writing a major article on the biology and conservation status of the East Usambara forests, gathering together much previously scattered information (Rodgers & Homewood 1982).

3. The background and objectives of the IUCN projects

In 1983 Dr. W.A. Rodgers, then the IUCN/WWF Tropical Forest Coordinator in Tanzania, opened discussions with the EEC regarding the possibility of an agricultural and forestry aid project on the East Usambaras. The concept of the project was approved by the Tanzanian Government in 1984.

An IUCN planning team, supported by the EEC, visited Tanzania in June/July 1985 to make a preliminary report. The objective was to examine land-use practices on the East Usambaras, as well as the status of the forests, and to advise on desirable types of aid. The latter ideas were formulated in conjunction with Tanzanian authorities. The team noted that forest reduction was related to the existence of unproductive, non-sustainable agricultural practices and recommended the initiation of an aid scheme to try and improve these practices. Activities in the forestry sector would include support for enrichment planting. It was also proposed to rehabilitate Amani Botanic Gardens.

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The above project (which is not the project described in the present report) received a promise of finance from the EEC and the Food Aid Counterpart Fund and the approval of the Tanzanian Government, and started work on the East Usambaras in early 1987.

Meanwhile, in early 1986, the Forest Division, in association with FINNIDA, was about to embark on field work for an inventory of the East Usambara forests (the third such inventory in a decade). IUCN agreed to assist this inventory, especially with tree identification; the concept of an IUCN project to help evaluate the forest resources of the East Usambaras was born. Field work for the Forest Division/FINNIDA inventory was to be between June 1986 and Febuary 1987, with the resulting report and forest management plan ready by the end of 1987.

Funding for the IUCN forest project was provided by the Norwegian Agency for International Development (NORAD). Field work commenced in June 1986 and continued through to June 1987. The present report is that of the forest project.

4. Related projects dealing with conservation of the East Usambara forests

Many organisations work in the East Usambaras. These include Tanzanian government bodies dealing with land-use and the environment, such as the departments of agriculture, forestry, water and livestock. Foreign-assisted organisations include the Tanga Integrated Rural Development Programme (TIRDEP), involved, as the title suggests, with many areas of development, but much more active on the West, than the East, Usambaras.

4.1 The Integrated Usambara Rain Forest Project

This project commenced work on the Usambaras in 1983. Its aims are to investigate the forest flora of the mountains (West and East Usambaras) and to identify places of biological importance. It is a joint Tanzanian/Swedish/Hungarian project, the main associated institutions being the Faculty of Forestry, Sokoine University (Prof. T. Pocs), the Tanzania National Herbarium (Mr. W. Mziray) and the Department of Systematic Botany, Uppsala University (Prof. O. Hedberg, Mr. S. Iversen). Forests on the East Usambaras were visited by members of the project during 1986 and 1987. The IUCN forest project and the Integrated Usambara Rain Forest Project exchange information and ideas.

4.2 Joint Tanzanian-Nordic Forestry Review Missions

Nordic countries are actively involved in assistance to the forestry sector in Tanzania, including in catchment forestry and higher forestry education (especially Norway), agroforestry (especially Sweden) and wood industries (especially Finland). A series of review missions involving visits and discussions have been arranged. The fourth of these toured the East Usambaras in 1984 and made various recommendations, including that the forests of the East Usambaras should receive priority in future forestry planning (Ahlback 1986; Ahlback *et al.* 1984).

5. Logging, FINNIDA involvement and growing criticism

Logging has been carried out in the East Usambara forests since German times, but it is thought to have been on a large scale only since the 1960-70's. By the mid-1970's only one sawmill remained operating in the higher altitude (submontane) forests, Sikh Saw Mills (T) Ltd (SSM). SSM was by then a nationalized company, a subsidiary of Tanzania Wood Industries Corporation (TWICO). During the early 1980's 80% of the logs used by SSM were coming from submontane forest. Logging was highly selective, with one species in particular, mtambara (*Cephalosphaera usambarensis*), being very important. Logging was proceeding at the rate of one hectare a day and was directed at 'intact' (unexploited or little exploited) forest, where the desired species still remained. Products made by SSM include timber and plywood, the latter mainly for tea-chests.

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SSM has been receiving aid from FINNIDA through consulting companies (in 1987 Ekono) since 1977. This has taken the form of assistance with management advice and equipment, the latter including bulldozers, skidders, lorries, chain-saws and a high capacity peeler to produce plywood. Since 1985 aid for new equipment has taken the form of import support i.e. SSM finds Tanzanian currency for foreign purchases, with FINNIDA supplying the necessary hard currency.

Two inventories were carried out by FINNIDA, again using a consulting company, Jaakko Pöyry, in 1977 and 1983. The first survey covered all parts of the forest except for those regarded as 'inaccessible' (to mechanical loggers); the second was confined to Kwamkoro Forest Reserve. The conclusions of these surveys were that there was plenty of timber available in the forests, and this provided a green light to SSM to continue with active logging.

Perhaps because of their terms of reference, the Jaakko Pöyry inventories have been widely criticized for:

- assuming that all 'accessible' forests were available for logging, with little regard being given to other values of the forests.
- assuming that logging in the forest would be by SSM, who seem to have acquired a 'right' over government forest reserves, rather than seeing the forests as clearly under the control of the Forest Division.
- overestimating the volume of wood which would be harvested. Available volumes of commercial species were given as 183 $m^3 ha^{-1}$ and 110 $m^3 ha^{-1}$ in the two inventories, though in fact, because of logging practices, SSM only removes 25 $m^3 ha^{-1.}$
- guessing the length of the cutting cycle (time between felling at any one site) to be 35 years, without providing any evidence for this figure or specifying systems of silviculture.

During recent years SSM and FINNIDA have come under much criticism for their activities in the East Usambaras. Adverse articles have appeared in the New Scientist (1985), Oryx (1985), the Tanzanian Daily News (1987), the Danish paper 'Information' (1987) and the Finnish daily 'Helsingin Sanomat' (1986). Questions have been raised as to why logging was taking place at all in such environmentally valuable forests, why the standards of the logging were so low, and why FINNIDA was involved in environmental degradation.

The Director of FINNIDA replied to these criticisms, stating that FINNIDA shared concern over environmental destruction on the East Usambaras, but that logging would continue until the results of the new, more broadly based, inventory became available (Helenius 1986). He defended the continuation of logging on the grounds that:

- SSM directly or indirectly supported 4,000 people.
- the products provided by the factory were needed, especially plywood for the manufacture of tea-chests.
- forest destruction would continue anyway (through agricultural spread and pit-sawing).

In May 1986 logging on the East Usambaras was temporarily suspended by the Forest Division as a result of concern expressed about the forests.

6. The Amani Forest Inventory and Management Plan Project (AFIMP)

In the light of doubts about the conclusions of the 1977 and 1983 inventories and the wisdom of continued logging, the Forest Division and FINNIDA decided to undertake a new inventory with the aim of producing a new forest management plan. New consultants, Finnmap and Silvestria, were to be employed by FINNIDA to work on the inventory. Plans were drawn up in 1985 and an aerial survey flown in January/February 1986. Fig. 1.3 shows the extent of forest on the East Usambaras according to an interpretation of aerial photographs resulting from this survey. Field work was carried out between June 1986 and February 1987. Fig. 1.4 shows the forest reserves.

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The new inventory was to be more environmentally sensitive than the earlier inventories. All trees, not just timber trees, were to be recorded, so as to gain a better idea of the distribution of forest types and rare species. IUCN was asked to assist with the identification of trees and to provide information useful for formulating management recommendations.

The aerial survey revealed a total of about 22,000 ha of forest, a figure which excludes some, mainly scattered and degraded, forest patches. Of the 22,000 ha of forest recognized, only 1,000–4,000 ha appeared to be 'intact' (not or little exploited). It was appreciated that this was likely to be an overestimate, since it was known that substantial parts of the forest had been underplanted with crops, particularly cardamom, and that this was often not visible on aerial photographs.

Substantial blocks of forest on steep slopes ('inaccessible areas') were excluded from the inventory because they were regarded as unsuitable for exploitation. With further areas not surveyed because of very steep slopes encountered during field work, the total area of forest covered by the inventory was 14,976 ha. The total area of 'inaccessible forest' was 8,125 ha.

Plantations of hardwood trees in the south-east of the main range were included in the inventory, in recognition of their suitability for logging.

7. Logging and related developments, June 1986 — July 1987

AFIMP is supervised by a Board with membership drawn from the Forest Division, TWICO, SSM, FINNIDA, Silvestria, IUCN and other interested parties. This board has met from time to time during 1986 and 1987.

At a meeting on 1 July 1986 the Board granted permission to SSM to resume operations on the East Usambaras for a period of 18 months "in view of the apparent raw material constraints and general lack of concrete planning information". This was supposed to provide a breathing space, giving SSM the opportunity to adjust its operations to use other raw materials and to allow its staff a chance to move. Logging resumed in Kwamkoro and Kilanga Forest Reserves. The Board also established a Monitoring Group to report on the standards of logging.

When the Forest Botanist first arrived on the East Usambaras, in July 1986, he visited the logging site in Kwamkoro Forest Reserve (and also that in Kilanga Forest Reserve) and confirmed that standards of logging had been very poor during the recent past:

- Many trees had been felled within 50 m of streams (which is against regulations).
- Logged areas were often left very open, allowing massive invasion of an introduced, fast-growing tree, *Maesopsis eminii*, and little chance for 'desirable species' to become established or otherwise grow successfully. The chance of being able to relog the forest after 35 years, as envisaged by Jaakko Pöyry, seemed remote, with little likelihood of a fresh crop of desirable trees, such as *Cephalosphaera*.
- The direction of tree-felling was haphazard, resulting in much felling damage, for example the splitting of trunks when trees came down across valleys.
- Roads were very poorly constructed, involving massive earth movements by inappropriately heavy machinery. The density of roads was very high, often with a track to every felled tree, their gradients were often very steep and their construction sometimes involved the damming of streams, resulting in flooding and the death of trees.
- The heavy trucks used by SSM degraded public roads, sometimes causing serious problems to other users, including the tea-estates, which use much smaller vehicles.

The standards of logging and forestry on the East Usambaras have not always been so poor. It is obvious from visiting others parts of Kwamkoro Forest Reserve that standards of road construction have declined greatly in recent years. Before the 1980's the Forest Division did engage in some post-logging silviculture, including enrichment planting and slashing.

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A meeting of the Monitoring Group on 29 August 1986 noted that there had been improvements in logging standards over the previous few weeks, although it was obvious that selective logging by mechanical means in tropical rain forest could not be carried out without causing considerable damage. Some bad practices remained, including the removal of some unstamped logs (trees to be felled should be selected and marked by Forest Division officers, who are also supposed to mark, at the felling sites, all logs coming from these trees). There was still the occasional construction of over-steep roads (IUCN 1986). It was disturbing to find SSM logging outside their designated logging area in Public Land near Kilanga Forest Reserve (this was then stopped).

In a preliminary report written in October 1986, IUCN (1986) pointed out that logging at the rate of 1 ha day^{-1} in the remaining rather small area of accessible intact forest would seriously deplete the area of such forest over the next 18 months, which was the period given to SSM for continued logging. From analysis of aerial photographs, FINNIDA had estimated that only 1,000–4,000 ha of 'intact' forest remained (including in areas 'inaccessible' to the loggers); according to their Logging Programme, SSM expected to log 490 ha of forest between July 1986 and December 1987. In Kwamkoro Forest Reserve, as an example, more or less all the remaining area of intact forest would be lost.

At a meeting of the Supervisory Board of AFIMP on 22 October 1986, SSM agreed to stop logging in 'mountain forests' on the East Usambaras by 31 December 1986. It was stated that during the next period logs would be obtained from the lowlands through private contractors and that no logging would be undertaken on Mt Mtai. There was no mention that trees would be felled and logs collected from Kwamsambia Forest Reserve. Logging by SSM did indeed cease in Kwamkoro Forest Reserve and in the Kilanga area (at the north end of the range) before 1 January 1987.

At a meeting of the Supervisory Board of AFIMP on 14 January 1987, it was stated that SSM would obtain 53% of its logs from the lowlands, mainly from sub-contractors operating in the Muheza area, 35% from the West Usambaras (softwoods) and 12% from teak thinnings from Longuza (where there is an extensive teak plantation).

At this meeting IUCN pointed out various reasons why the lowland forest at Kwambsambia was of great value for genetic conservation, including:

- that for conservation of genetic resources it was important to set aside examples of all major forest types (lowland forest is actually very endangered in eastern Tanzania).
- that lowland Kwamsambia adjoined the largest and most species-rich area of intact submontane forest on the East Usambaras (in Amani-Sigi, Kwamkoro and the upper part of Kwamsambia Forest Reserves) (Chapter 24).
- that it was easier to manage one large area of forest as a nature reserve than many small areas scattered around the mountains.
- that lowland forest should be retained near the important submontane forest in Amani-Sigi and neigbourhood, so as to preserve the integrity of the whole ecosystem. It was known, for example, that some species of birds move altitudinally between lowland and submontane forests during the course of the year (Chapter 35).

In January or February 1987 SSM started to clear-fell the lowland part of Kwamsambia Forest Reserve and to remove logs. It was planned to clear 100 ha per year for five years, making a total of 500 ha. It was explained that this was not an initiative of SSM, but rather that SSM were taking advantage of an existing Forest Division plan to clear the lowland forest at Kwamsambia and plant teak.

A meeting of the Monitoring Group was held in Kwamsambia Forest Reserve on 8 May 1986. The following arguments were advanced by the Forest Botanist against the clear-felling of lowland forest at Kwamsambia:

- It is specious to say that the clear-felling is following a management plan, in that the management plan referred to (that for the Longuza plantations) has not been followed, so

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far as teak planting is concerned, since 1979. Clear-felling is a drastic step to take when new management proposals are in the process of being formulated.

- There was Forest Division land available elsewhere for teak planting (500 ha at the north end of Longuza Forest Reserve).
- No thinning of existing teak had been carried out for some time. Is it wise to plant more teak, while that already existing is not being properly tended?
- The desirability of including the lowland part of Kwamsambia in a nature reserve was re-emphasized.
- It is against Forest Division policy to replace good natural forest with single-species plantations.

The Monitoring Group agreed that logging should cease, but that the area already cleared (about 45 ha) should be planted with teak.

At a meeting of the Supervisory Board of AFIMP on 3 June 1987 it was agreed that clear-felling at Kwamsambia should indeed not proceed. It was agreed that the lowland part of Kwamsambia Forest Reserve should be incorporated into a nature reserve which should also embrace the rest of Kwamsambia, Amani-Sigi and the unlogged parts of Kwamkoro. The Forest Division confirmed that it is against its policy to replace good natural forest with monospecific plantations.

It was also agreed that Forest Division would soon supply a survey team for resurvey/regazetting of forests on the East Usambaras.

The future of the Monitoring Group was discussed and it was decided to re-establish the group to examine the problems of pit-sawing.

IUCN is concerned about a further aspect of logging by SSM during the first part of 1987. The system by which SSM obtains timber through sub-contractors is unsatisfactory, as it removes responsibility for proper logging from the sawmill. Under this system, chain-saws have been issued to subcontractors, who then are responsible for obtaining the necessary felling licences and who report back to SSM when logs are ready for collection.

8. IUCN programme of work and achievements, 1986—87

8.1 Help with tree identification for the Forest Division/FINNIDA inventory

An initial training course for the inventory's 'forest botanists' was provided by Mr. J. Lovett and Mr. C.K. Ruffo. Some further assistance was provided by IUCN botanists accompanying the inventory field crews during recording. The 'local botanists' were villagers recruited to name the trees during the inventory work, while the Forest Division and FINNIDA workers concentrated on measuring the trees, noting environmental features and compiling the records. The bulk of this IUCN work fell on Mr. C.K. Ruffo, assisted by Ms C. Mmari. Mr. R. Abdallah collected specimens for identification by Mr. S. Kibuwa, who was often unable to be in the field due to ill-health.

Conclusions on the accuracy of tree identification achieved in the inventory are given in Chapter 24. It is thought that the results of the inventory are acceptably reliable for trees familiar to the 'local botanists', usually useful trees. On the other hand, it is thought that the method of inventory, with its emphasis on a high density of sampling and hence speed, is unsuitable as a means of recording the distributions of the many trees unfamiliar to local villagers. In future, where knowlege of the distribution of unfamiliar (non-useful) trees is required in a Tanzanian forest, it would be better to employ the services of competent professional botanists, even at the cost of covering a much smaller area.

8.2 IUCN help with analysis of inventory results

IUCN requested various analyses of the inventory results, including a numerical classification of the forests by the TWINSPAN method (Chapter 24). The TWINSPAN results showed that:

- The forest is altitudinally zoned, with, for example, a series of forest types replacing one another with increasing altitude in Kwamsambia and Amani-Sigi Forest Reserves.
- The higher altitude (submontane) forests at the south end of the main range are the richest floristically.
- There are floristic differences between the lowland forests on the main range, notably Kwamsambia, and those further east (e.g. Marimba and on Mt Mhinduro). Kwamsambia seems to have more species (though a contrasting results given by an analysis of floristic records (Chapter 23) and further research is needed).

8.3 Variable-area tree survey (Chapter 22)

Initial instruction in this method was given in the field to the Forest Botanist by Mr. J. Lovett and the method was then used to examine forest composition along three altitudinal transects. These transects were sited basically in 'inaccessible areas', as required by IUCN (Section 1), but, in view of the perceived limitations of the inventory regarding the identification of unfamiliar trees, it was decided to extend them to cover the full altitudinal range of forests. Field work took place over two months and only 65 plots were sampled, due partly to the large amount of time necessary to ensure reasonable accuracy in tree identification. Either Mr. J. Lovett or Mr. C.K. Ruffo was present to assist with tree identification when nearly all of the plots were sampled.

The results show that there are two main types of forest on the East Usambaras; these may be termed lowland forest and submontane forest. The two forest types intergrade. Analysis of the distributions elsewhere of species found on the East Usambaras shows that many (about 40%) are only present within a belt of land 50 – 100 km wide running down the coast of East Africa. Many submontane species have very restricted distributions within this East African coastal forest belt, since there are very few places with climates suitable for their growth.

8.4 Intensive sampling of forest types

Following instructions given to the Forest Botanist (Section 1), six large sample plots were placed along catenary sequences in undisturbed or little disturbed examples of lowland and submontane forests and studies made of vegetation structure and the floristic composition of the tree strata (Chapter 25), understory vegetation (Chapter 28), seed banks (Chapter 29), soil arthropods (Chapter 32) and soil profiles (Chapter 10). Floristic diversity and biogeographical relationships were examined (Chapter 25).

The results show that lowland forest has many deciduous trees and is of lower stature than the very tall evergreen submontane forest. There is a major difference in the species composition of the tree strata between lowland and submontane forests (Chapter 25).

The number of tree species per unit area is similar in all six plots. Many species occur at low densities, indicating that, if areas are set aside for genetic conservation, they should be large.

Among understory plants, there are many more endemic species in submontane forest than in forests rich in *Maesopsis* (Chapter 28).

Seed banks in the forest plots proved to contain considerable numbers of seeds of pioneer trees, climbers and herbaceous species and very few seeds of primary forest trees, even though the plots were situated in undisturbed or little disturbed forest (Chapter 29). Viable seeds of pioneer species, including the introduced *Maesopsis* and *Clidemia*, are abundant and widely distributed in the soils, ready to take advantage of gaps in the forest when they appear, for example through logging.

Many oribatid mites collected from soils in the submontane forest plots proved to be new to science (Chapter 32), providing further evidence that the East Usambara forests are very rich in endemic and near-endemic species (Chapter 34).

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Permanent sample plots were not established by IUCN (as had initially been requested) due to shortage of time. Two permanent plots were established by the inventory team, with help in tree identification from Mr. C.K. Ruffo.

8.5 Survey of forest herbaceous communities (Chapter 26)

A survey of variation in herbaceous vegetation in the forests was carried out along two altitudinal transects in conjunction with part of the variable-area tree survey. The results show that herbaceous vegetation is altitudinally zoned, with the floristically richest and most endemic-rich community seen being in submontane forest near Amani.

This work provides evidence that other types of organisms, as well as trees, are altitudinally zoned. The results reinforce arguments for setting aside examples of forests at all altitudes for genetic conservation.

8.6 Analysis of the distribution of forest trees on the East Usambaras (Chapter 23)

A list of tree species occurring in the forests was prepared (Chapter 17). Records of occurrence in different parts of the East Usambaras and the wider distributions of species were noted.

The results show that there are about 217 species of tree (10 m or more in height) found in the East Usambara forests. Of these, 33% can be classified as lowland species, 48% as submontane species, 9% as occurring in both lowland and submontane forests and 10% with distributions too poorly known to be classified. The number of strict East Usambara endemics is only 11 (5%), less than previously estimated, mainly due to recent botanical exploration in previously little known forests on other mountains in eastern Tanzania. A comparison of the East Usambara flora with that of these other mountains, collectively known as the Eastern Arc mountains, is given in Chapter 21.

The richest area of submontane forest, including for endemics and near-endemics, is the southern part of the main range, including Amani-Sigi, Kwamsambia, Kwamkoro and the forests around Amani. The largest continuous tract of intact submontane forest is also found within this region, which therefore emerges as the most valuable area of submontane forest in which to establish a nature reserve for conservation of genetic resources.

Lowland forest species seem to be relatively evenly distributed, without a clear centre of species richness, though with an indication that lowland forests to the east of the main range have more species than those on the main range, notably Kwamsambia (a conclusion opposite to that emerging from an analysis of the inventory data – see Chapter 24). Further studies of the floristic composition of the (few) remaining patches of lowland forest on the East Usambaras are needed.

8.7 Assessment of the fauna

A survey of the literature and new collections confirm that the forests of the East Usambaras have many endemic and near-endemic species in many groups of animals (Chapters 34 & 35). Some birds undergo seasonal altitudinal movements, emphasizing the desirability of conserving lowland as well as submontane forests.

8.8 Survey of medicinal and useful plants

Local people use the forests of the East Usambaras for a variety of purposes. Interviews were held with 14 traditional doctors living in a range of ecological contexts (Chapter 20). A list of 185 medicinal species was obtained, of which 63 (34%) are forest plants.

A list of useful forest plants, other than medicinal, was compiled by Mr. C.K. Ruffo (Chapter 19). Many species are used, for many purposes. The collection of firewood and, especially, small trees for construction purposes (poles) are major influences on forest ecology.

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8.9 Soil surveys (Chapter 10)

At a meeting of the Supervisory Board of AFIMP on 21 October 1986, IUCN was asked by the Forest Division to provide information on soil types on the East Usambaras. Topsoil samples had earlier been collected from all 65 plots used in the variable-area tree survey (Chapter 22) and submitted for analysis at the National Soil Service Project, Tanzania Agricultural Research Organisation, at Mlingano. Only pH measurements were carried out on the bulk of these samples, it being explained that many of the samples were 'too small' for the other tests requested (organic matter, exchangeable bases). In view of this, staff of the National Soil Service Project were asked to carry out field sampling and soil description (in addition to laboratory analyses) at seven sites, including the six plots used for profile diagrams (Chapter 25).

The results confirm earlier opinion that there is a big difference between lowland and submontane forest soils. The zone of change was found to lie at 850–900 m (i.e. the greater parts of the escarpments have lowland, not submontane-type soils). Lowland soils were found to be more fertile and much less acidic than submontane soils which are agriculturally very poor and only suitable for growing tea, in the opinion of the National Soil Service. There are catenary differences in the soils (early work had suggested that ridges are the poorest sites for agriculture).

8.10 Climate and climatic change

Climatic statistics for meteorological stations were collected (Chapter 11). It was confirmed (Moreau 1935) that the temperatures on the upper slopes of the Eastern Usambaras are depressed compared with inland Tanzania. A similar depression is probably found on other near-coastal Tanzanian mountains.

At a meeting of the Supervisory Board of AFIMP on 14 January 1987, IUCN was asked to examine recent climatic trends on the East Usambaras. Records for several stations on and near the East Usambaras were therefore studied (Chapters 12 & 13).

Some of the more recent meteorological records from the East Usambaras are unreliable. This restricts the conclusions which can be reached from the data. However, there is some evidence of temperature increase from the mid-1970's, and also an increased number of years with extreme rainfall, especially very dry years, since 1960.

Interviews were conducted with a few long-term residents at Amani and Marvera to ascertain their opinions about climatic change (Chapter 14). They all insist that there has been a major change in climate during the last 10–15 years, with less sustained rainfall, decreased mistiness and increased warmth.

There has been an exceptional number of recent deaths among large trees at one locality where natural tree falls were investigated in Kwamkoro Forest (Chapter 27). The same phenomenon has been reported from Mazumbai Forest on the West Usambaras (Hall 1985). There is a strong suspicion that this is due to climatic change.

There has been a major decrease in the abundance of vascular epiphytes around Amani since 1970 (Chapter 28). This is probably due to decreased atmospheric humidity.

It seems likely that climatic change is responsible for causing alterations to the types of crops which can be grown at higher altitudes on the East Usambaras (Chapter 14) and contributing to the appearance and subsequent serious spread of malaria (Chapter 6).

It is thought that climatic change is partly due to local deforestation. However the decreased reliability of rainfall is regional and can only marginally have been caused by vegetation change on the East Usambaras. Widespread ecological degradation in East Africa could be a contributory factor.

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8.11 Studies of the '*Maesopsis* problem'

Maesopsis eminii is an introduced tree in the Amani forests and has been regarded as a problem because of its perceived ability to invade the forests, displacing other (including rare) species. IUCN was asked by AFIMP to examine the issue.

A seed bank experiment showed that viable *Maesopsis* seeds are present in some soils collected from apparently intact, undisturbed submontane forest (Chapter 29). *Maesopsis* seedlings have been shown to germinate readily when lying within damp topsoil and to be potentially capable of rapidly exploiting gaps created by natural tree falls or human activities (Chapter 27).

The question of *Maesopsis* invasion into natural forest required a study of rain forest dynamics (Chapter 27). This work confirmed that the forest undergoes cycles involving the creation and filling of gaps. *Maesopsis* can readily become established in gaps, is well dispersed by birds, has a very high growth rate in its more juvenile stages and is rather long lived. It is concluded that the species has adaptations enabling it to be an aggressive invader.

There is no doubt from these results, as well as from historical records of the spread of *Maesopsis* and maps of its present distribution (Chapters 24 & 27), that *Maesopsis* is rapidly invading the forests, including the 'intact' forests. It is starting to spread into new areas of submontane forest and into lowland forest.

The upper organic soil horizons normally present in submontane forest disappear when *Maesopsis* becomes abundant (Chapter 31), the dense superficial root-mat characteristic of submontane forest disappears (Chapter 30), the litter becomes thinner, the pH is raised (Chapter 30), the soil fauna changes in its species composition and becomes more uniform (Chapters 30 & 32) and the rate of soil erosion is thought to increase substantially (Chapters 30 & 33). It is concluded that many ecosystem characteristics are quite different in *Maesopsis*-rich forest compared to natural forest (Chapter 33).

Maesopsis-rich forest is floristically distinct from natural forest. Many of the endemic or near-endemic trees and understory plants are absent (Chapter 28) and other species. including several introduced species, become common (Chapter 27). There is no evidence that natural forest, with its abundance of rare species, is able to replace *Maesopsis* forest, for example through a process of succession, though possibly it may be able to do so after a long period of time.

The East Usambara forests are very exceptional among tropical forests in being susceptible to invasion by introduced species, including *Maesopsis* (Chapter 27). This unusual feature may be related to the long isolation of the forests of the East Usambaras (and those of other Eastern Arc mountains) from the main world tropical forest areas, such as in West and Central Africa. Long isolation of relatively small ecosystems seems to make them prone to invasions. This is well known in the case of isolated oceanic islands, which are readily invaded by species introduced by man and in which many indigenous species have become extinct as a consequence.

The implications are that steps should be taken to control *Maesopsis* in areas designated for conservation of genetic resources and also in catchment areas (because its presence is thought to increase soil erosion substantially).

8.12 Studies of hydrology and water quality

Most types of experimental work in hydrology are long-term and comparatively little can usually be achieved in a year, as was available for the IUCN forest project. Some short-term field studies were, however, undertaken in order to gain rough assessments of the magnitudes of some major variables.

Field work was confined to the rainy season of October—December 1986 and was carried out by Mr. A.K. Inima (a research student of Dr. M. Bruen), Ms. C. Muller, Mr. I. Mwasha and Mr. B. Retzer, following directions received from Dr. M. Bruen (the IUCN Catchment Specialist) and Dr. M. Litterick (Nairobi University). Studies were devised to examine, in particular, the hydrological impact

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of logging in submontane forest, a topical subject at the time when logging was actively proceeding and when questions were being raised about its environmental impacts.

Sediment traps were dug to investigate soil erosion on logging tracts. These rapidly became filled with sediment and there is no doubt that logging tracks are major foci for soil erosion. From the hydrological point of view, construction of roads probably represents the main hazard to catchment protection resulting from mechanical logging. However, it is noted that, over the mountains as a whole, soil erosion is a much more serious problem in agricultural land than in any type of forest.

The possible effects on water quality of forest clearance and other activities in the submontane forest zone were considered (Chapter 16). Water quality is a concern, not only because of the large number of people who directly use water in rivers arising on the mountains, but also because there are industrial users such as the sisal estates, and especially because the Sigi River provides drinking water for Tanga Town (population 100,000) by means of a reservoir impounded behind a dam. It was concluded from the evidence available that deforestation will not significantly influence water quality, although attention was drawn to the problem of siltation of the dam due to soil erosion. (This is happening already – Chapter 7). The major risk to water quality in the Sigi catchment is rehabilitation of sisal estates, many of which are at present in a run-down state. Rehabilitation would almost certainly result in the release of large quantities of organic wastes, making water from the Sigi reservoir sometimes undrinkable. The establishment of forest plantations in areas now under sisal would seem to be environmentally and perhaps economically preferable to the reinvigoration of the sisal industry in this high rainfall area.

Mr. A.K. Inima was not available for a second period of field work planned for the March-May rainy season in 1987 and it proved impractical to establish further hydrological experiments.

A theoretical analysis of the values of different parts of the East Usambaras for catchment purposes has resulted in the identification of areas regarded as 'critical' (Chapter 15). So far as possible, a forest cover should be retained in these places, since this represents the best practical method of preserving their valuable catchment properties. It is essential to maintain good river flows. It is estimated that, with the growing population, the present arrangement for supplying water to Tanga Town based on the Sigi River and the dam will soon become inadequate (Chapter 7).

The vital catchment function of the East Usambaras would be further protected by the establishment of new forest reserves, enrichment planting in degraded forest and soil conservation measures in agricultural land.

8.13 Progress of the IUCN/EEC environmental conservation & agricultural development project

Since field work started in March 1987, nurseries have been established to supply seedlings for forest reserve boundary marking, for enrichment planting in forest reserves and for the use of villagers. Work has begun in the villages on the improvement of farming systems, especially soil erosion control measures. Studies have been initiated on cardamom farming sytems and some information has been gathered on pit-sawing, especially social and economic aspects.

8.14 Recommendations for future natural forest management studies elsewhere

The following points should be considered when preparing natural forest management studies elsewhere:

- Socio-economic surveys should be undertaken at the same time as studies of the forest resources.
- Higher density timber inventories can be useful for determining the distribution of easily recognised species but are of limited use for other species.
- Studies of ecological processes provide information essential for management planning.
- Assessments of localised catchment values should concentrate on analysis of climate, topography and stream-flow patterns. In general, since the resources and time required for

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water balance studies are so large, these should be concentrated in a few carefully chosen sites in East Africa.

9. Results of the inventory (see Fig.1.3)

The total area of forest described by the inventory is about 23,101 ha, subdivided as in Table 1.1 (subdivisions for inaccessible areas from analysis of aerial photographs).

Table 1.1 Subdivision of the forest as described by the 1986/1987 inventory.

	Accessible forest (ha)	Inaccessible forest (ha)	Total (ha)
Intact forest	3025	2189	5214
Exploited forest	7169	3881	11050
Forest with cultivation	2657	1008	3665
Poorly stocked forest	1537	735	2272
Maesopsis plantation	588	0	588
Barren lands	0	312	312
Total	14976	8125	23101

The largest area of intact forest lies within Amani-Sigi, Kwamsambia and parts of Kwamkoro Forest Reserves. Smaller patches are also present on north-east Mtai and in Lutindi and Kilanga Forest Reserves and on nearby Public Land.

There is extensive agricultural encroachment in Lutindi and Kilanga Forest Reserves, but only local encroachment elsewhere. This pattern is related to the administrative structure of the Forest Division, Lutindi and Kilanga being administered by the Korogwe Catchment Forest office and the others being administered by an office within Muheza District.

A numerical classification of the floristic data from the inventory was undertaken at the request of IUCN (Section 8.2). This shows that both lowland and submontane forest vary in floristic composition from place to place.

Not all forests on the East Usambaras were included in the inventory survey (Fig. 1.3). These excluded forests amount to several thousand hectares and are mainly lowland forest. They should be visited and assessed soon. Semdoe Forest, in particular, could be of importance for conservation of genetic resources.

10. Summary of values of the East Usambara forests

Forests on the East Usambaras are valuable as resources for a variety of reasons, including:

- **Conservation of genetic resources** (Chapter 36). The forests have many species of plants and animals found nowhere else or of only very local occurrence elsewhere. Furthermore, the East Usambara populations of many of the more widely distributed species are likely to be genetically quite distinct from populations elsehwere, by virtue of prolonged isolation. Both lowland and submontane forests are valuable.

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- **Protection of catchments.** Water in rivers arising on the mountains is used by many people on and off the mountains, including those living in Tanga Town. A forest cover is the most practical means of ensuring infiltration of precipitation into the soil and preserving the soil body from erosion. A deep moist soil helps to ensure a reliable water yield.
- **Protection of climate.** Although there is controversy over the role of vegetation in regulating climate, there is enough evidence of climatic deterioration associated with forest destruction from the East Usambaras and elsewhere in Africa (Hamilton 1984) to justify extreme caution in destroying more forests. From the national perspective, Tanzania is a poorly forested country.
- **Provision of timber and plywood** harvested by mechanical means or pit-sawing.
- **Provision of forest products** in addition to timber and plywood. including poles, fuelwood, medicines and animal products.
- **Conversion to agricultural land.** The forest soils can initially give good yields of cash and food crops. At higher altitudes, in particular, yields are likely to fall greatly with time as the soils become exhausted, given present agricultural methods.

11. General guidelines for development

The following points should be considered in planning the development of the East Usambaras:

- The long-term economic returns from conversion of forest to agriculture are unlikely to match those from sustainable forest utilisation. It is noted that the economic returns include a range of important indirect benefits (Section 10).
- The various uses to which the forest may be put have different degrees of inter-compatibility.
- A balance must be sought between conflicting interests, such that the overall management plan carries enough acceptance within the community to be workable. Balance should be sought overwhelmingly through zoning the forest into areas assigned to different purposes, rather than encouraging a combination of many uses in the same area.
- The management plan must take a long-term perspective.
- In many cases there are conflicts between long-term conservation interests (e.g. genetic conservation, catchment protection) and short-term interests (e.g. maintaining employment in a sawmill, the immediate provision of food for a family). Government has the responsibility of assuming the role of protector of resources for the future, which will often involve the prohibiting of immediate exploitation.

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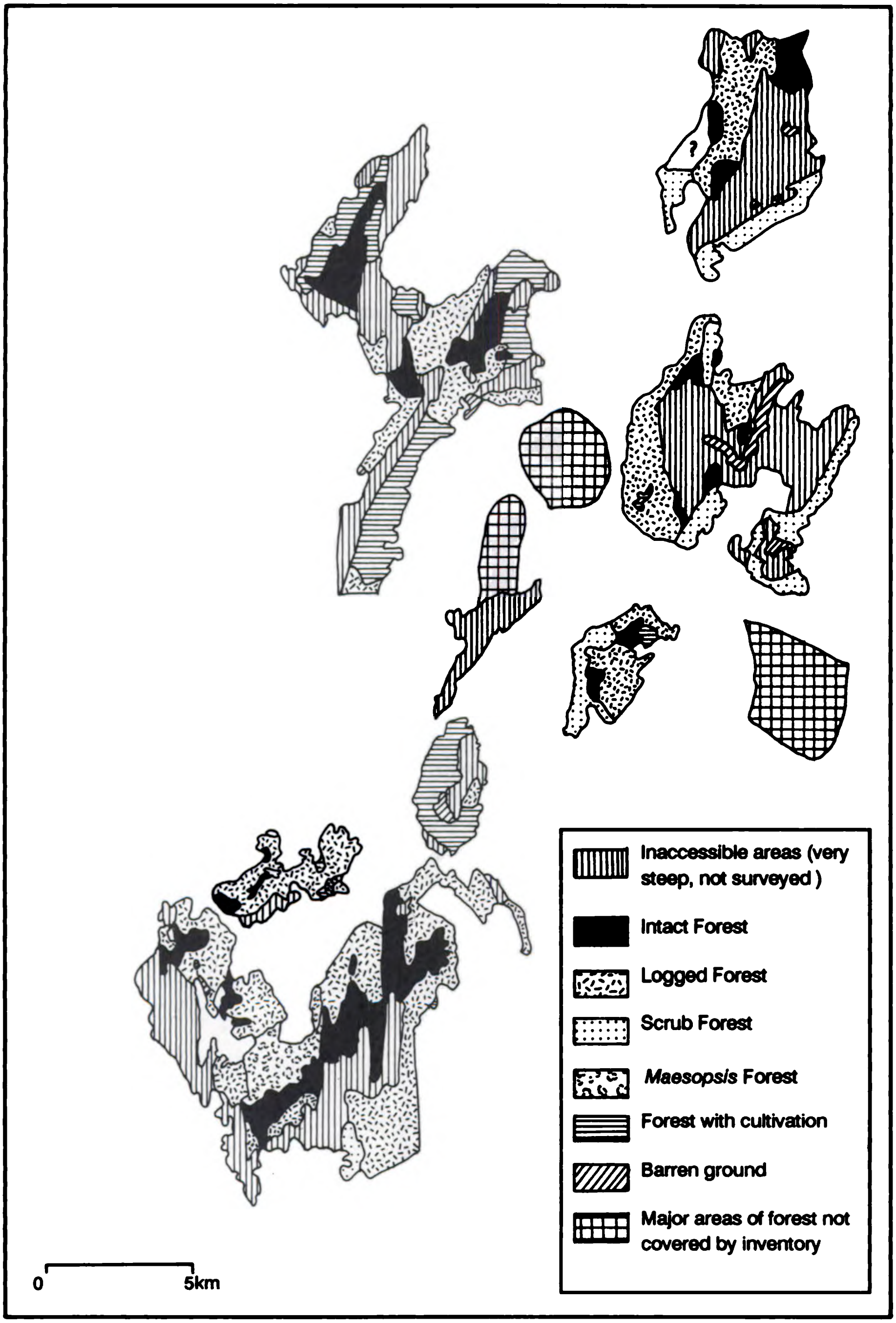

Figure 1.3 Extent of natural forest on the East Usambaras according to 1986/1987 inventory. The forest is classified according to its predominant forest type/land use.

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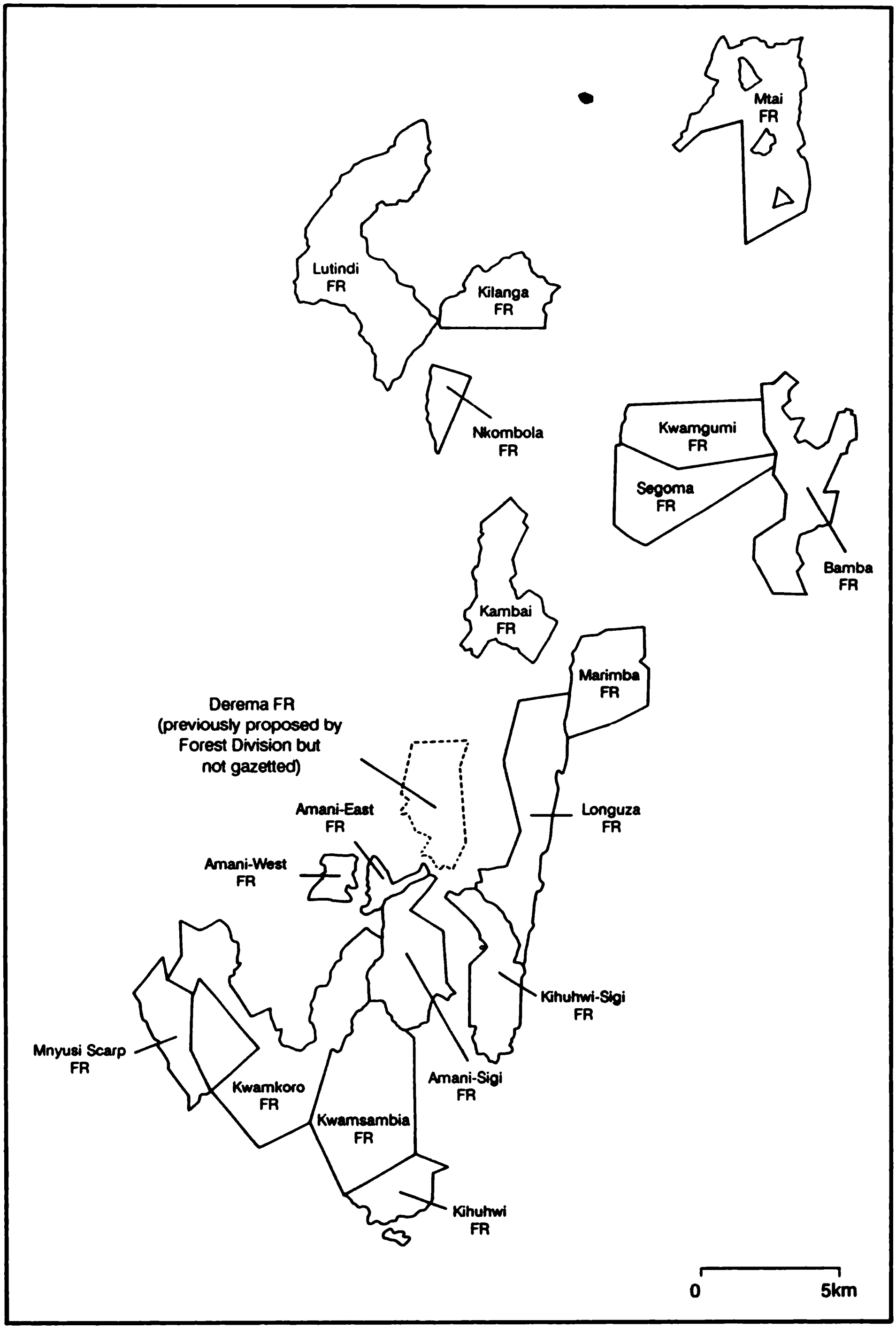

Figure 1.4 Forest reserves on the East Usambaras as mapped by the 1986/1987 inventory.

12. Recommendations

12.1 To ensure the survival of forest

Assumption: Forests in forest reserves, managed by Central Government, have the best chance of survival. The recent tendency on the East Usambaras and elsewhere in East Africa has been for forests outside Central Government forest reserves to disappear.

Strengthening of the Forest Division

- The Forest Division must be the forest managers. Where provision is made for exploitation, for example by a sawmiller, then the exploiter must operate within a framework clearly defined by the Forest Division. In the case of sawmilling, there should be written contracts, with penalties for abuses.
- The Forest Division should take a firm line against illegal activities in the forests, for example cultivation.
- Forest Division presence should be strengthened in that part of the East Usambaras which is administered from the Korogwe Catchment Forest Office. There should be appointment of more senior staff to live and work in the Lutindi/Kilanga area.
- Ways should be found of improving the pay and conditions of Forest Division workers. A limitation is that salaries are government-controlled and cannot be altered for the East Usambaras only. Perhaps fringe benefits could be supplied and assistance given for housing, uniforms and transport.

Ensuring the survival of existing forest reserves (Fig. 1.4)

- Existing forest reserves should be resurveyed, where necessary, to ensure agreement between the reality on the ground and official maps.
- Strips of boundary trees should be planted around all forest reserves (except on some internal boundaries or where there is an obvious boundary provided by a road, river or cliff). These strips should be wide (at least 10 m) and be composed of trees useful and accessible to the local community, especially for provision of poles and fuelwood. Care must be taken to choose species incapable of spreading into the natural forests.
- There should be regular monitoring of the forests, especially by ground patrol. Any illegality should be dealt with immediately.

Enlarging the area of forest within forest reserves (Fig. 1.5)

Limitation: This is generally only possible where there is a substantial area of forest with no, or minor, cultivation or occupation.

- To legalise (gazette) areas which have already been surveyed with the intention of declaring them forest reserves (Chapter 6), namely:
    - a northward extension to Kwamgumi Forest Reserve.
    - a south-west extension to Kilanga/Lutindi/Nkombola Forest Reserves.
- To create or enlarge new forest reserves as follows:
    - to enlarge Mtai Forest Reserve to include the three (legal) enclaves and to include the valley of the Muzi (a tributary of the Sigi) on the south-western part of the mountain.

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- to enlarge Kwamkoro Forest Reserve southwards to include patches of forest outside the reserve. This will be valuable for biological conservation and will provide further protection for the most important catchment area within the East Usambaras.
- to create a forest reserve on the summit of Mt Mlinga. This area contains some biologically unusual forest (Chapter 23).
- to enlarge Kihuhwi-Sigi Forest Reserve so that it extends up to Amani-Sigi Forest Reserve. This area is an escarpment with a high rainfall and steep slopes and should be under a forest cover, as noted by ex-President Nyerere on a visit some years ago. The creation of a forest here would also provide a buffer to protect part of the proposed Amani Nature Reserve (Section 12.2). This is an area largely cultivated at present and no reservations should be made without full consultation with all interested parties. The area shown on Figs. 1.5 and 1.6 should be regarded as open to adjustment in the light of these consultations. This forest should be managed to supply fuelwood, poles and perhaps timber, but it should not be open to mechanical logging, given the very steep slopes.

Conserving forest on Public Land

There is a substantial area of forest on Public Land, outside the proposed new reserves. In general this land is more valuable as forest than as agricultural land. The retention of forest cover depends on the local people, since they may choose to convert the forest to agricultural land rather than use the forest sustainably. In order to encourage them to maintain the forest, which is in the interests of the region as a whole, it is important that the local people receive most of the direct benefits from the forest. The IUCN/EEC conservation and development project is studying ways to promote conservation of the Public Land forest, including increasing village involvement in forest management, with the assistance of Forest Division.

12.2 To conserve the flora and fauna

- This requires maintenance of 'intact' forests, that is forest undisturbed, or little disturbed, by man. Exploitation, such as logging or pole-gathering, will create conditions under which many species are unlikely to regenerate. One or more strict nature reserves are needed. The proposal here is for the creation of one relatively large strict nature reserve, with its own administrative structure. It is also proposed that two other, much smaller, areas of forest should be set aside for biological conservation. Many forests outside these three places are also biologically of great interest; it is hoped that the prohibition of exploitative activities in 'inaccessible' areas (Section 12.3) will help to provide some further protection of species and ecosystems. The special staff, which, it is suggested should be employed to manage the nature reserve, should monitor biological resources on the mountains generally.

- An inviolate nature reserve should be declared to embrace Amani-Sigi, Kwamsambia and the southern more intact part of Kwamkoro Forest Reserve (Fig. 1.6). This area is the most suitable as a major nature reserve because it contains the biologically richest submontane forest, because it contains the largest area of intact forest, because it includes a wide range of forest types at different altitudes and because it is already quite well protected by buffer-zone forests on some of its boundaries. It is suggested that a suitable name for the nature reserve is Amani Nature Reserve, partly because of the meaning of the word in Kiswahili (peace).

- The entire area of the proposed nature reserve should be administered as a single unit (at present its forests fall under both Catchment and Longuza Forest Projects), as a non-exploitable catchment forest. Accordingly, Kwamsambia and the relevant part of Kwamkoro should be transferred from Longuza Project to the Catchment Forest Project. At the same

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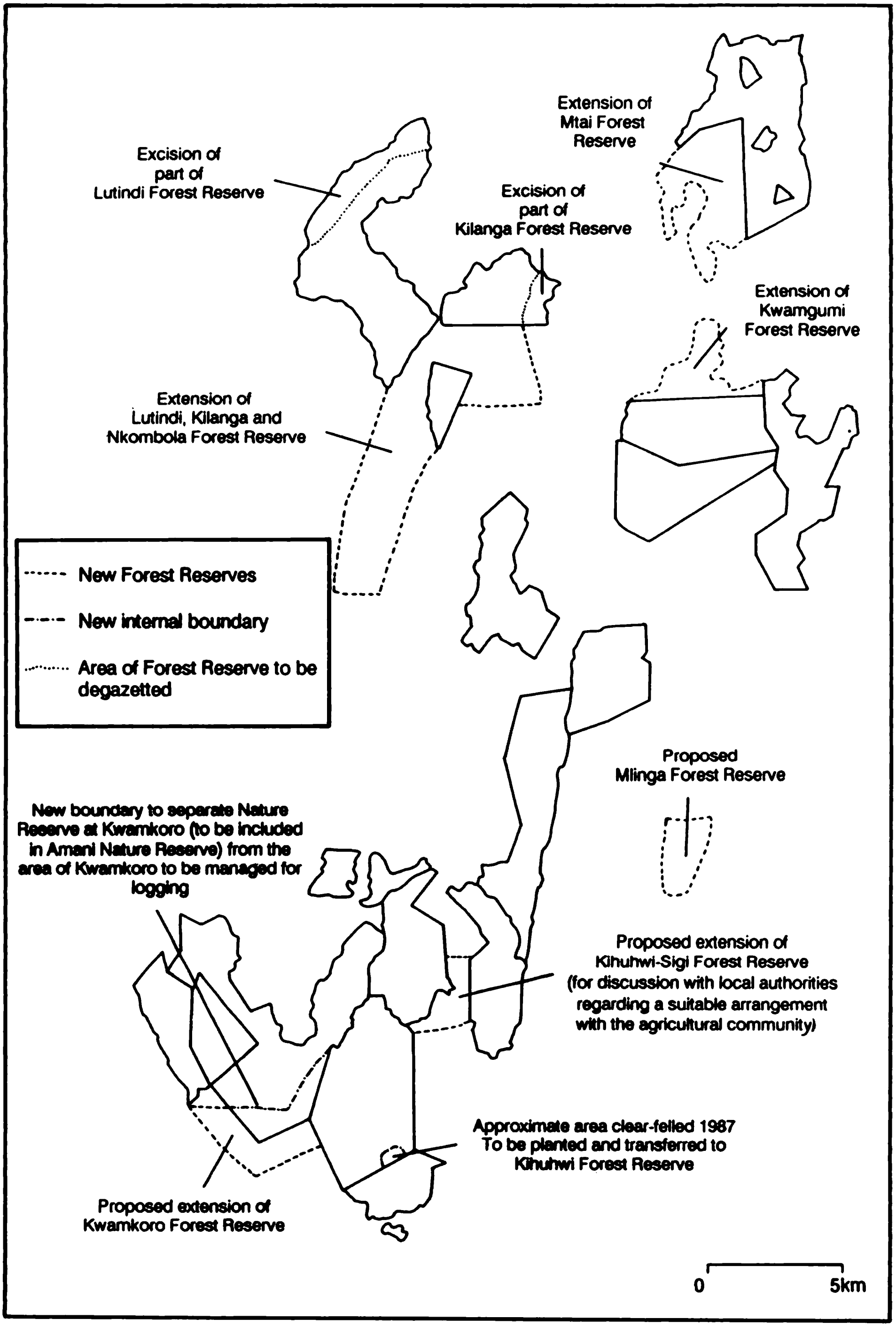

Figure 1.5 Proposal for changes in forest reserve boundaries and status of forest reserves.

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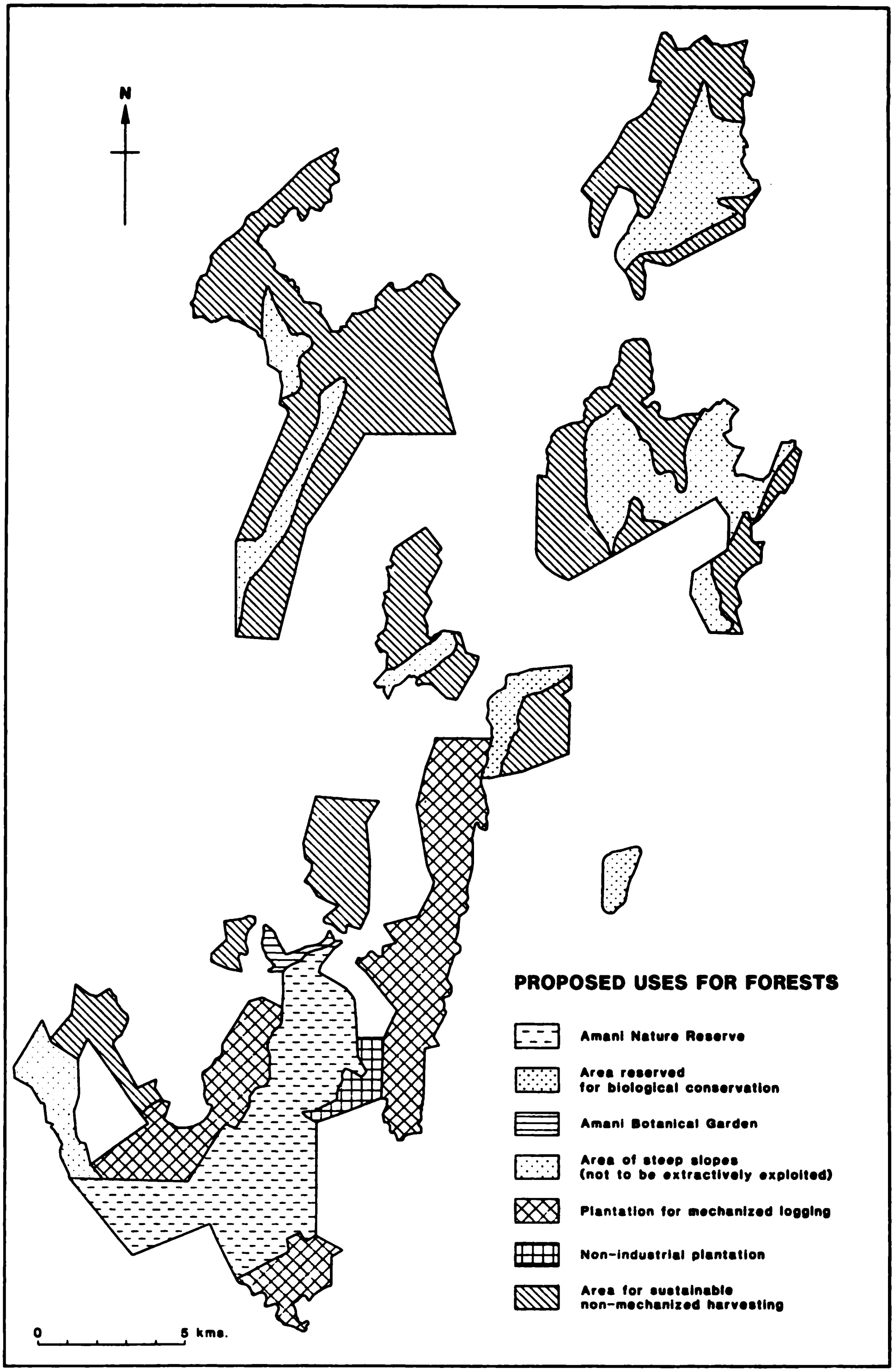

Figure 1.6 Proposal for use of different forest areas in existing or proposed forest reserves.

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time that part of Kwamsambia which has recently been felled to plant teak should be transferred to the Longuza Forest Project and form part of Kihuhwi Forest Reserve. To avoid competition for resources at the local level, Amani Nature Reserve should be financed directly from Forest Division Headquarters, that is separately from other catchment forests in Tanga Region (this matter is discussed in Hall 1983/84).

- The headquarters of Amani Nature Reserve should probably be situated at Amani, where some infrastructure already exists. It would be desirable that the actual building which serves the reserve staff should also serve as the headquarters of the Amani Botanical Garden and, if it is established, of the Ecological Research Station (Chapter 37).
- It will be necessary to control *Maesopsis* and other introduced organisms in the nature reserve (Chapter 27). Measures should only be started after careful research has established methods of control which do not have unacceptable side-effects.
- Two other areas are especially important biologically and should not be extractively exploited. They should be non-exploitable catchment forests, administered by Catchment Forest Project officers. These are:
  - the western part of Marimba Forest Reserve. The area of lowland forest included in the proposed Amani Nature Reserve is small, and a further area of lowland forest should be set aside for genetic conservation. Lowland forest is possibly even more under threat of destruction in Tanzania than submontane forest, because it is more accessible to agriculturalists and because it is regarded as having a lower catchment value than submontane forest. Western Marimba has been selected because the forest (although partly rather 'bushy') is relatively intact and because it contains forest types not or poorly represented at Kwamsambia (Chapter 24).
  - the summit forest on Mt Mlinga. The surviving forests on Mlinga are not in forest reserves and a new forest reserve has to be created (Section 12.1). Mt Mlinga must receive an exceptionally high rainfall and it is a pity that forest reserves were not established much earlier to protect the headwaters of such important rivers as the Mruka (a tributary of the Sigi) and Mkulumuzi. The summit forest of Mlinga is floristically unusual, with *Podocarpus* and various endemics.

12.3 To protect catchments

Background: A forest cover is the best practical means of protecting catchments. All parts of the East Usambaras are of some value as catchments, but the most important are those at higher altitudes (especially the plateau area at the south end of the main range) and those which receive higher rainfall (south-eastern aspects).

- The remaining forest cover should be protected from further reduction, in so far as this is possible (Section 12.1).
- Mechanical logging degrades the catchment value of forests, especially through increasing soil erosion and compacting soils. This is one reason why no more mechanical logging should be allowed in natural forests on the East Usambaras (except for the *Maesopsis* 'plantation' at Kwamkoro – Section 12.5).
- All areas in which steep slopes are common (the 'inaccessible' areas of the inventory) should not be extractively exploited (e.g. for timber or poles). These are marked on Fig. 1.6. Elsewhere, in areas of forest open to extractive activities, no trees should be cut on slopes exceeding 60%.
- No timber extraction should be permitted within 50 m of streams (a stream being defined as a stream-bed, since many streams are seasonally dry).

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- The main pollution hazard in the East Usambara region is contamination of the Sigi River by sisal waste. The water supply to Tanga Town is likely to be placed in danger by rehabilitation of run-down sisal estates in the Sigi catchment. It would be environmentally preferable to convert these estates to other uses, notably tree plantations. The economics of such conversion should be examined.

12.4 To ensure future supplies of timber and plywood

Background: Plantations are much more suitable for the provision of these products than natural forest. Higher yields can be obtained and management is easier.

- Existing teak and *Terminalia* plantations under the Longuza Forest Project should be properly tended. New technology is desirable to enable sawmillers to exploit small sizes of logs. The old teak stand at Kihuhwi, being an exceptionally good provenance, should be retained as a source of seeds.
- The Kwamkoro plantation should be exactly defined geographically (Fig. 1.6) and managed as a plantation of indigenous hardwoods (Section 12.5).
- According to the Tanzanian-Nordic Review (1985) there is at present much softwood available in Tanzania, including at Lushoto. This material should be utilized. The sawmilling industry around the East Usambaras needs to educate its customers away from using high quality timber for all purposes. The production of tea-chests from such economically and environmentally valuable trees as *Cephalosphaera* should cease. It is ironic that some of the very trees which serve to protect the tea-climate have been destroyed to pack the tea. Logging of softwoods should always be accompanied by replanting schemes.
- Plantations of trees should be expanded or established on a large scale in the East Usambara area. Planting within forest reserves should be by the Forest Division. Logging companies should not be permitted to be responsible for such planting, as this may jeopardise Forest Division control; they are however encouraged to establish their own plantations. A 500 ha site is available immediately for planting by the Forest Division at the north end of Longuza Forest Reserve.
- The Forest Division should try and establish new forest reserves for plantations. The proposed expansion of Kihuhwi-Sigi Forest Reserve on the south-east escarpment of the main range is for a plantation (but not to be harvested by mechanical means, because of the steep slopes). Another possible site is an abandoned citrus plantation near Segoma Forest Reserve. Sisal estates are obvious targets for turning into forest reserves, especially within the Sigi catchment.

12.5 To control *Maesopsis*

Background: Our work has shown that *Maesopsis* is a threat to the indigenous flora and fauna and should be controlled. It also degrades catchments.

- It would be desirable to eliminate *Maesopsis* from the East Usambaras, but at least it should be controlled, especially in the proposed Amani Nature Reserve. Methods of control should be established by research.
- The *Maesopsis*-rich area in Kwamkoro Forest Reserve should be managed as a plantation of indigenous trees and *Maesopsis* should eventally be eliminated. Silvicultural operations and harvesting should begin under the following conditions:
    - harvesting must form part of a silvicultural scheme, devised and controlled by the Forest Division.

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- no felling should be done until methods of harvesting *Maesopsis* and replacing it with indigenous species have been devised. These will almost certainly involve various silvicultural operations such as tree planting and weeding.
- new roads should not be constructed (unfortunately, some of the existing, poorly made roads will need restructuring).
- vehicles should not be permitted off the main logging roads. Great care must be taken to avoid degradation of both public and forest roads. Logs must be pulled to roads by cable and winch.

It is noted that an exception is being made in suggesting that industrial logging be allowed at high altitudes in the *Maesopsis* 'plantation' at Kwamkoro. This is in recognition of earlier plans that the area should be developed as a plantation (actually not of *Maesopsis*, but rather of *Cephalosphaera* and other indigenous species) and because the most efficient means of removing the *Maesopsis* is probably through industrial logging.

12.6 To ensure a supply of forest and tree products to the rural community

Background: The collection of poles, which is often on a large scale, must be seriously harming forest regeneration. The collection of fuelwood will also eventually result in damage to the forests, unless provision is made for supplies from plantations.

- The collection of poles and fuelwood should not be permitted in areas specifically reserved for biological conservation or in places with steep slopes (the 'inaccessible' areas shown on Fig. 1.6). Elsewhere, licensing arrangements should continue as at present.

- Pole-cutting should be managed on a sustainable basis and this will require the establishment of rotations, using a coupe system and silvicultural measures to ensure future crops. The management of forests for pole-cutting and timber supply for pit-sawing should be considered in combination by the Forest Division.

- In the long run, poles and fuelwood should be obtained from plantations and on-farm tree growing. Organisations, such as the Forest Division and the tea-estates, have major roles to play here, since the individual resident of the East Usambaras can still obtain poles and fuelwood fairly easily from the natural forests and is likely to lack the motivation to grow trees. The Forest Division can help by making the belts of trees, which it is proposed should be planted on forest boundaries, wide and composed of useful species (which can regrow after cutting and which will not invade the forest). It is suggested that the proposed extension to Kihuhwi-Sigi Forest Reserve be managed mainly as a pole and fuelwood plantation.

- The establishment of fuelwood and pole plantations on agricultural land should take account of soil and catchment conditions. The ridges are the least useful for agriculture and would seem a good place for fuelwood and pole plantations. The soils near rivers are more fertile, but should not be cultivated because of dangers of erosion; perhaps fruit trees could be planted here.

- In view of widespread underplanting with cardamom in Derema Forest, it would be very difficult to turn this into a forest reserve, as has previously been proposed. However the forest serves a major catchment function. A possibility is that the forest be managed as a local forest reserve or village forest to provide fuelwood, poles and timber for the use of the local community.

- The legal ban on hunting in forest reserves is not enforced at present; the forests are full of animal traps. Research is needed to establish the scale of hunting and its social and dietary roles. Recommendations for management can then be made.

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- The collection of such minor forest products as medicinal plants should be allowed in forest reserves, except for those set aside for conservation of genetic resources.

12.7 On pit-sawing

Background: Pit-sawing is on a large scale in the East Usambaras. Much of the profit goes to businessmen and transporters and little to the local people. One advantage of pit-sawing over industrial logging is that it is less destructive to catchment properties. In the case of the East Usambaras, the standard of the product from pit-sawing is said to be comparable to that coming from industrial logging. There are obvious problems of over-cutting by pit-sawyers in some places on the East Usambaras, creating large open areas similar to those made by sawmillers. The establishment of a new crop of trees in these large gaps will take a long time. It is also clear that pit-sawing is at present a scavenging operation and does not form part of proper silvicultural systems, as it should. Control by the Forest Division could be improved by the provision of the necessary facilities.

- Pit-sawing should be restricted to those parts of the forests not set aside for biological conservation or as areas not to be exploited because of very steep slopes (Fig. 1.6).
- The system of controlling the pit-sawyers should be improved, with centralisation of licensing, the issue of identity cards and the public posting of the names of licence-holders. There should be regular patrolling by Forest Division staff. Pit-sawing, both in forest reserves and in Public Land, should be restricted at any one time to small, well defined coupes to ensure easier forest management.
- Pit-sawing should be a component of silvicultural systems, probably involving enrichment planting and slashing of weeds. Suitable silvicultural systems need to be established by research (Chapter 37). Enrichment planting is needed in any case in severely degraded forests, notably parts of Lutindi and Kilanga Forest Reserves. Only species indigenous to the East Usambaras should be used.
- In the case of Public Land forests, control systems should be arranged to give villagers more responsibility for forest management (with assistance from the Forest Division). A necessary corollary of this is that the villagers should receive more of the financial benefits, to ensure that it is in their financial interests to maintain the forest properly.

12.8 On industrial logging

- Industrial logging should be restricted to plantations. It should be allowed in the 'plantation' area of Kwamkoro only after suitable systems of logging and post-logging management have been devised to ensure that *Maesopsis* will be replaced by indigenous species.
- Sawmillers must educate their customers to accept new products, e.g. made from softwood from the West Usambaras.
- New investments will be needed in equipment, especially in small machinery to exploit smaller diameter logs. The high capacity of existing heavy equipment owned by SSM should not be accepted as an argument for harvesting timber at rates which are unsustainable.
- Sawmillers should be encouraged to purchase land for the establishment of their own plantations. They must not be allowed to establish plantations in forest reserves.

12.9 On the tea and sisal estates

- The boundaries of the tea-estates should be properly defined in law. This would encourage investment by the estates. Tea-estates should discuss with Forest Division the best use of their land, in the light of the forest management plan.

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- Owners of sisal estates in the higher rainfall areas around the East Usambaras should seriously consider whether it would not be more profitable for them to grow trees, rather than sisal. Advice on this could be sought from the Forest Division. Any increased production of sisal by estates using water from the Sigi River for decortication is liable to endanger water supplies to Tanga Town.

12.10 On the farming community

- Current efforts to encourage farmers to adopt more productive, sustainable farming systems should be maintained. The farming community should become more aware of the full values of the forest and should be assisted to use forest products in an advantageous, sustainable way.
- Encouragement should be given for the establishment of tree plantations by individuals, churches and schools. Advice should be made available by the Forest Division on the best sites and species for such plantations.
- Farmers at higher altitudes on the East Usambaras should be encouraged to grow cash, rather than food, crops. A higher return per unit area can be expected, less ground needs to be cultivated and higher returns could encourage the adoption of good soil conservation practices.
- Research is needed to find methods of agriculture which are sustainable at higher altitudes on the East Usambaras, especially on how to grow cardamom without degrading the land.

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Section B

History of resource utilization and management, and proposals for the future

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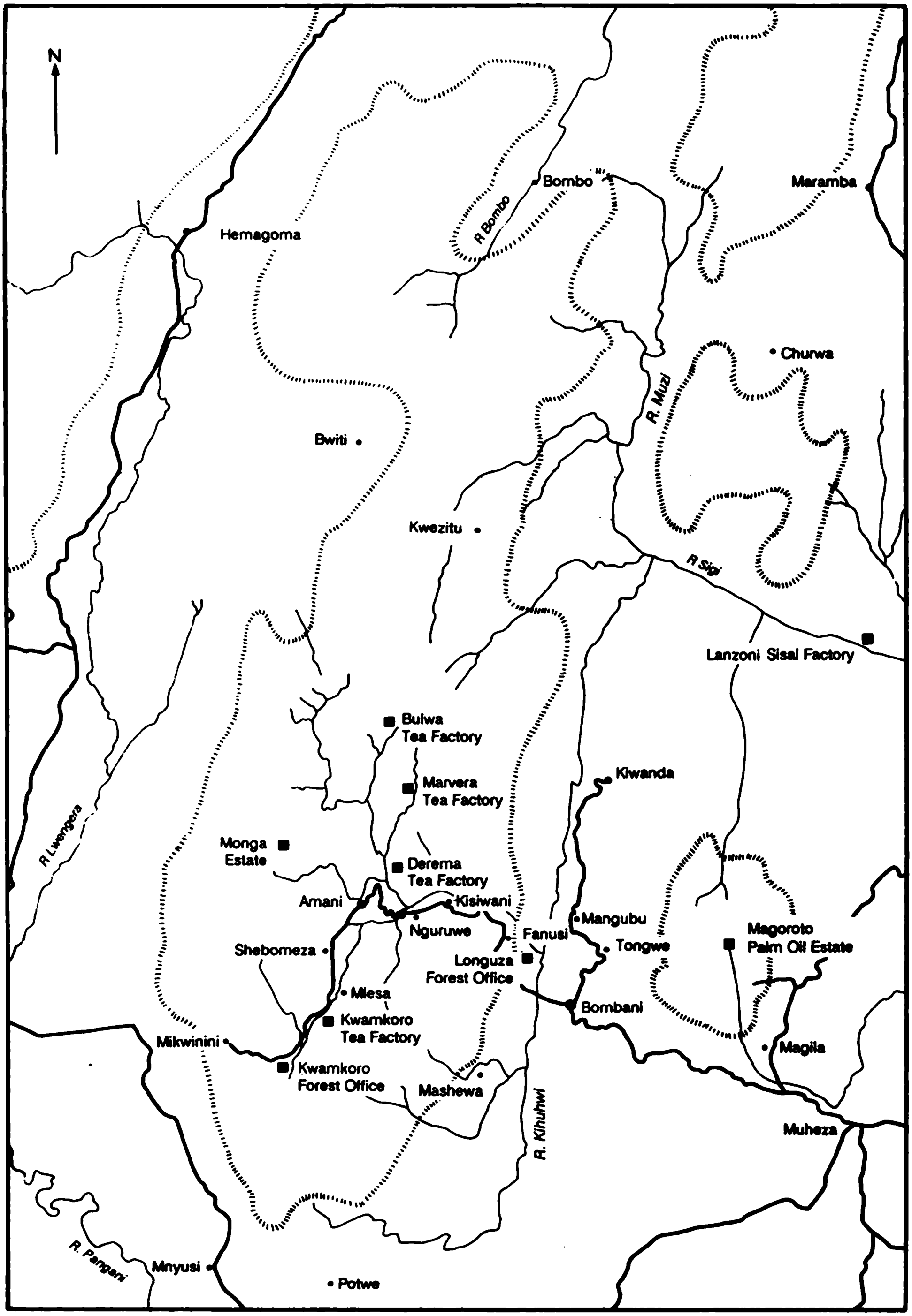

Figure 2.1 The East Usambaras – general location map.

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2. The Place and the Problem

by A.C. Hamilton

An outline of the geography of the East Usambaras is followed by a brief introduction to the problems of managing its natural resources in the future.

The East Usambaras (Fig. 2.1) are a range of low mountains close to the coast in the north-eastern corner of Tanzania. They cover an area of 1,300 km^2 between 4° 48' and 5° 13' S and 38° 32' and 38° 48' E. On their eastern edge they are only 40 km from the sea and are often readily visible from the port town of Tanga. Proximity to the sea contributes to their high rainfall and probably also, in comparison with inland parts of Tanzania, to the exceptionally low temperatures experienced on their upper slopes (Moreau 1934, 1935). Administratively, the mountains fall into two districts, Muheza and Korogwe, both part of Tanga Region.

The East Usambaras are one of a chain of isolated mountains stretching in a great arc around eastern Tanzania (Fig. 1.1). Inland from the East Usambaras, a line of mountains runs to the north-west, parallel to the Tanzania-Kenya border; these are the West Usambaras, separated from the East Usambaras by the deep Lwengera Valley, and then the Upare Mountains, Kilimanjaro and Mt Meru. Each of these mountains is easily seen from the next, in general contrast to the more distantly spaced mountains along the south-eastern rim of the arc. Here the next mountain range is the Nguus, then the Ngurus 160 km distant, the Ukagurus, the Ulugurus and various others such as the Uzungwas. With few exceptions, such as the recently extinct volcanoes Kilimanjaro and Meru, these mountains are composed of old crystalline rocks and are believed to be of great age. The rocks of the East Usambaras are rather uniform and belong to the Precambrian Usagaran system, consisting mostly of gneisses, with some granulites and amphibolites (Fig. 2.2). There is doubt about the age of the block-faulting which raised the mountains (Rodgers & Homewood 1982), but uplift was certainly earlier than 25 Myr ago and could have been more than 100 Myr ago (Griffiths in prep.; Sampson & Wright 1964).

The East Usambaras comprise a main range running SSW-NNE in a fault-determined direction and three isolated mountains in a parallel line to the east. The main range is bound on the west and east by the valleys of the Lwengera and Sigi/Muzi rivers. The area considered in the present report includes the lowlands lying between these various mountains, but does not extend to some more distant smaller mountains, such as Mt Tongwe, which are sometimes regarded as part of the East Usambaras.

The main range, 40 km long and 10 km wide, rises abruptly from the lowlands at 150–300 m and is bound on all sides by steep escarpments, levelling off at about 900–1,050 m onto a deeply dissected plateau, which is most extensive in the south. It is this southern plateau which is most familiar to the outside world, being readily accessible since the beginning of this century by means of a road leading up to the village of Amani and a number of plantations. This is the most important water catchment

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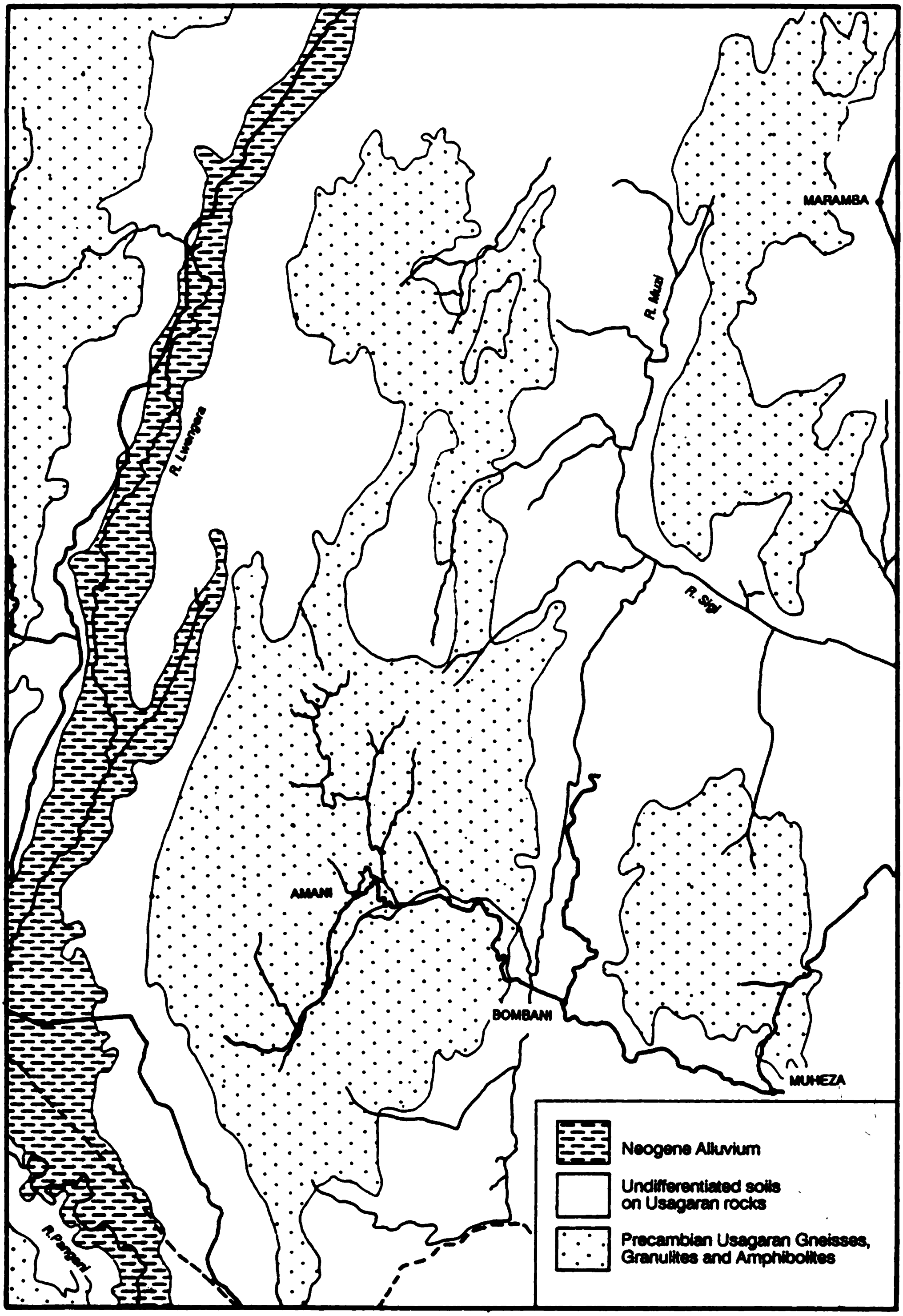

Figure 2.2 Geology of the East Usambaras.

area of the East Usambaras and is the home of many rare plants and animals. Amani was once the site of the principal agricultural research centre in East Africa and today harbours a medical research institute. The highest peak on the main range is Nilo (1,506 m) which is in the north; the highest peak in the southern area is Ubili (1,141 m).

The three isolated eastern mountains are, from north to south, Mtai (1,060 m), Mhinduro (1,033 m) and Mlinga (1,069 m). All rise abruptly from the lowlands and have only relatively limited areas of more level ground at high altitude.

The climate (Chapter 11) is monsoonal, the rainy seasons coinciding with the northward and southward passages of the Intertropical Convergence Zone in March to May (the long rains, with usually the most rain) and October to December (the short rains). There tends to be occasional precipitation even during the dry seasons, all months except February at Amani receiving on average over 3 inches (7.62 cm) of rain (Dowsett *et al.* 1954). Relative humidity is high.

The temperature/altitude relationship is abnormally steep; at Amani mean maximum (24.6° C) and mean (20.6° C) temperatures are respectively 4–5° C and 2–3° C lower than is experienced at the same altitude (910 m) in more inland parts of East Africa and it is probably for this reason that many species of montane forest trees are present at altitudes lower than in central Africa. There is a 5° C difference in mean temperatures between the hottest and coldest months. Frost is unknown.

Four seasons can be recognized. The hottest and driest period is January to March; during the long rains (March–May) temperatures are falling and mist is common at higher altitudes; June to September is relatively cool; during the short rains (October–December) temperatures are moving upwards towards the early year maximum.

There are major variations in rainfall associated with altitude and aspect. Rainfall is greatest at higher altitudes and to the south-east, the part of the mountains first encountered by the moist south-easterly trades moving off the Indian Ocean. Mean annual rainfall in the lowlands around the mountains varies from about 1,000–1,300 mm to the south and east, to less than 600 mm in the north. On the plateau of the main range there is a decline from over 2,000 mm in the south to 1,650 mm in the north. Abundant epiphytic lichens and bryophytes show that isolated steep summits and some escarpment edges have unusually humid climates.

The mountains form the source of several rivers (Chapters 14 & 15), most notably the Sigi which, due to slight easterly tilting of the plateau, drains most of the southern part of the main range; the Sigi also receives tributaries from the south-eastern escarpment of the main range and from its north-eastern sector, as well as from parts of the isolated eastern mountains. The Sigi is impounded by a dam at Mabayani, 15 km from the coast, from where water is extracted for Tanga Town.

Except in the rain-shadows in the lowlands to the west and north, nearly all of the East Usambaras was once covered by forest, of which sizeable patches locally remain (Chapter 24). Forests in the lowlands and at high altitudes (submontane forest) differ greatly in the species of plants present and there is a continuous range of intermediate types on the escarpments (Chapters 22 & 24).

The lowland forests are floristically rather similar to some other lowland forests found near the East African coast in eastern Kenya, eastern Tanzania and countries to the south (Chapter 21). These East African coastal lowland forests are biologically distinctive, with many endemics (White 1983), but they also contain many species found much further west in the main African lowland forests of West and Central Africa.

The submontane forests of the East Usambaras have long been famous to biologists for their many rare animals and plants, some found nowhere else in the world (Rodgers & Homewood 1982). These forests are among the most luxuriant in Africa, with some trees reaching heights of 65 m. The peculiar nature of the flora and fauna has been attributed to their isolation and assumed great age (Hamilton 1982). The nearest localities with similar climates and biotas are found at appropriate altitudes on the Eastern Arc mountains to the south, especially the Ngurus, Ulugurus and the Uzungwas (Chapter 21).

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A somewhat similar, but more impoverished, forest type occurs at a slightly higher altitude on the wetter side of the West Usambaras.

All the submontane forests of eastern Tanzania are of first-rank importance to biologists and to those concerned with conservation of genetic resources. These forests differ in details of species composition from one mountain to another, with some groups of organisms tending to be more widely distributed than others (Chapter 24). It is perhaps invidious to make a ranking between such worthy candidates for conservation, especially since some of the forests are inadequately explored, but the forests on the East Usambaras are always considered as either the most important or among the most important of those in eastern Tanzania. Writing about birds, Stuart (1981), for example, regards the East Usambaras as a "unique area in terms of species diversity and degree of endemism". Schiotz (1981), dealing with amphibia, reports that the faunas of the Usambaras and Ulugurus are comparable in species richness to those of important West and Central African forests, especially when the relatively minute size of the eastern forests is taken into consideration. Furthermore, he writes that "the conservation of the rapidly vanishing, rich forests on the basement hills in Eastern Tanzania is the most urgent conservation problem in Africa today".

The mammals form the one group of organisms with no or very few endemic species or subspecies in the East Usambaras forests (Rodgers & Homewood 1982; Chapter 34) and this is perhaps a pity since mammals more than any other group tend to attract conservation support. There are few species of large animals. Elephant are recorded historically as occurring in the lowlands and were abundant in the Sigi-Muzi valley in the 1950's (Dowsett *et al.* 1954); they are no longer present. Duiker are still found and bush pig are abundant. Leopards occurred until recently, but none have been seen for five years. There are only two species of forest monkey.

Soil variation parallels forest variation, with two main types, corresponding approximately to the original occurrences of lowland and submontane forests (Chapter 10). The soils are clays or clay-loams, red or otherwise brightly coloured, usually deep, very freely draining and have their nutrients concentrated in the topsoil which is no more than 20 cm deep.

The submontane forest soils, found above 850 – 900 m, are acidic to very acidic (pH 3.5 – 5.5), have been exceptionally well leached and are very impoverished in nutrients below a thin upper organic-rich stratum. Nutrient circulation under undisturbed natural forests is clearly very tight and streams emanating from such forest are very clear. At one time stream water was used in the laboratories of the agricultural institute at Amani, being purer (having equal or lower electrical conductivity) than their manufactured distilled water (Walter 1971). These soils, and also the lowland soils, have low cation exchange capacities and, unless a high content of organic matter is retained in the topsoil, cannot be efficiently enriched through the application of artificial fertilizers. The high altitude soils are really unsuitable for long-term agriculture, except for crops which actually prefer very acidic soils, notably tea and quinine. Widespread peasant agriculture on these soils is now, however, a reality and obviously special attention needs to be given to the prevention of soil erosion and to the build-up of soil fertility.

The lowland soils are richer in cations and much less acidic (pH 6 – 7), but are still fragile and also need to be managed carefully to prevent deterioration.

Forests on the East Usambaras have been exploited by man for at least 2000 years (Chapter 8) but have recently come under severe pressure (Chapter 9), the result of greater industrial activity and an increasing human population. Large areas of submontane forest were still present at the beginning of the 20th Century, but even at that time the lowland forest had probably been considerably reduced through small-scale agricultural activity. Very large tracts of land at all altitudes were expropriated by the Germans as estates and these continued to be privately owned under early British rule. The Germans declared few forest reserves, but the British gradually managed to enlarge the forest reserve area by taking over some of the estates at higher altitudes. In the lowlands, forest on estate land was destroyed on a large scale to create plantations of sisal, exotic trees and other crops. Until the 1960's the higher altitude forests were comparatively little affected by estate activity: plantations (eventually of tea) were essentially clearings lying in a general forest cover.

Since the mid-1960's there has been a major assault on the submontane forests through a big expansion of peasant agriculture and large-scale logging operations for sawmills and by pit-sawyers. Demands for fuelwood and construction poles have been greatly intensified and there are few parts of the forest from which poles have not been removed. These developments have been accompanied by soil deterioration on land previously cleared for farming, and also by a deterioration in the climate (Chapters 12–14), putting further pressures on cultivators to clear more forest. At the same time, there has been reduction in the effectiveness of government control over exploitation of the forests. There is extensive agriculture in some forest reserves and elsewhere boundaries have been violated. Control over the activities of both mechanical loggers and pit-sawyers has become inadequate and silvicultural measures to ensure a continuing yield of timber from forest which has been exploited have not been carried out.

This is a critical time for the East Usambaras. Sufficient forest remains in a reasonably natural state for it still to be possible to create a nature reserve of major international importance. There is still a chance to safeguard stream-flow to the lowlands through retention of existing forests and establishment of plantations. There is still a chance to evolve methods of exploiting selected forests to provide sustainable harvests of forest produce for local inhabitants. But all this depends on the adoption of a clearly conceived, simple management plan, capable of enforcement by government authorities and with a degree of local acceptability. A resolute approach in favour of long-term conservation of resources rather than short-term destructive use is absolutely essential.

The next four chapters outline in more detail the history of resource utilization and management on the East Usambaras.

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Lowland forest, Kwamgumi Forest Reserve, 210 m. The photograph is taken within the lower slope plot used for a profile diagram (Chapter 25, profile C). The large trees are Antiaris. January, 1987.

Submontane forest, Kwamkoro Forest Reserve, 1050 m. The forest structure is exposed at the side of a tree fall caused by pit-sawing (Chapter27, site A). Some of the trees have been damaged by the tree fall and note the long straight trunks typical of this forest type. March, 1987

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3. History of Resource Utilization and Management

The pre-colonial period

by A.C. Hamilton

Man has been living on the East Usambaras for at least 2000 years. It is surprising that extensive forest still existed at the end of the 19th Century, the time of the earliest written accounts. Probably virtually all forests on the mountains have been influenced by man to some extent.

The land of the East Usambaras and the forests which it carries may be regarded as resources, that is assets available for the use of people. Individual people and groups within society differ, however, in perception of what the resources are, how the resources should be utilized and in their abilities to attain their objectives. In the middle of the last century the East Usambaras were probably regarded primarily as land available for small-scale farming. Following colonisation, the Germans expropriated much of the land from the peasants and encouraged the establishment of large plantations for the benefit of their homeland. Under the British, colonial policy came to emphasize retention of surviving forests to protect the climate and ensure water supplies. Since Independence the wishes of small-holders and lumbermen have assumed major roles in determining the fate of the forests, resulting in much forest destruction and degradation.

There were Early Iron Age settlements, dating back about 2000 years, in both the West and East Usambaras (Chapter 8). Forest must have been destroyed both to create agricultural land and to provide fuel for iron-smelting. The scale of Early Iron Age activity has not yet been established, but, contrary to the views of many biologists who regard many of the East Usambara forests as surviving in their original states into the present century, it is likely that few areas of forest have escaped disturbance by man at one time or another during the past 2000 years. During the course of the present study, soils were examined in areas of both lowland and submontane forest thought to be little disurbed (Kwamgumi) or even completely undisturbed (Kwamsambia) by man. Charcoal and pottery were encountered at both sites during excavation, which even revealed a possible house site at Kwamgumi (Chapter 10). The pottery at Kwamsambia, from soil under tall submontane forests, is Early Iron Age.

With hindsight it may be guessed that some characteristics of the modern forests may have been determined by man's actions many years ago. There are very large trees of *Ocotea usambarensis* on upper slopes in the submontane forests; the species is not regenerating (Chapters 24 & 25), nor is it believed that conditions are suitable for it to do so, since it is a plant usually found at higher altitudes and requires very open sites to become established (Abraham 1958). Could establishment date to a time of forest colonisation of clearings abandoned after Early Iron Age occupation? It is possible that a seed source could have been available from a few individuals of *Ocotea* growing on rocky summits: such summits have an unusually wet climate and harbour small populations of species characteristic of higher altitude montane forests (Chapter 23).

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Early historical records show that the inhabitants of the Usambaras were Washambaa, who have been on the mountains for several hundred years (Feierman 1974). The lowlands were (and still are) occupied by the Wabondei (people of the valley). Interestingly, the Washambaa were once organized under a loose political system dominated by iron-smiths (Kimambo & Temu 1969), demonstrating a continuing importance of iron-working in the region, though possibly not principally on the Usambaras. During the last few centuries it is the Wapare of the mountains to the north-west who have dominated iron production and working (Feierman 1974).

The arrival of the Kilindi family in the 18th Century resulted in a centralization of political power. A series of powerful kings, notably Kimweri, who ruled from about 1815 to 1868, expanded the area of their authority. Eventually the Washambaa Kingdom embraced not only the mountains, but extended well down into the lowlands as far as the coast of the Indian Ocean. The capital of the kingdom was at Vugha in the West Usambaras, where the main body of the Washambaa were concentrated; in contrast, the East Usambaras were rather lightly populated during the last century and still carried very extensive tracts of forest.

It is not easy to determine the main areas of settlement on the East Usambaras prior to the arrival of the German colonists. Dowsett *et al.* (1954) state that most of the Amani plateau was densely forested with scattered settlements concentrated chiefly along the western escarpment. The main village, Kazita, was on Mgambo Mountain overlooking the Lwengera valley (see also Feierman 1974). There were settlements also near Kizara at the northern end of the main range, while Bwitu on the northern slopes of Mt Mtai was an important trading centre during the 19th Century (Feierman 1974). Lowland forest to the east of the main range was certainly much more extensive than it is today. Engler, quoted by Moreau (1935), writes that lowland forest once extended from Longuza to Muheza. Judging by a map prepared by Moreau (1935) many scattered patches of lowland forest were present in the 1930's all the way between the East Usambaras and the coast.

Perhaps the most informative account of the 19th Century environment of the East Usambaras is by Farler (1879), a missionary with the Universities' Mission to Central Africa, working at Magila on the southern slopes of Mt Mlinga. Magila is the oldest Christian mission in mainland Tanzania, operating intermittently from 1868 (Moffett 1958) and permanently with the arrival of Farler in 1875 (Farler 1879). Farler describes a walk from the coast to Magila and then up into the East Usambara mountains. Leaving a coastal cultivated strip about 3 km wide, the path inland from Tongoni (near Tanga) passed westwards through a wilderness (nyika — hence Tanganyika) of giant grass and thorn scrub for a distance of 25 km. Then the land started to rise and the climate to become moister. The village of Umba, just south of the present day soil laboratory at Mlingano, is described as being "surrounded by jungle". The country between Umba and Magila was densely cultivated. The East Usambara mountains were "as a rule ... covered with jungle to their summits". Both Mts Mlinga and Lukindo (Mhinduro) were largely forest covered, though with numerous villages dotted on the side of Mlinga. The lowlands around Mhinduro were "well cultivated, with a large population". Farler walked up the Sigi valley onto the main range and describes the lower part of this valley as largely covered with tall forest, though also with some patches of cultivation with tobacco and maize. After a difficult ascent up the escarpment he reached the top where he found "a soft bed of turf, consisting of short grass and scented herbs", herds of cattle and goats, and groves of bananas. He then walked westwards from the village of Msasa, on the edge of the eastern escarpment across the Amani plateau, eventually reaching Hendei, all the time passing through tall forest. He then went northwards along the edge of the western scarp through the villages of Mgambo and Bulwa. The impression of a relatively dense population in this western escarpment-top area, as later suggested by Dowsett *et al.* (1954), is certainly reinforced by Farler's description of the hills frequently taking "the form of grassy cones, with clumps of trees and patches of jungle..... For miles along the upper heights of the Hendei Mountains no trees were visible, only a short turf..... To the right and left of us, but at some distance from the path, we could see the smoke rising from tiny hamlets".

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Farler, like many Europeans since, had his eye on transforming and 'developing' the landscape. He writes — "I should say that no more fertile soil could be found in the world, and it will, I am sure, produce every tropical plant. The flora of Usambara is extensive" and many trees could produce "valuable wood". He would "be happy to welcome a scientific botanist as (his) guest, and should feel well repaid if he would teach us how to turn the vegetable wealth of the country to account... When we consider the wondrous fertility of this country, together with its vicinity to the coast, the mountains being only separated from the sea by a level plain of 30 miles, it is impossible to doubt but that it has a great future before it. I have had several pressing invitations from the chiefs to be their king; but I have been obliged to decline, as it would require far more capital to organise a government than I could command. But with a government that would develope its resources, it would quickly repay any money laid out upon it". Maybe the Rev. J.P. Farler is even today looking down on the East Usambaras from an even better home with some gratification at the way in which his words were in some respects prophetic and no doubt also with some distress at the ways in which development has actually proceeded.

It is rather a mystery why so much forest, either in its original state or as well grown secondary vegetation, managed to survive on the East Usambaras for so long. The pattern of settlement was no doubt an influence, with the Washambaa preferring to settle on the western rim of the escarpment facing their main base on the West Usambaras. The typical Shambaa village was spread along the crest of a ridge, with virtually permanent banana gardens running downhill (Farler 1879; Feierman 1974): valley forests might have been subject to comparatively little exploitation. There is a view that in pre-colonial times farming systems on the Usambaras were in a state of ecological equilibrium with the environment: agriculture was practised in such a way as not to endanger the long-term viability of the community (Scheinman & Mchome 1986). However, it is known that elsewhere in East Africa early agriculture did sometimes lead to environmental deterioration (Hamilton *et al.* 1986; Chapter 8) and this view is undoubtedly too idyllic. On the other hand, the Washambaa had, and still to a degree have, a vast store of knowledge about their biological world (Feierman 1974; Chapters 19 & 20) and the survival of forest could be due partly to an appreciation of the limitations of the land. External influences may also have played a role in limiting the degree of forest destruction. Slaving became a major enterprise in the Usambara area during the 19th Century (Kimambo & Temu 1969), leading to massive local depopulation (Feierman 1974).

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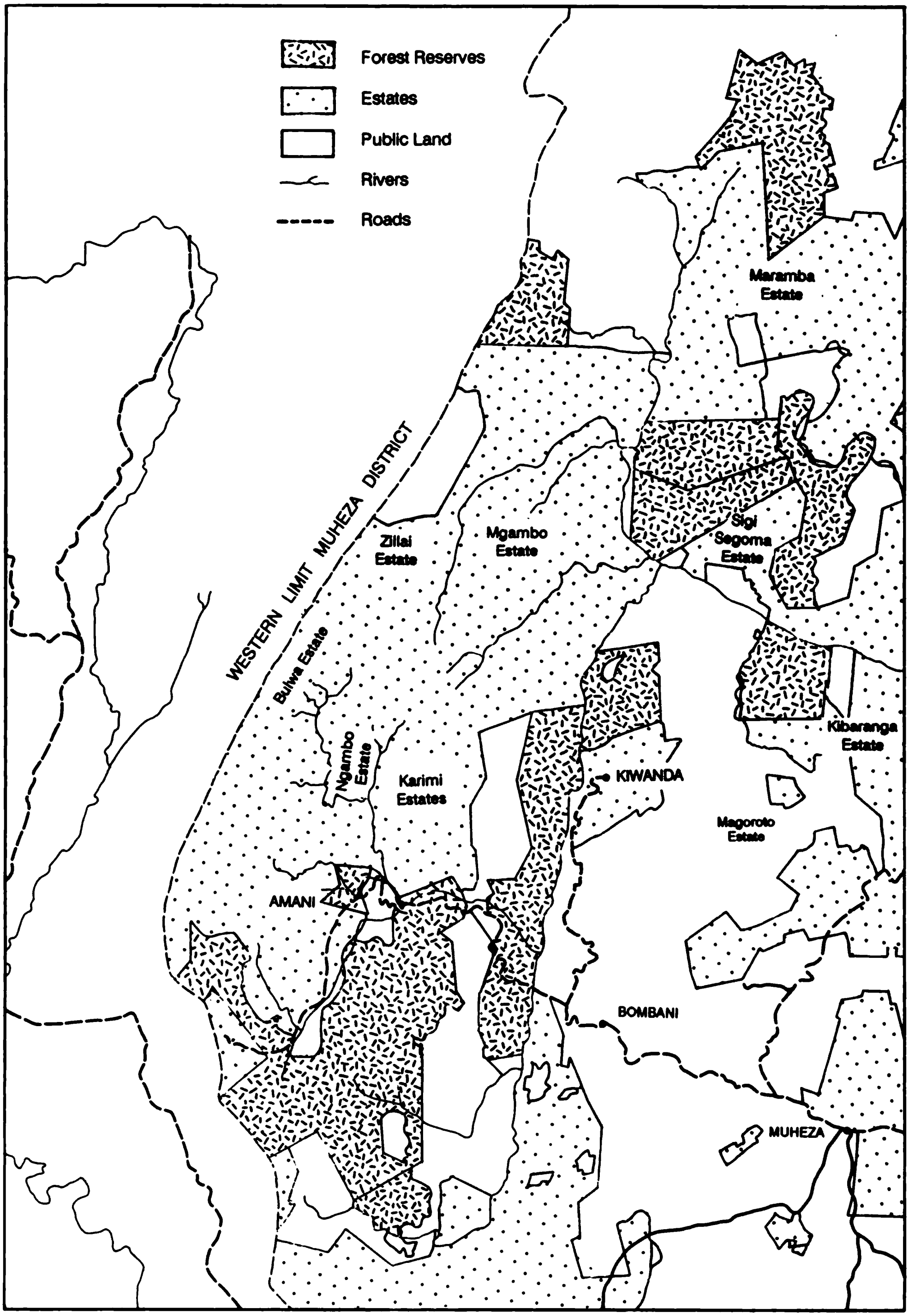

Figure 4.1 Map of estates and forest reserves in Muheza District of the East Usambaras according to Ministry of Lands, Housing and Urban Development, 1973/1974.

4. History of Resource Utilization and Management

Under German rule

by A.C. Hamilton & I.V. Mwasha

The Germans expropriated most of the land on the East Usambaras as estates, planting coffee at higher altitudes. The coffee soon failed, due to a failure to appreciate the severe limitations of the strongly leached soils at higher altitudes.

The Germans perceived the resources of the Usambaras in a very different way from earlier inhabitants, laying the foundations of conflicts over land-use which persist to the present. In 1885 Herr Juhlke, acting for Karl Peters' Society for German Colonization, arrived on the East Usambaras and concluded a treaty with a Washambaa chief living at Mgambo on the western side of the Amani plateau. This chief was probably called Kibanga (Farler 1879; Feierman 1974), although Dowsett *et al.* (1954) refer to him as Mkande. The treaty handed over almost all the land of the East Usambaras "for all time" to the Germans, with only one small area on the upper slopes of the main range, at Mzirai, being left for African use as a 'native reserve'. There was a condition that a further 600 ha on the plateau would be granted later as an additional 'reserve'. In 1891 the German Government took over administration of German East Africa from Karl Peters.

Since 1885 this treaty has formed the basis of legal land tenure on the East Usambaras and naturally has been contested at times as being a grossly unfair arrangement. It is likely that Kibanga did not appreciate the concept of land ownership contained in the document. In any event it is possible that there seemed to be no shortage of land and thus that all interests could be comfortably accommodated.

There was no resistance to the Germans on the Usambaras (Feierman 1974) and indeed their arrival may to some extent have been welcomed as introducing political stability. An upsurge in slaving, as well as the impetus of increased trade in other commodities, had led to disruption of the Shambaa Kingdom during the preceeding years, with much warfare and social unrest (Feierman 1974). The southern part of the main range had become an independent political unit.

The government of German East Africa was interested mainly in economic development, especially in export of agricultural goods to Germany. Three main areas were set aside in the country for plantation agriculture, one being the Usambaras. Outside the 'native reserves' most of the rest of the land on the East Usambaras was parcelled up into large estates and allocated to settlers (Fig. 4.1). Only six forest reserves were created, of which only two included submontane forest (Lutindi, Mtai), the others being in the Sigi valley (Marimba) and in the lowlands to the east of Mtai (Bwiti, Magogo, Msimbazi). The last three were probably intended as estates, but were not taken up (Dowsett *et al.* 1954); unlike the others, they have since been degazetted. Forest reserves were surveyed and, according to reports, forest rules were enforced with vigour and some brutality (e.g. as implied by Grant 1924).

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The German planters in the submontane forest zone encountered considerable difficulties in establishing their plantations and the area of cleared land was never great. The plantations resembled clearings. The first crop tried was arabica coffee and 1,815 ha had been cleared and planted by 1902 (Milne 1937). Little further expansion occurred because of problems with disease and because yields were starting to fall. Cattle, introduced on some estates for their manure, probably resulted in some improvements, but the application of artificial fertilizers gave negative results. With this poor performance the companies started to diversify, with establishment of sisal and rubber plantations in the lowlands. Teak was planted in 1906 at Kihuhwi and rubber, later replaced by oil palms (still present, along with cardamom), on the Magoroto Esate on Mt Mlinga (now owned by Amboni Ltd.).

The problem was that it had been assumed that the presence of tropical forest signified abundant soil fertility. Even at the end of the German period there is little evidence that the lesson had been learnt, "namely that large-scale exploitation of this forest land under *any* crop without a revision of the old assumptions about soil fertility, was likely to lead to financial loss" (Milne 1937). Indeed, Milne later demonstrated that the plateau soils are highly leached, have a low subsoil capacity to absorb nutrients and that such nutrients as are present are virtually confined to the organically- enriched topsoil. Under natural forest there is tight nutrient-cycling between vegetation and soil; when this is disrupted by clearing forest for plantations, the nutrient capital steadily drains away.

In 1902 a biological and agricultural research station was founded at Amani on land donated by one of the estates. A great deal of money was devoted to this project, reportedly a million pounds at 1954 prices (Moffett 1958). Three hundred hectares of land were set aside as a Botanical Garden, running from the lowlands up to the plateau. Published guides to the garden were later written by Greenway (1934) and Fernie (1948). Many exotic trees and crops were tried at Amani or on the estates, including tea, cinnamon, cardamom, cinchona, camphor and robusta coffee, but only one, Ceara rubber *(Manihot glaziovii)*, attracted much interest and this became extensively planted in the lowlands after 1906 (Milne 1937). The Ceara plantations were however abandoned before 1925 (Moreau 1935). There was no agreement on a suitable crop to replace arabica coffee at higher altitudes.

The extent of logging on the East Usambaras by the Germans is unknown. They certainly cut *Ocotea* and a company, Sigi Export Gesellschaft, was founded to export timber to Germany, especially Mfimbo *(Beilschmiedia)* used in ship-building. A railway was built to Sigi to transport this product but reportedly few trains ever actually ran.

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5. History of Resource Utilization and Management

Under the British

by A.C. Hamilton and I.V. Mwasha

Under the British, some of the old German estates were converted to forest reserves, mainly because of concern about environmental degradation following forest clearance if the estates remained in private hands. Tea-planting expanded from the 1940's, resulting in some forest clearance. The timber industry was relatively unimportant before the 1960's.

During the First World War the Government of Tanganyika passed into British hands. British troops arrived on the East Usambaras in 1916 and removed the German settlers to camps in Rhodesia and South Africa. The staff at Amani Research Station were allowed to stay on and three remained voluntarily after the end of the war as caretakers until the British took over in 1920.

An early decision was made by the British authorities to carry forward concepts of land ownership applied by the Germans. The estate companies continued to be owners of their land and the forest reserves established by the Germans remained in being. An opportunity was lost to revise the legal basis for managing the land. The German owners were not given permission to return until 1925, when about half of them did so. Sooner or later, however, all the estates passed to people of other nationalities, though in some cases not until after the end of the Second World War. During the decade after 1918 there were further considerable investments, followed by financial losses, on the estates. Yields of coffee dropped to near vanishing point, there was heavy mortality among older bushes and a complete failure of new plantings in their place. By the 1930's nearly all the coffee plantings were abandoned (Milne 1937).

A Forest Department in Tanganyika was formed by the British in 1921 and devoted itself initially to trying to expand timber production, though with little success (Forest Department 1935). Only two large sawmills were operating in Tanganyika in 1923 and only four in 1927 and the level of sawmilling remained very low until the Second World War, when it rose steeply. Amazingly, one of the mills was granted a 100-year concession in 1924 to exploit 69,000 acres of Shume-Magamba Forest Reserve on the West Usambaras (Forest Department 1928), a blunder which received severe critism from Troup (1936). In the absence of sufficient internal capacity, there were large imports of wood into Tanganyika between the Wars, much of the timber being inferior quality softwood from northern Europe (Forest Department 1935; Troup 1936). Control of the sawmillers was very poor, comments in Eggeling (1951) suggesting that some operations (not actually in the East Usambaras) were as poor as those of Sikh Saw Mills recently in Kwamkoro Forest Reserve.

Concern for retention of forest as a protector of climate, soils and water supplies is evident from the early days of British rule (Forest Department 1928 & s.d.) and repeatedly emphasized (e.g. Troup 1936). There was also much talk of encouraging small plantations for poles and fuelwood in the villages. By 1932 the problem of soil erosion in Tanganyika as a whole had become a major worry to the

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government and a Standing Committee on Erosion was established in 1933 under the chairmanship of the director of the agricultural research station at Amani.

The Forest Department was unhappy that there were so few forest reserves on the East Usambaras, with the danger of over-cutting by leasehold owners. One step, taken in 1931, was to appoint two residents of the East Usambaras as honorary forest officers; they were given the full powers of forest officers to keep an eye on the private forests. This was followed by a requirement in the Forest Conservation Rules published in 1935 for owners of private estates containing forest to abide by approved plans in respect of their forests, thus avoiding rapid and extreme clearing (Forest Department s.d.). There were debates about the amount of land which needed to be left on the estates for climatic protection, guesses varying between 35% and 50% in the case of tea (Dowsett *et al.* 1954). Reports suggest that rules governing clearing were rigorously enforced. There was, however, hardly any timber exploitation until the late 1940's. Writing in 1935, Troup declared that the forests of the East Usambaras were "of little commercial importance, since they consist mainly of very large trees of non-marketable species". The same impression of little exploitation by commercial operators during the 1930's is given in a history of the Forest Department (Forest Department s.d.).

While there was no question of compulsory purchase, the colonial government made considerable efforts to convert the estates to forest reserves whenever this became possible. Amani-Sigi, Kihuhwi-Sigi and Kihuhwi became forest reserves before the Second World War, while Kwamkoro was acquired by the research station at Amani on the understanding that the forest on the estate would be preserved (Dowsett *et al.* 1954). After the War, Kwamsambia, Longuza, Manga, Bamba, Segoma and Kwamgumi were purchased by the government for forest reserves; small portions of the Amani Estate (now Amani East and Amani West Forest Reserves) were also transferred to the Forest Department, as was the old teak plantation at Kihuhwi. Kwamkoro has had a complicated history, the estate becoming divided during the 1940's and 1950's into an area for 'African agriculture' at Mlesa, a forest reserve and a new smaller estate (Dowsett *et al.* 1954; Nightingale & Steele 1963).

The new British rulers decided to continue operation of the research station at Amani and after a shaky start re-established the station in 1926 as The East African Agricultural Research Station. Many internationally known scientists, including P.J. Greenway, G. Milne and R.E. Moreau have been resident at Amani. It is salutory to note that the fundamental research carried out by these scientists is still of great use to us today, but that the former presence of the centre seems to have resulted in no lasting improvements to peasant agriculture, as observed today. This could be taken as a warning to those who stress the importance of applied over pure research. The station closed in 1952, the headquarters of the East African Agricultural Research Organisation (later to include forestry) having moved to Maguga in Kenya in 1948. During its many years of existence, marked by much expenditure and accumulated experience, it was concluded by the staff of the Amani Research Station that the only possible plantation crops which were suitable for the plateau of the East Usambaras were tea and quinine, though reasonable yields of tea were only possible with the application of large quantities of fertilizer (Dowsett *et al.* 1954). The buildings vacated by the agricultural staff became occupied by a medical research station specializing in vector borne diseases, such as malaria, which ironically did not occur at Amani during the 1950's.

Tea was first planted commercially on the East Usambaras on the Kirimi Estates of Karimjee Jivanjee, at Monga in 1941 and later at Derema. Tea plants were brought from Ceylon and planters from Ceylon and Southern India. Later in the 1940's, tea was started by Bird & Co. at Kwamkoro, Sikh Saw Mills at Bulwa and George Williamson at Mgambo. Marvera was bought in 1953 by the Bombay Burmah Trading Corporation, who acquired in the process a small sawmill. Sikh Saw Mills later acquired the Zillai and Mgambo Estates. The motive for the acquisition of estate land by Inder Singh Gill of Sikh Saw Mills differed in emphasis from that of the other purchasers: Sikh Saw Mills were extensively involved in sawmilling in Kenya and Uganda and tea-planting was seen more as a side-line to sawmilling, rather than the other way round.

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A long report dealing with utilization of land on the East Usambaras was prepared by the Provincial Commissioner for Tanga and some of his staff in 1954 (Dowsett *et al.* 1954). It gives a valuable insight into the thinking of the colonial government and of the development of pressures on the land. Great stress is laid on the value of retaining forest, especially on the Amani Plateau, to maintain a good tea climate, to protect soils from erosion and to safeguard the catchment of the Sigi River. Despite the recent creation of many new forest reserves, it was still felt that the Sigi catchment was inadequately protected.

The report deals with the question of African 'squatters' on the estates, actually a minor problem compared with later developments. 'Squatting' had not been an issue before the development of the tea-estates. About 650 'illegal' farmers were identified and it was suggested that they should be moved onto well defined parcels of land obtained from the estates. The allocation was to be about 10 acres (4 ha) per family. The British attempted to distinguish between descendants of the original inhabitants of the East Usambaras and newcomers, the latter mostly immigrants who had come to work on the estates; only the old-timers were considered as having rights to the land. There was hesitation in taking 'squatters', to court since there was no guarantee that the government would win a disputed eviction order. Some 'squatters' questioned the validity of the contract between Juhlke and Kibanga, claiming that the deal had been made over their heads and that they had every right to live where they liked. I understand that the result of this report was that some new land was indeed allocated to farmers, but that nobody was forced to move.

The 1954 report gives the strong impression that there was relatively little sawmilling in the East Usambara forests. The submontane forests were regarded as of little production value, few of the species being marketable for timber. Eggeling (1951) had earlier described *Cephalosphaera* and *Allanblackia* as lesser-known timber trees which merited detailed investigations regarding their commercial viability; *Cephalosphaera* has since become the main target of mechanized logging on the East Usambaras. There were, however, small sawmills on some of the estates, with another in the lowlands at Bombani. There was little or no pit-sawing.

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Pit-sawing an Ocotea in Kwamkoro Forest. Note that the construction of the platform requires felling of smaller trees. May, 1987. Credit DP.

Pit-sawn Ocotea planks await collection at the roadside in Kwamkoro Forest. Maesopsis behind. May, 1987. Credit DP.

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6. History of Resource Utilization and Management

After Independence

by A.C. Hamilton & I.V. Mwasha

There has been a move towards more immediate exploitation of the natural resources of the East Usambaras since 1961. This has involved increased sawmilling and an expansion in small-scale agriculture, resulting in destruction or degradation of substantial areas of forest. There is some, mainly anecdotal, evidence that this has resulted in some adverse climatic and hydrological changes.

Tanzania became an independent state in 1961. This has contributed to many changes on the East Usambaras, with major adjustments in the abilities of different social groups to secure utilization of the resources for their own ends. The balance of power has tended to move away from those interested in long-term environmental protection. This is partly the result of government policy and partly due to a decreased ability of government to enforce regulations. The British found it easier to adopt aloof, long-term attitudes towards land management precisely because they were foreigners. Politicians since Independence have had to be much more alert to local wishes, they themselves having deep roots in the communities.

There has been a major increase in small-scale agriculture on the East Usambaras, often at the expense of forest. There was, for example, a 50% reduction in forest in the 30 km^2 area around Amani between 1954 and 1976 (Rodgers & Homewood 1982). At lower altitudes, farm expansion has mostly been on Public Land and degazetted forest reserves. The former Bwiti, Magogo and Msimbazi Forest Reserves have all been degazetted, one becoming a cocoa plantation. At higher altitudes, farms have spread predominantly on leased land belonging to the tea-estates. The 1986–87 Forest Division/ FINNIDA forest inventory (Chapter 24) showed that the only higher altitude forest reserves which have become extensively cultivated are Kilanga and Lutindi, at the north end of the main range; elsewhere there have only been local encroachments. There are actually illegal villages within both Kilanga and Lutindi Forest Reserves.

It is a tribute to the Forest Division that illegal cultivation is not more extensive inside forest reserves. Undoubtedly the reason why Kilanga and Lutindi have been particularly badly affected is related to the fact that they are administered by Korogwe Catchment Forest Office, while nearly all the other forests come under either the Muheza Catchment Forest Office or the Longuza Project. The Forest Division has twice attempted to oust cultivation from Lutindi, once in about 1979 (Mndambi 1987) and again in early 1987. In both cases crops (mainly cardamom) were cut, but the areas of crops destroyed were relatively small, compared to the total. On the first occasion, cultivation soon resumed, though tending to be deeper inside the forest.

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Loss of land by the Forest Division has been relatively low compared with on the West Usambaras, where 13,400 ha of Shume-Magamba Forest Reserve were degazetted and given to small-holders in 1963 as a response to a popular cry for land (Egger *et al.* 1980; TRDP 1975). Forest destruction due to farm expansion is still continuing on the East Usambaras. Large parts of Shume-Magamba are now reported to be barren.

One cause of forest reduction has been a shift in political power in favour of the immediate interests of the peasant farmer. The newly independent state had different priorities to that of its predecessors, and acquisition by the common man of land 'alienated' in estates and forest reserves was seen by some people as one of the Fruits of Independence. It became more difficult for estates or the Forest Division to take legal action against farmers, especially following an act of parliament in the early 1960's stating that all underdeveloped land belonged to the state. In this context underdeveloped land could be seen as including uncleared forest on the estates, especially by those ignorant of the value of forest for maintaining a tea-climate. The taking of land on the estates was nevertheless illegal and those politicians who encouraged peasants to take estate land were acting outside their constitutional authority.

Clearing of land for farms on the tea-estates started on a big scale in 1967 – 68. It is said that this clearing was predominantly done by 'newcomers' to the East Usambaras, causing some resentment among the local Washambaa (IUCN 1985). The newcomers included people who had come to the mountains specifically to seek financial opportunities, as well as some who had earlier worked on the tea-estates. With this sudden upsurge in forest clearance, for a time tea-estate managers feared that all might be lost and in about 1968 approached the government to stress the seriousness of the problem. This resulted in a visit by the then Minister of Lands and Natural Resources, who requested the villages to draw up new boundaries, with provisions for buffer zones of forest between farmland and tea. This was an administrative convenience rather than a legal measure, which worried the estates. Following further pressure, a team was assigned to survey and mark the new boundaries. On some estates government action and firm estate management have prevented further encroachment, but on others the acquisition of land by farmers still continues. Claims have been lodged by the estates for compensation for loss of land, but these have not been met.

Another survey team visited the East Usambaras in 1974 – 75 to draw new forest reserve boundaries in cases where there had been marginal encroachment and to establish new forest reserves where this was possible. Proposed new forest reserves south-west of Lutindi-Kilanga and at Derema and a downslope extension of the forest reserves on Kwamgumi Forest Reserve were probably a result of this survey, but these new areas have never been legally incorporated in the forest estate.

There has therefore been a *de facto* if not *de juro* extension of Public Land at the expense, mainly, of leasehold land on the plateau of the main range. The legal situation remains muddled, but the new areas of 'Public Land' have received quasi-official recognition in a map showing 'village boundaries' prepared by TIRDEP (Tanga Integrated Rural Development Project). This map was apparently constructed by asking villagers where the boundaries of the villages lay.

Today, farms on the East Usambaras are regarded by the farmers as private property and are bought and sold. Even before the arrival of Europeans, the custom of selling land was practised on the Usambaras (Dobson 1955). Today, the practice represents a contradiction with the official government position, which holds that all land belongs to the state and that, when land is transferred between individuals, compensation is only payable for crops and other property. There are some surprisingly high prices for banana trees on the East Usambaras! The Arusha Declaration of 1967 set Tanzania on a new socialist path with *inter alia* an emphasis on communal ownership of land under the control of villages: in practice, this policy appears to have had marginal impact on the reality of individual land ownership on the East Usambaras. There was also resistance to this policy on the West Usambaras (Fleuret 1980).

A contribution to the intensification of small-scale farming on the East Usambaras has been the decline in the tea-estates over the last 10 – 15 years. Real wages on the estates have fallen and there

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has been a reduction in fringe benefits; many workers have found it more profitable to work their own land. Problems on the estates include a shortage of labour, insufficient money to pay for fertilizer and spare parts for machinery, and poor management. Tea plants in many fields no longer form a complete cover, presumably leading to increased soil erosion, while other fields have been allowed to revert to scrub. Yields have declined, which has not been wholly unwelcome, since lower growth rates mean that harvesting need be less frequent and more land can be kept in production with the same labour force.

Despite the socialist policies of post-Independence governments, tea-estates in Tanzania have not been nationalized and it is only by default that some of those on the East Usambaras have passed into government hands. Kwamkoro Estate once belonged to Bird & Co., whose main business was sisal. When this company was nationalized, the parastatal Sisal Authority was surprised to find it had a tea-estate on its hands. Sikh Saw Mills' interests in Tanzania were sold to the parastatal TWICO (Tanzania Wood Industries Corporation) in 1975 and by default more tea land passed into public hands. Recently the Sisal Authority's and TWICO's estates have been transferred to the Tanzania Tea Authority and negotiations are in progress to return them all to private ownership.

In addition to the exodus of workers from the estates, further factors which have led to the spread of small farms are reduction in yields on land already cultivated and the attractions of cardamom and sugar cane as cash crops. However, not all movements of people have been onto the mountains. While some people have come from elsewhere to grow cardamom, others, especially the younger generation, have been attracted to the towns to seek employment and new life-styles. The population of Amani Division, covering a section of the East Usambaras, was 14,888 in 1967 and 17,400 in 1975 (TRDP 1975).

When forest on the East Usambaras is cleared for agriculture, the soil is relatively fertile and can initially give reasonable crop yields, but with time its productivity declines as nutrient reserves are depleted through harvesting, loss of organic matter, leaching and soil erosion. There comes a time when it becomes worthwhile to abandon the land and seek fresh land from the forest. A similar pattern of forest reduction following declining agricultural yields is described for the West Usambaras (Scheinman & Mchome 1986). Depletion of the soil resource occurs everywhere, but is most serious at higher altitudes where the soils are particularly poor (Chapter 10). It must be pointed out, however,that not all agriculture is transitory; well-mulched banana gardens are common and are probably more or less permanent. There is no evidence that the original forest is able rapidly to recolonize abandoned agricultural land. Instead, there is growth of an agriculturally useless scrub with *Lantana* and *Pteridium*; only hardy trees like *Harungana* are able to become established.

The British colonial government was very concerned about the problems of soil erosion and impoverishment in Tanganyika and tried to enforce regulations to protect the soil. A large-scale anti-erosion scheme was applied to the more heavily populated West Usambaras in the 1950's and, although contrary allegations have been made (Egger *et al.* 1980; Scheinman & Mchome 1986), there may have been a degree of success. Moffett (1958) reports that by the late 1950's soil conservation measures were being used to a greater or lesser extent by all inhabitants of the West Usambaras. However, the measures were often unpopular (Attems 1968) and not all were well conceived (Kimambo & Temu 1969) and some politicians campaigning for Independence attacked them as being alien impositions on people's fundamental rights. After Independence, the government withdrew regulations to control soil erosion and only since the mid-1970's has it again started to voice much concern for soil conservation (Forest Division 1975; TRDP 1975). Efforts are now made to educate farmers to look after the land properly, but there are no legal requirements to do so.

Cardamom cultivation started to become big business in the early 1960's, creating a major force for forest destruction. Cardamom was the third largest cash crop in Tanga Region in the mid-1970's and, in turn, Tanga Region supplied over 90% of Tanzanian production (Jorgensen 1976; TRDP 1975). Tanzania grows 9% of the world crop (Stilz 1980). Cardamom is a large, ginger-like herb which grows

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well on fresh forest soils in the submontane forest zone after smaller trees and shrubs have been removed. Yields peak about five years after planting, but decline thereafter and less demanding crops are usually planted after about eight years. The forest cannot regenerate while cardamom is being grown and the large remnant trees left standing above the cardamom are exposed to the wind and tend to fall. The most common consequence of cardamom cultivation is that the forest is destroyed. By law, growers are required to sell their cardamom to TARECU (Tanga Region Cooperative Union), but this has led to problems. The growers have not always been promptly paid and some have abandoned cardamom, going over to sugar cane (grown for making drink), which is seen as a more reliable source of income. A much higher price can be obtained for cardamom in nearby Kenya and at least half the crop has been smuggled over the border during recent years (Jorgensen 1976).

Wood resources have been placed under strain by agricultural expansion. At the present time all the tea-estates use wood for tea drying and some, such as Bulwa and Marvera, have always done so. Before the fuel crisis of the 1970's, Kwamkoro, Derema and Mgambo relied on diesel to provide a source of heat. At that time those estates which used wood obtained it from natural forest on their land. With loss of forest land due to encroachment and increased oil prices, the estates established eucalyptus plantations, beginning in 1971/72. Today, these plantations are said to meet the bulk of the estates' fuel requirements, but they would need to be enlarged if the estates were to be worked more intensively.

The gathering of fuelwood and poles must have increased as the rural population grew. Wood is used by virtually everybody for cooking and to heat water. There have been no investigations of the amount of wood fuel consumed locally, but, given the relatively easy access to wood in most places, annual consumption is likely to be about 1 – 2 m^3 per head, as elsewhere in Tanzania where there is no great wood shortage (Kikula pers. comm.). Despite much forest clearance, trees are still found close to most households and there is no reason to suppose that women and children, who do this work, have yet to make long wood-gathering journeys, as is the case in some places on the West Usambaras (Fleuret & Fleuret s.d.; Geissen 1984). Effects on forests are therefore assumed to be concentrated mainly near margins and near settlements. The only legal restriction on fuelwood gathering concerns forest reserves, within which only dead wood may be collected, with permission. There is no charge. It is doubtful whether permission is ever actually sought. Since dead wood is widely available, live trees are almost certainly not felled for fuel, as happens in some other parts of Tanzania. Impacts of fuelwood gathering on forest ecosystems include reduction in the organic status of the soil, the removal of nutrients and the creation of more open patches. The removal of branches from the crown areas of fallen trees encourages the the spread of *Maesopsis,* an introduced tree which is invading the forest (Chapter 27).

The gathering of poles is selective in terms of species, but geographically extensive. Large quantities are removed even for the construction of a single house (Chapter 19 Section 4) and only the most remote parts of the forest show no signs of this activity. Pole gathering is prohibited in forest reserves, except with permission and on payment of a fee, but it is doubtful whether the legal route is ever followed. Pole cutting is a major influence on the forest, for example in altering the balance of species and in inhibiting regeneration.

The Forest Division has been active in developing plantations, starting just before Independence (Ahlback 1986). These plantations have been developed mostly, perhaps even nearly entirely, at the expense of natural forest, either through clear-felling or through underplanting or enrichment planting following selective logging. The small plantation of teak at Kihuhwi, which was established in 1906, is of an excellent provenance and is used as a source of seeds for home use and export. Since 1961 a large plantation was established in Longuza and Kihuhwi-Sigi Forest Reserves, resulting in a total of 1,756 ha of plantations, mostly of teak *Tectona grandis* (1,471 ha) and *Terminalia (T. ivorensis* and *T. superba*, 274 ha) by 1984 (Ahlback 1986; Ahlback *et al.* 1984; FINNIDA 1985). No planting has been carried out since 1979 due to lack of funds (FINNIDA 1985) and thinning has also been in abeyance. In 1987 there was further clear-felling of lowland forest to plant more teak, this time in Kwamsambia Forest Reserve.

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Logging began in Kwamkoro Forest Reserve in 1958, followed by the introduction of active regeneration measures in 1962 (Ahlback *et al.* 1984). An early aim of the Forest Division was to encourage the growth of a further crop of *Cephalosphaera* and other valuable commercial timber trees by planting these species in the logged areas under a canopy of *Maesopsis*, which was supposed to supply necessary shade. This planting, at least of *Cephalosphaera*, was not very successful and the practice changed to relying mainly on natural regeneration, though with some enrichment planting. Planting stopped in 1980 (FINNIDA 1985) and there has been very little active silvicultural work of any type during recent years. Meanwhile, logging has continued, proceeding during 1986 at a rate of about 1 ha a day. The logged areas, which are very open, have become readily colonized by *Maesopsis*, which has proved an extremely invasive and fast-growing plant; the logged part of Kwamkoro is sometimes referred today as a *Maesopsis* 'plantation'. In 1984, Ahlback *et al.* gave the area of the plantation as 703 ha, consisting mostly of pure *Maesopsis* (242 ha), *Cephalosphaera* (23 ha) or a mixture of the two (436 ha).

Industrial logging has increased greatly during recent years. There had been very little activity in German and early British times, with some expansion when the tea-estates developed from the 1940's, clearing forested land for this purpose. Even so, the colonial government appears to have carefully regulated the amount of forest cut and, as stated earlier, many of the species which have subsequently become valuable were not so regarded in the 1950's. The sawmills on the estates gradually closed down, with only three left in the mid 1970's. These were one near Marvera run by IBC Co. and two at Bulwa and Kwamkoro belonging to Sikh Saw Mills. The Marvera mill closed soon thereafter, followed by Bulwa and finally, at the end of 1986, Kwamkoro.

Thus the only logging company operating in the submontane forests since 1975 has been Sikh Saw Mills (T) Ltd., a subsidiary of Tanzanian Wood Industry Corporation (TWICO). The company has been under national ownership since 1969. Sikh Saw Mills have a long record of logging in the submontane forests of the East Usambaras and, although it has had access to other sources of wood, it has regarded these forests as its chief resource. Between 1980 and 1984 Sikh Saw Mills had an average annual log input of 16,000 m^3, of which 7,000 m^3 were for a plywood mill and 9,000 m^3 for sawmills (FINNIDA 1985). The main species used was *Cephalosphaera*, accounting for 90% of plywood logs and 45% of sawnwood logs, making a total of 10,000 m^3. *Cephalosphaera*, one of the East Usambara trees with a very limited African distribution, has emerged from obscurity since the 1950's to be the main target of logging. *Cephalosphaera* only grows in submontane forest.

Standards of logging by Sikh Saw Mills have been very poor during the last few years, though they did improve in the second half of 1986 after the creation of a Monitoring Group by the Supervisory Board of the Amani Forest Inventory and Management Plan Project (Chapter 1). The poor practices drew much criticism (e.g. Kaigarula 1987; New Scientist 1985) and probably contributed to a decision that the sawmill should cease its activities on the upper slopes of the East Usambaras by the end of 1986. It can easily be seen that standards of construction of logging roads have drastically declined: old roads in Kwamkoro Forest Reserve were properly laid out and, apart from fallen trees, could easily be used again; in contrast, recent roads, such as those made during 1986 in Kwamkoro Forest Reserve and on Public Land near Kilanga Forest Reserve, are already becoming difficult to use and will undoubtedly soon be blocked by landslides, washed-away bridges and other obstructions. The gradients of roads have sometimes been much too steep and the roads have been pushed haphazardly through the forest, often with major displacement of soil. Sikh Saw Mills has also been logging near streams, which is against regulations, and opening up the forest to such an extent that some logged areas, which have occasional standing damaged trees, look as if they have been exposed to aerial bombardment. Only *Maesopsis* and a few other light-demanding species like *Trema* regenerate freely under these conditions. Trees have often been felled carelessly, for example across valleys, causing breakage and loss. Streams have become dammed through poor bridge construction, causing flooding. It has become a common practice to create a logging track to almost every felled tree, resulting in major unnecessary soil disturbance and compression, and greatly increasing soil erosion.

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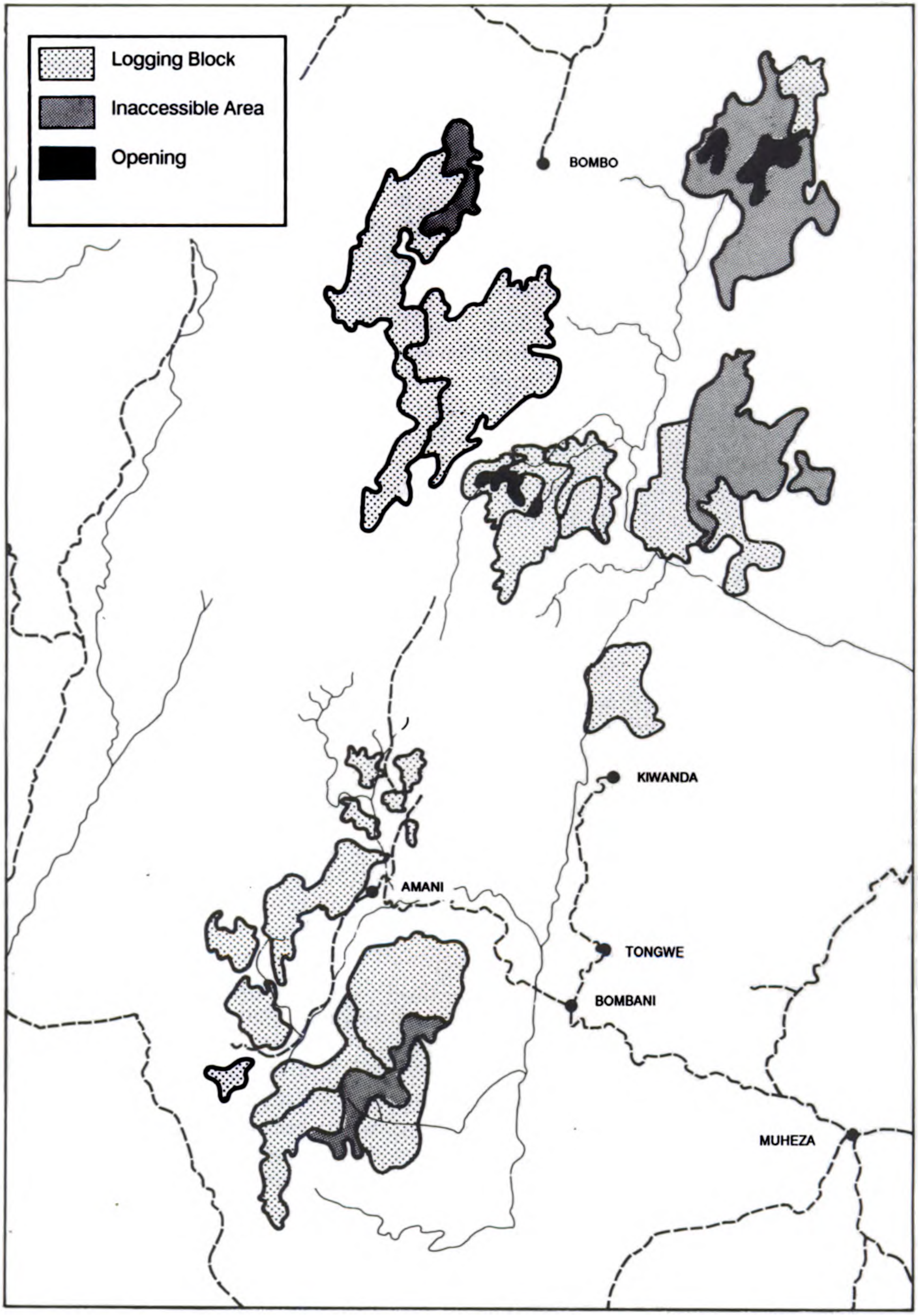

Figure 6.1 Logging areas on the East Usambaras according to Jaakko Pöyry.

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The Forest Division is responsible for enforcing logging regulations and should have controlled Sikh Saw Mills. There have, however, been problems of transport, making access to the logging areas difficult for some officers. It appears that there have been no precise concessionary agreements between the Forest Division and Sikh Saw Mills. No fines or other penalties have been imposed for breaking logging regulations. Probably, the fact that the mill is nationalized has tended to obscure the principle that it is the Forest Division which is the forest manager. There is a parallel with Uganda, where nationalization of sawmills in 1973 resulted in a decline in logging standards and a weakening of control by forest officers (Hamilton 1984).

Sikh Saw Mills has been receiving aid from the Finnish International Development Agency, FINNIDA, since 1977. This assistance has been channelled through private consulting companies, Ekono since 1984. Sikh Saw Mills was selected for assistance because, unlike the other sawmillers operating in the East Usambara area, it is owned by the state. The aid has taken the form of managerial and financial assistance, the latter including gifts of new machinery and support in maintaining the machines. Numerous chain-saws and also bulldozers, skidders, heavy trucks and a high capacity peeling plant for plywood have been supplied. Since 1985 aid for new equipment has taken the form of import support i.e. FINNIDA provides hard currency for purchases but Sikh Saw Mills has to find the equivalent in Tanzanian currency.

This aid has resulted in additional pressures on the Usambara forests. There has been a drive to increase production. The numerous chain-saws have made it easier to fell trees. The heavy bulldozers have resulted in large movements of earth. The lorries have severely damaged some of the public roads, creating difficulties for the tea-estates and the general public. A new high-capacity peeler, replacing old machines, has increased the demand for trees for plywood.

FINNIDA has justified logging on the East Usambaras on several grounds (Helenius 1986). It is claimed that logging protects the income of 4,000 people, who are said to be directly or indirectly dependent. It is stressed that there is a need for the products, especially tea-chests for exporting tea. It is even argued that the forests will be chopped down anyway (by pit-sawyers and farmers). The argument about tea-chests may not now be valid. Apparently, many tea-estates in Tanzania are now packing tea in plastic-lined paper sacks, which are much cheaper, more convenient to use and acceptable to tea-importers. In any case, at least one tea estate on the West Usambaras has found that it is cheaper to import tea-chests from India than to purchase them from Sikh Saw Mills.

Inventories of the amount of timber available in the forests have been carried out by the Forest Division supported by FINNIDA, operating through consulting companies, in 1977, 1983 and 1986/7. These are not the first inventories on the East Usambaras. In 1937 there was a 10% enumeration of the Amani-Sigi/Kihuhwi area (Forest Division s.d.) and there was an inventory of Kwamkoro during the 1950's. The main objective of the first two FINNIDA-supported inventories was to determine the amount of timber available for exploitation. A map drawn in 1982 for the first inventory shows that all areas of forest, both inside and outside forest reserves and except for places with very steep slopes, were regarded as potential targets for logging (Fig. 6.1). Indeed, the plan envisaged the forests as being solely available for exploitation by Sikh Saw Mills, without consideration being given to other potential loggers or to other values of the forest.

The first two FINNIDA inventories have been widely criticized, especially for not making sufficient allowance for the highly selective nature of logging by SSM and losses during harvest, for ignoring other values of the forest, and for questionable estimates of regeneration time (and hence the lengths of the cutting cycles). Available merchantable wood volume was calculated as 185 m^3 ha^{-1} in the 1977 survey and (based on a localized sample area) 110 m^3 ha^{-1} in the 1983 survey (FINNIDA 1985; Jaakko Pöyry 1980, 1983), though for various reasons Sikh Saw Mills actually obtains only about 25 m^3 ha^{-1} (quoted in a document outlining their proposed logging operations for 1 July 1986 – 31 December 1987). The inventories assume a 35-year cutting cycle, though without evidence to support such a figure and without describing silvicultural measures, if any, needed to provide the necessary stocking and growth-

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rates. The third inventory in 1986/87 was more intensive and had broader aims, including assessment of other resources, such as the biological and hydrological, as well as the amount of timber. The help of IUCN was requested to provide a wider perspective: hence this present report. A few of the more important results of the 1986/87 inventory are given in Chapter 24.

When Sikh Saw Mills ceased operations on the upper slopes of the East Usambaras in December 1986, they intensified their activities at lower altitudes. Clear-felling of the lowland part of Kwamsambia Forest Reserve commenced in early 1987. It was stated by the Forest Division that the timber gained by Sikh Saw Mills from this operation was incidental to the purpose of the exercise, which was the preparation of the ground to plant teak. The Forest Division claimed to be following an old plan to expand the Longuza teak plantation, but this is a rather dubious justification since the plan has not been followed in other respects for a number of years. The felling of the natural forest at Kwamsambia has now ceased, after clearing about 45 ha. Teak seedlings are being raised in nurseries for planting out in 1988.

Sikh Saw Mills has also been obtaining timber from the lower slopes of Mt Mtai, an area which had been earlier specifically excluded from logging by a decision of the Supervisory Board of the Amani Forest Inventory and Management Plan Project (Chapter 1). Additionally, the sawmill has started buying logs from trees felled on Public Land by subcontractors, who have been issued with chain-saws and who report back when logs are ready for collection. This is legitimate but allows Sikh Saw Mills to sidestep the problem of obtaining felling licences itself. At the same time Sikh Saw Mills has been seeking to increase its supplies of timber from plantations, principally softwoods from the West Usambaras, and has recently been allocated a large area of Public Land elsewhere in Tanga Region, said to be degraded forest, for establishment of its own hardwood plantation.

All felling of trees in (central government) forest reserves, by whatever agency, is legally under the control of the Forest Division. On Public Land the public has a right to fell trees, without any licence, when expanding their farms, except for ten 'reserved' species (of which only four grow on the East Usambaras – *Beilschmiedia*, *Cephalosphaera*, *Khaya* and *Milicia*), for which special felling licences must be obtained.

Until 1972 the system for obtaining licences for the felling of trees was simple. Felling of trees in central government forest reserves and on Public Land was controlled by the Forest Division and felling in local authority forest reserves was under district councils. (There are no local authority forest reserves on the East Usambaras.)

In 1972 many government powers, including in forestry, were decentralized to the regions, while at the same time district councils were abolished. The overall effect was to concentrate power in the hands of Regional and District Development Directors, coming under the Prime Minister's Office. The Forest Department lost control of all central government forest reserves except for a few regarded as of national importance (Ahlback 1986). On the East Usambaras the latter were Longuza, Kihuhwi-Sigi, Kihuhwi, Kwamsambia and Kwamkoro, all regarded, at least in part, as plantations or potential plantations. These were, and still are, managed by the Longuza Forest Project.

Decentralization of government control resulted in serious loss of forests in Tanzania (Lundgren 1985), mainly because the regional and district authorities were anxious to secure quick revenue from selling licences to fell trees. As a response, the government acted by placing some forests in Tanga Region and three other parts of the country in a new status of forests, 'Catchment Forest Reserves', coming once again directly under the Forest Division. Catchment forests in Tanga Region are regarded as serving three functions, catchment protection, gene-pool conservation and timber production, of which the first is held to be the most important (Forest Division 1975; Lundgren 1985). All the old central government forest reserves on the East Usambaras became catchment forest reserves, with the exception of those already under the Longuza Forest Project.

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Pit-sawing has been practised on a small scale on the East Usambaras as far back as German times, but major expansion did not occur until the early 1960's. Pit-sawing involves the felling of individual trees, cross-cutting the trunks, rolling the logs onto frameworks usually over pits and then sawing planks by hand with a big vertical saw operated by two workers, one above and one below the logs. Felling is usually done much more carefully than is the case with Sikh Saw Mills, because otherwise it might prove impossible to roll the logs to positions where they can be sawn. Pit-sawing can, however, create large gaps and when conducted on a large scale can rapidly degrade a forest (Chapter 27). Only four species are normally taken on the East Usambaras – *Khaya*, *Milicia*, *Newtonia* and *Ocotea*.

Trees for pit-sawing are selected by agreement between a pit-sawyer and a forest officer. In the case of forest reserves, the forests are supposed to be divided into annual felling coupes, restricting the area of operations. For both forest reserves and Public Land, licences are required, these being obtainable from different offices for different places. Licences are obtained from the Longuza Forest Project for the forests under its control, from one of two offices (in different districts) of the Catchment Forest Project for catchment forests and from one of two offices (again for different districts) of the District Administration for trees on Public Land. Licences are in two parts, Part One to be obtained before trees are cut and Part Two following measurement of the trees on the ground to assess their value prior to sawing.

Considerable capital is needed for pit-sawing and licences seem to be issued mostly to local businessmen. The actual sawyers are mainly from Iringa District in the south of Tanzania and are a group of people who readily move around the country in response to opportunity. Lorry owners, mainly urban people in Tanga, benefit substantially from the transport of the timber. Some of the timber is exported legally to Kenya, to which some is also smuggled, possibly as much as 60% according to one report. About 60% of the timber coming from the East Usambaras in early 1987 was said to be cut by pit-sawyers.

The British administration had repeatedly stressed the value of forest on the East Usambaras as a protector of climate and water supplies. It is appropriate to ask whether recent deforestation has lowered the value of these resources.

The Tanga Water Master Plan (1976) contains an analysis of climatic change and concludes that there has been no long-term trend in the amount of annual rainfall, while noting a tendency for a few years prior to 1976 to be exceptionally dry. A problem in dealing with climatic change is that climatic records from meteorological stations in the East Usambara area have tended to become unreliable during recent years (Chapters 12 & 13), but even so one analysis of rainfall trends does point to a tendency for the entire region of the East Usambaras, including stations as distant as Tanga Town, to have experienced increasingly unreliable rainfall since about 1960, with, in particular, an exceptional number of dry years (Chapter 12). Recent temperature records from the East Usambaras are too unreliable to be of much value.

Long-term residents of the East Usambaras consistently report that the climate has changed dramatically during the last 10 to 15 years (Chapter 14). The climate has felt drier and warmer, with mist much less common and with rainfall tending to come in discrete heavy showers rather than being more prolonged. Farmers and tea-planters have faced increased problems, for example in deciding the best times to plant crops.

There are so many factors which can influence the climate that assigning causes to climatic change is difficult and requires sophisticated modelling. The regional change in rainfall noted above cannot be due to deforestation on the East Usambaras, except as a minor contribution to more widespread events. A possible cause could be very widespread reduction in vegetation cover over much of East Africa, as is indeed known to have occurred.

The decline in mistiness which has occurred at higher altitudes on the East Usambaras can be blamed with greater confidence on local forest clearance, because it is precisely the type of climatic change

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which Dowsett *et al.* (1954) predicted would occur with forest destruction. Forests release more water into the atmosphere than most other types of vegetation and help to maintain a high relative humidity.

A number of biological changes in the East Usambaras may be due to climatic changes brought on by deforestation. Mangoes, citrus trees and coconuts today yield fruit in the Amani area, but formerly did not (Chapter 14). There is an exceptionally high mortality among large trees in one part of Kwamkoro Forest (Chapter 27) and also in Mazumbai Forest on the West Usambaras (Hall 1985). Malaria, formerly unknown as an endemic disease in the plateau area around Amani, is now serious; higher temperatures favour malaria (Bruce-Chwatt 1985). Probably a more direct result of deforestation is a large reduction in the numbers of black flies *(Simulium woodi)* and the infectivity rate of man with onchocerciasis at Amani between 1964 and 1986 (Muro pers. comm.). The larvae of this fly are associated with small heavily shaded streams, the numbers of which have been declining with forest clearance.

The spread of malaria is interesting and this is not the only place to experience this phenomenon. Malaria used to be absent (until the 1970's) in the highland (1,800–2,200 m altitude) area of south-west Kigezi in Uganda. There has been a climatic change from the 1970's of the same type as recorded on the East Usambaras, that is greater warmth and decreased mistiness and general wetness. This is attributed by local people to forest and tree destruction and swamp drainage (Hamilton 1984).

Records of river flow are either inadequate to reveal any possible adverse trends or show only slight changes (Chapter 15). Again long-time residents of the East Usambaras recall that springs have dried up and that the water is now much less clear. The flow of the Kihuhwi is reported to have become reduced even in 1954, allegedly due to forest clearing in the headwaters (Dowsett *et al.* 1954). The drying up of springs following forest clearance is reported from the West Usambaras (Egger *et al.* 1980) and from many other parts of East Africa.

Streams and rivers originating on the East Usambaras have always been vital as sources of water for rural populations living along their lengths. Apart from their use for domestic purposes, many streams also service small patches of irrigated land used for rice-growing. Sisal estates are major industrial users of some of the rivers, notably the Sigi and Mkulumuzi. The sisal industry uses large quantities of water to decorticate the sisal leaves, resulting in production of an organic-rich waste which is a major hazard to water quality unless treated (Chapter 16). Over the years, the sisal estates have given insufficient care to water treatment and have been major polluters of the Sigi River (Gauff 1976); sisal estates downstream have sometimes blamed those upstream for depriving them of good water. Discharge from Amboni Sisal Estate runs into the Sigi River close to the sea and even today can cause the river to become black, putrid and bubbling (?methane) and of no use for other purposes.

The pollution problem in the Sigi has become a matter of great significance since the building of a dam in the 1970's at Mabayani 15 km from the sea to serve as a point of extraction for the water supply of Tanga Town. Problems have not yet arisen only because the sisal industry is suffering from a period of decline. If the sisal estates along the Sigi were reinvigorated, then, judging from the previous behaviour of the estates regarding water treatment, the people of Tanga could well be deprived sometimes of drinkable water.

The final pressure on the East Usambara forests considered here is collecting by professional biologists and by dealers in animals and plants. The collection of occasional specimens of plants and animals for scientific purposes is not a serious problem, but I have reliable information that some professional botanists have been collecting large quantities of African violets *(Saintpaulia)*, presumably either for growing in the laboratory or at home, or for commercial purposes. African violets belong to a genus with a very restricted range in Africa, with more species known from the East Usambaras than anywhere else (Chapter 18). The plants usually occur on moist shaded rocks, often under trees and are very local; they are endangered not only by over-collecting, but also by forest clearance.

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Certain commercial collectors come frequently to Amani to purchase tree-frogs and chameleons from children. Tree-frogs and chameleons are two of the many groups of animals which are exceptional on the East Usambaras, with many endemic species (Schiotz 1981). There are also reports of a commercial butterfly collector working the East Usambaras, but bird collectors (who operate on the West Usambaras) have not been reported.

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TRDP – see Tanga Regional Development Plan.

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7. Safeguarding the Resources of the East Usambaras

by A.C. Hamilton

The values of the various natural resources of the East Usambaras are assessed and ways are suggested of conserving them for the benefit of future generations.

1. The concept of sustained use of natural resources

It makes sense to manage natural resources to maintain their long-term value. Conservation of resources implies that systems of usage are such that the values of the resources are not degraded, but rather managed for the benefit of future, as well as present, generations. Note that conservation does not imply that resources are not to be used: conservation of timber resources, for example, involves the concept of a sustained timber yield, not no timber yield. Conservation entails knowledge of how natural systems function, as well as the development and application of suitable systems of control.

The perception of the value of a resource differs between different groups in society. A balance must be struck between these varying interests. On the East Usambaras the poor peasant farmer will often judge that the acquisition of land for cultivation is a first priority, even if he realizes that the productive value of the land will soon disappear. On the other hand, the people of Tanga Town and others using water coming from the mountains have an interest in keeping a forest cover. Loggers and wood users might like to see the production of timber and plywood maximized. Foresters, the medical world and scientists generally realise the value of conserving species, partly because of the possibility that they might provide new usable products. It is the job of the planner to produce a workable system of management which balances these and many other interests in a way which is generally acceptable.

2. Planning should be long-term

Major conflicts have arisen between those interested in long-term conservation of resources and those interested in immediate exploitation. During recent years the latter have tended to be favoured by government policy. Additionally, they have been at an advantage because some regulations controlling the use of resources have not been vigourously enforced.

It is mistaken to hold that appeasement of short-term interests will lower pressure on the remaining resources, except on the shortest of time-scales. Indeed, the opposite is the case – one concession leads to another and new exploiters may move in to take advantage of the opportunities. If land is taken from forest and given to agriculturalists who destructively utilize the soil, then the biological, catchment and climatic qualities of the area are lowered, for practical purposes permanently. Meanwhile, the farmers, who are not necessarily local people, may add to the local population and will sooner or later demand more land as that which they possess becomes exhausted. Again, timber concessions

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without adequate measures to ensure regeneration lower the timber value of the forests. Having exploited one place, the lumbermen ask for another. Many people who have never before been involved in the timber trade have realized recently that there are large immediate profits to be made from pit-sawing and are now moving in to grasp opportunities.

This constant pressure is not conducive to good planning since there is an atmosphere of continual stress and conflict; planners are under pressure to give way to immediate interests. Each concession may possibly be seen as having only a minor impact on the environment, but collectively they are very destructive. Agriculturalists may argue that cultivation in one area of forest is justifiable because much more forest remains — but will they not use the same argument again later to take over another piece of forest? Sawmillers may argue that the felling of one small forest will not significantly decrease the total forest area — but next year they will say the same thing about another area.

It should be an objective of government planning to remove this atmosphere of pressure and crisis. Where uncertainty exists as to the value of a resource or to the area of forest needed for its sustainment, then decisions should always be made on the side of caution. There is much debate about the sizes of forest needed to sustain biological, catchment and climatic values. It is pointless for the forest planner to try and estimate the minimum possible sizes of forest necessary for these purposes. Any reduction in forest area is likely to have some adverse influence on these resources and it is extremely dangerous to try and reduce a resource to near its critical level, at which point any adverse, unpredictable circumstance can easily tilt the balance towards disaster.

Control over utilization of resources on the East Usambaras has always been a political issue. Since Independence there has been a relaxation in the regulations governing farming (Chapter 6), one objective being to make immediate use of resources for national prosperity and another being to remove from the farmer restrictions which were seen as colonial impositions. In the forests, there has been a relaxation in the enforcement of government regulations over logging. These moves are not justifiable either by socialist ideology or national interest. On the contrary, socialism, which has become the dominant political creed in Tanzania, favours long-term planning over short-term interests in most countries. The responsibilities of government towards the environment are not diminished by a government's national composition, although priorities may differ. Given that the resource base of the East Usambaras is being allowed to decay through the removal of rules over agriculture and the general failure of the population to take up better practices on its own initiative, is it not the duty of government, with its wider and longer-term perspectives, to reconsider its attitude towards agricultural rules? After all, government has no compunction in applying regulations for the general benefit in many other spheres of national life.

3. Division of land into zones to be managed for different purposes

The land of the East Usambaras serves many purposes, some of which are mutually incompatible, while others can be accommodated within the same area. Increasing land pressure means that clear zoning of land for different activities has become essential. Management structures should reflect this.

Legally, the Forest Division is responsible for the forest reserves, but power is divided between the Longuza Forest Project and the Catchment Forest Project. The latter operates out of two offices, each dealing with forests which roughly, though not exactly, fall within one of two administrative districts. The Korogwe office has proved relatively ineffective in exercising authority in some of its forest reserves (Lutindi and Kilanga). The Korogwe office needs strengthening and there should be a bigger Forest Division presence on the ground in Lutindi/Kilanga. At least one senior officer should be appointed to live near these forests.

The Forest Division should re-examine its administrative structure in the southern part of the main range, especially if it is agreed to set up a nature reserve as proposed later in this chapter. All forests within the nature reserve should be administered from a single office, probably associated with the

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Catchment Forest Project. Therefore, Kwamsambia Forest Reserve and part of Kwamkoro Forest Reserve should be transferred from the Longuza Forest Project to the Catchment Forest Project. The Longuza Project should only be responsible for plantations.

Where allowed, all timber and pole harvesting in the forests should be confined to small clearly defined areas, with properly drawn up agreements, which incorporate adequate powers for the Forest Division to deal with abuses. Silvicultural measures can then be applied more efficiently and control over harvesting will be easier.

The boundaries of forest reserves should be marked by belts of planted trees, which experience has shown help to cut down on agricultural encroachment. These boundaries could be wide and composed of species useful to the local community; in effect, they could amount to linear plantations. The species selected for boundary trees should be able to grow readily from cut stumps and should not be types liable to invade the natural forests.

The estates should have their boundaries legally defined so that they can be sure of the areas which they own and be able to manage them more efficiently.

4. The importance of forest reserves, old and new

Many of the suggestions for management in this report deal specifically with forest reserves. The reason for this emphasis is not that areas outside forest reserves are unimportant, but that it is much easier to control activities in forest reserves than on Public Land, giving the best prospects for conserving biological, catchment, soil and climatic resources. The estates also represent areas in which active management to improve the environment is relatively easy and must not be forgotten.

It is essential that larger forests are managed by the central government Forest Division, not by local authorities. The management of these forests should be directed at long-term, not short-term, interests. Biological, catchment and climatic values of the forests affect people far beyond the locality of the forest. These points were recognized by the Government in 1976 when the old central government forest reserves were returned to the Forest Division.

New central government forest reserves ought to be created on the East Usambaras despite the difficulties in doing so, especially the problem of finding money to pay compensation to established occupants. The following extensions to the forest reserve estate are proposed (see also Chapter 1; Fig. 1.5.):

- Lutindi, Nkombola and Kilanga Forest Reserves should be combined and extended towards the south-west. There is much cardamom here and compensation to farmers will be necessary for loss of crops. There should also be excisions from Lutindi and Kilanga on those sides where there is much agriculture and settlement (Fig. 1.5).
- Kwamkoro Forest Reserve should be enlarged to the south to embrace surviving forest outside the reserve.
- Mtai Forest Reserve should be enlarged to include the important catchment valley of the Muzi.
- Kwamgumi, Segoma and Bamba Ridge Forest Reserves should be combined and extended northwards (the extension is already the *de facto* situation).
- A small forest reserve should be established on the upper slopes of Mt Mlinga to protect a biologically unusual forest containing *Podocarpus latifolius* and various endemics (Chapter 23).
- Kihuhwi-Sigi Forest Reserve should be extended westwards as far as Amani-Sigi Forest Reserve to protect this important catchment (facing the direction of the moist south-easterly trades) and to provide a buffer zone for the nature reserve. The high catchment value of this area was noted earlier by Dowsett *et al.* (1954). However, this is an area largely cultivated at

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present and no reservations should be made without full consultations with all interested parties. The area shown on Figs. 1.5 & 1.6 should be regarded as open to negotiation.

- While it would also be desirable to establish Derema as a forest reserve, since it has major catchment value, this could be difficult given the extensive amount of cardamom present under the forest canopy. Possibly, Derema Forest could be converted into a plantation for village use and managed as a village forest.

The managers of the tea and sisal estates should be brought into management plans. The estates, like the forest reserves, serve relatively wide and long-term interests. Estate boundaries should be properly legally defined. Given the problems of making profits from sisal and tea, estate owners should be encouraged to diversify by planting other crops, such as plantation trees and, at higher altitudes, quinine. The estates could develop small fuelwood and pole plantations for the use of villagers.

5. Conservation of the flora and fauna

The world is fast losing one of its major resources — the diversity of animals and plants inherited from the past. Mankind relies on organisms for survival and yet only a minute fraction of species are as yet directly utilized. Once lost, species cannot be recreated. The greatest wealth of species is in tropical forests, which are rapidly being destroyed. Hence, there is special interest among those concerned with our biological inheritance over the currently great rate of destruction of tropical forests all over the world.

Not all tropical forests are equally valuable for genetic conservation and our studies have confirmed that the East Usambaras are outstandingly important, containing many species of plants and animals found nowhere else or present in only a few other forests, often also under threat of destruction (Chapters 21–23, 34–35). For comparison, it may be noted that no forest in Uganda approaches the East Usambaras as a site for rare species. Given their small size, some biologists argue that the East Usambara forests are among the most valuable biologically in Africa. Because of their high biological importance, special consideration should be given to genetic conservation in any management plan.

The East Usambaras lie within a zone of relatively high rainfall 50–100 km wide running along the East African coast, mainly in Tanzania. Forests in this zone have a flora and fauna markedly different from those of the main African tropical forests in West and Central Africa (and extending into western Tanzania). For many organisms the East African coastal forests have been biologically separated from the western forests for millions of years, leading to evolutionary divergence. The degree to which this has happened varies between different groups of organisms (Chapter 34), depending presumably on their abilities to cross the relatively unfavourable interval between the East African coastal forests and forests to the west and their varying rates of evolutionary change.

The East Usambaras contain both lowland and higher altitude (submontane) forests. Lowland forest once occurred quite widely within the East African coastal forest zone, though it is now greatly reduced everywhere and even the remnants are under threat. On the other hand, submontane forest is confined to a relatively few mountains of sufficient altitude. These mountains, with their distinctive East African coastal forest fauna and flora, are known as the Eastern Arc mountains (Chapter 21). They include, in addition to the East Usambaras, the Ulugurus, Ngurus, Uzungwas and others (Fig. 1.1).

The East Usambaras have usually been considered as either the most, or among the two (with the Ulugurus) most valuable mountains of the Eastern Arc from the biological point of view. This may be partly an artifact of the state of biological knowledge. The East Usambaras have been relatively well explored; recent findings suggest that for some groups of organisms, such as birds and mammals, other mountains, such as the Uzungwas, may be more important (Rodgers & Homewood 1982; Stuart & Jensen 1981). Actually in a sense such arguments miss the point. All these Eastern Arc forests are biologically valuable: they represent an evolutionary situation similar to archipelagos such as the Galapagos Islands, though they are archipelagos of isolated habitats rather than true oceanic islands.

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Within the context of the Eastern Arc mountains, two of the distinctive features of the East Usambaras are that there is an exceptionally large area of submontane forest (a consequence of the levelling out of the Amani plateau at an altitude favourable for this species-rich forest type), and that there is an exceptionally large amount of lowland forest (Chapter 21). Lowland forest is probably under even greater threat than submontane forest within the East African coastal forest belt, because it tends to be found in places more accessible to farmers and because it is regarded as having lower catchment value.

Biological conservation on the East Usambaras is not only important for the rare species. Populations of many species in the East Usambara forests must have been isolated from other populations of the same species elsewhere for very long periods of time, probably in many cases for millions of years. The populations are very likely to be genetically distinctive. Foresters, among others, are aware of the value of such distinctive varieties, for example in the selection of provenances for tree planting (Ledig 1986).

Analyses of forest types on the East Usambaras (Chapters 22–24) show that the forests vary floristically with altitude. Examples of forests at all altitudes should be conserved for genetic conservation purposes. Endangered species occur in all forest types. Some species of birds are known to move altitudinally during the course of the year (Chapter 35), demonstrating another reason for conserving all types of forest, that is to maintain the integrity of the ecosystem.

The submontane forests of the East Usambaras are not biologically uniform and we have established that it is those at the southern end of the main range which are richest in species and thus can be regarded as of prime importance for biological conservation (Chapters 23, 24). It is proposed that a nature reserve be established here, embracing all of Amani-Sigi and Kwamsambia Forest Reserves and the southern more intact part of Kwamkoro Forest Reserve. All of Kwamsambia, including lower lying areas, should be included in the reserve (Fig. 1.6). Troup (1936) and IUCN (1983) had earlier called for a nature reserve in about this area. A suggested name is Amani Nature Reserve.

Our analyses suggest that lowland forests to the east of the main range, in Marimba Forest Reserve and on Mtai and Mhinduro, are biologically rather different from Kwamsambia on the main range (Chapters 23, 24). Because there is only a small area of lowland forest in the proposed Amani Nature Reserve, it is proposed that the more intact western and north-western parts of Marimba Forest Reserve be set aside as an area used for genetic conservation and should not be extractively exploited.

The forest on the top of Mt Mlinga is biologically very unusual, with *Podocarpus latifolius* and some endemics, and should be protected for reasons of biological conservation. It is proposed that a small forest reserve be established here. This was earlier recommended by Dowsett *et al.* (1954), who pointed out that the forests on Mlinga, few as they are, help to protect a number of perennial streams, notably the headwaters of the Mkulumuzi and Mruka Rivers.

It is proposed that west/north-west Marimba and Mlinga be managed as non-exploitable catchment forests.

It is suggested that a special administrative structure should be established to manage Amani Nature Reserve. It is considered that the establishment of a single, comparatively large nature reserve will make management easier and will probably give a better chance for species to survive. Ease of management is a very important consideration in recommending only one major nature reserve on the East Usambaras. The whole nature reserve should be managed from a single office set up specifically for this purpose and associated with the Catchment Forest Project. Kwamsambia Forest Reserve and the relevant part of Kwamkoro Forest Reserve should therefore be transfered to the Catchment Forest Project from the Longuza Forest Project. To avoid confusion of purpose and to reduce competition for finance at the local level, it would probably be best if this office is financed separately by Forest Division headquarters from the other parts of the Tanga Catchment Forest Project. Hall (1983/84)

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has made many useful suggestions about the best ways to administer and practically run a forest nature reserve in the Tanzanian context.

There has been considerable debate over the best sizes and shapes for nature reserves (e.g. Diamond 1975; Gilpin & Diamond 1980; Higgs & Usher 1980), partly based on a theory ("The Theory of Island Biogeography" by MacArthur & Wilson 1967), which has been widely criticized (Gilbert 1980; Margules *et al.* 1982). A major question is whether a nature reserve (or system of reserves) is large enough to prevent species from becoming extinct – this can only be assessed if solid information is available on the autoecology of species (Jarvinen 1982; McCoy 1982). Knowledge is needed on the internal disturbance dynamics of ecosystems, for example, in the case of tropical forests, about the sizes, frequencies and other characteristics of tree-falls. Binggeli (Chapter 27) has attempted to investigate this question in relation to *Maesopsis* on the East Usambaras. Our almost total lack of knowledge about the ecology of forest species on the East Usambaras makes it sensible to retain as large an area as possible for genetic conservation. Our studies (Chapter 25) have indicated that many tree species occur at a low density in the forests and may require large areas for populations to be viable.

Although it is suggested here that the nature reserve should come under the Catchment Forest Project, this might not be the best arrangement in the long-term. Rodgers and Homewood (1982) have discussed legal aspects of forest conservation in Tanzania. There is at present no category of Nature Reserve or Forest Nature Reserve (see Legislative Council of Tanganyika 1953). The desirability of creating a special new legal category should be considered; the experience of other countries such as Kenya (Laws of Kenya 1982) would be useful in making a decision.

The nature reserve should be completely surrounded by a belt of planted trees or, preferably, by a buffer zone of forest used for other purposes. Fortunately the proposed area is already protected on one side by the 'plantation' part of Kwamkoro Forest Reserve and by the teak plantation of Kihuhwi Forest Reserve. The eastern edge of the reserve is vulnerable to agricultural encroachment and exploitation, which is one of the reasons why it is proposed that negotiations should be pursued for the creation of a new forest reserve in this area.

Tropical forests are complex systems, about which we know little, and normally the best way to maintain populations of species is not to interfere but to keep natural systems as intact as possible. No timber extraction, pole-cutting or gathering of fuelwood should be allowed within the nature reserve. Apart from other considerations, timber harvesting creates large gaps, within which many species cannot regenerate (Newberry *et al.* 1986; Chapter 27). There is one immediate problem which may, however, require active measures. This is the invasion of several exotics, especially *Maesopsis* and to a lesser extent *Melia.* The East Usambara forests are very unusual in containing such invaders; probably, they are vulnerable because of long isolation from the main world areas of tropical forest (compare the vulnerability of many animals and plants on isolated oceanic islands), combined with climatic change increasing the mortality rate and otherwise affecting the reproductive success of some indigenous species. The numbers of invasive species are liable to increase if not checked, presenting threats to the survival of some of the indigenous species through competitive displacement. Methods of controlling these invaders should be established by research.

In arguing for a single large nature reserve, largely because of the practicalities of management, it should not be overlooked that other forests on the East Usambaras, apart from those included in the nature reserve or the two small proposed non-expoitable areas of catchment forest in Marimba and on Mlinga, are biologically interesting. Some rare species are known only from other parts of the mountains. Some of the rare species occurring outside the nature reserve should be able to survive in the fairly extensive areas of forests on steep slopes, which, it is suggested here, should not be extractively exploited (Chapter 1). The staff of the proposed nature reserve should monitor biological resources in forests on all parts of the mountains.

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6. Conservation of water resources

A number of river systems originate on the East Usambaras, including that of the important Sigi River, feeding Tanga Town via a reservoir (Fig. 7.1). The Sigi catchment is very vulnerable to degradation by man. The Sigi River almost dried up between December and March 1966–67 (Gauff 1976); if such a dry period occurred today with the decreased amount of forest in the catchment, then flow in the river might well stop completely and water-supply to Tanga could be endangered. According to Kamugisha (pers. comm.), a hydrologist working in the regional water office in Tanga, the Tanga Municipal Water Supply Report of 1983 indicates that, with the estimated increase in water demand, the water in the Sigi, as now obtained through the reservoir, will not be enough in 1995. It suggests that further storage or diversion of water into the Sigi from other catchments will be necessary. The Sigi is obviously vulnerable, but other river systems should not be ignored.

Areas which are believed to be of prime importance for catchment purposes are shown on Fig. 15.2. These should be kept under as complete a cover of vegetation as possible. While in theory the actual composition of this vegetation cover is not very important, in practice the management of tea-estates and agricultural areas from the point of view of catchment protection is very poor and as much as possible of the vulnerable areas shown on Fig. 15.2 should be kept under forest. For climatic and topographic reasons the most important catchment area is the plateau on the southern end of the main range. Smaller areas of great value include other places contributing to the Sigi, notably the south-eastern slopes of the main range (e.g. in Kwamsambia Forest Reserve) feeding the perennial Kihuhwi, the Semdoe catchment on the north-east of the main range, the Muzi valley on the south-west of Mtai and the Mruka River on the northern side of Mlinga. The eastern and southern parts of Mlinga feed the important Mkulumuzi River, serving a large lowland area with several sisal estates. The north-eastern part of Mtai is the source of the Msimbazi River, also reaching extensive parts of the lowlands. Lutindi and Kilanga forests protect the headwaters of the Bombo River flowing northwards.

It is not necessary to prohibit all timber harvesting in catchment areas, but any harvesting which does occur must be done very carefully. The main dangers lie in the construction of roads and paths and in the compaction of the soil. Mechanical logging involves much construction of roads and tracks, exposure of bare soil and soil compaction; especially in view of recent experiences of logging in Kwamkoro Forest Reserve, it should not be allowed in the future in catchment forests. Pit-sawing involves less destruction and is environmentally more acceptable, but it also causes some damage through creation of much-used paths and excavation of pits, so it should be carefully regulated.

The main question concerning the possibility of mechanical logging in important catchments of the East Usambaras is whether such logging should be allowed in the *Maesopsis* area of Kwamkoro. To allow logging would represent a compromise between catchment and timber interests. If logging is allowed, then, in so far as it is possible, only roads already existing should be used and logs should be pulled to the roads by cable and winch. It is unfortunate in this context that recent forest roads in this area have been so poorly constructed and some will need restructuring. Only light machinery should be employed in timber and road-building operations, not the inappropriately heavy trucks and bulldozers supplied by FINNIDA to Sikh Saw Mills. The latter vehicles have not only done unnecessary damage to the forest, but have degraded access roads, causing problems for other users.

Further forest destruction will cause flow of the rivers to become more erratic and will cause an increase in suspended sediment. Both these effects are undesirable to those using the water for drinking or for other domestic purposes and to people cultivating near river margins. Water quality, as opposed to water quantity, is however likely to be much more influenced by events in lower parts of the catchments (Chapter 16). By far the greatest threat is revival of the sisal industry, leading almost certainly to major pollution of rivers. A good solution would be to turn these estates over to other forms of land-use, with forestry a prime candidate. These sisal estates are exceptional in Tanzania for their high rainfall, sufficient in many places to support plantations of hardwood trees. With the growing world shortage of hardwoods, tree plantations would seem to have high economic potential, with good export

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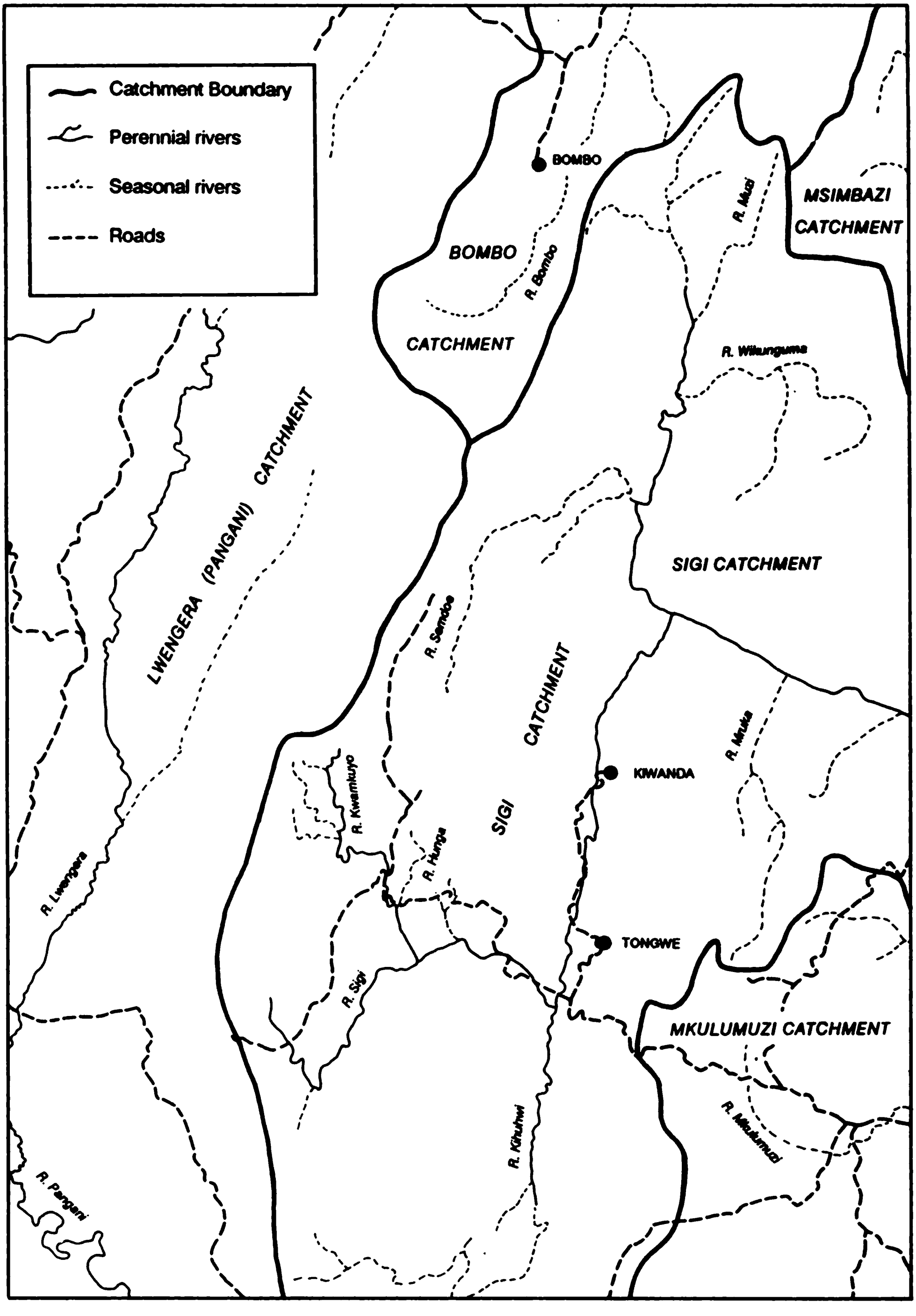

Figure 7.1 River catchment areas of the East Usambara Mountains.

prospects. Perhaps the sisal estates could themselves convert to forests, if unwilling to sell to other companies or to the Forest Division.

7. Conservation of soil resources

There are two main soil types on the East Usambaras (Chapter 10). Above 850–900 m the soils are very infertile beneath a thin forest-generated topsoil; below this altitude soils are better. Very special attention must be given to retaining the fertility of both soil types, particularly that at higher altitudes. Soils can easily be depleted either under agriculture or through forestry activities. It is possible that even a low rate of timber, pole or fuelwood extraction from the higher altitude forests may have an adverse effect on long-term forest productivity.

It is important to protect the soil from erosion, not only to prevent loss in fertility, but also to maintain a deep reservoir to store water for catchment purposes. There are not only the obvious dangers of sheet and gully erosion, but there could be a very real hazard of landslides (Temple & Rapp 1972). It is also vital that the water supply dam on the Sigi is not rapidly filled by siltation from eroding soils. Here the greatest danger is probably from the lowlands and it should be noted that spot readings already indicate decreasing water depth in the dam (Kamugisha pers. comm.).

Soils are most readily eroded when left exposed or when present on steep slopes. Slopes are steep not only on the escarpments but also everywhere at higher altitudes. Soils can be protected by very careful, well planned agriculture, but in practice a forest cover is the best method of preventing erosion. Erosion prevention thus calls for as large a forest cover as possible at high altitudes and on the escarpments; where the land in these areas is cultivated, then a complete cover of vegetation or of mulch should be maintained.

Not all types of forest are equally efficient at preventing soil erosion. Teak plantations, for example, are known to be poor in this respect (Bell 1973) and teak should not be planted on steep slopes. There is also evidence that erosion is greater under *Maesopsis* than natural forest (Chapters 30, 33).

The prevention of soil erosion calls for some afforestation as well as retention of existing forest. Tree planting, combined with other activities aimed at lowering erosion, should be encouraged on agricultural land.

8. Conservation of the climatic resource

The effect of forest on climate is a controversial subject. According to Reynolds and Wood (1977) no incontrovertible evidence has ever been produced that clearing forest has materially altered rainfall (meaning total annual rainfall). On the other hand, these authors do quote Pereira (1973), who provides evidence that the clearing of 800 km^2 of tall forest in southern Tanzania for subsistence farming appears to have halved the number of occasions on which slight rainfall was recorded. People on the East Usambaras report a similar decline in the incidence of rain-days during a recent period of major deforestation and also report greatly reduced mist (Chapter 14). A decline in epiphytic ferns at Amani (Chapter 28) and a large number of recent tree deaths in Kwamkoro Forest (Chapter 27) could be due to climatic change. Although it cannot be proved in retrospect that these changes have been brought about by local deforestation, the coincidence suggests that it has, at least in part. Theoretically, forest should increase local humidity more than most other types of vegetation, since forest intercepts more water above ground than other vegetation types (later to be evaporated), and because the deep roots of forest trees can draw on a larger soil-water reservoir. No less than 22% of rainfall is intercepted by the canopy of submontane forest at Mazumbai, West Usambaras, and does not reach the ground (Lundgren & Lundgren 1979). Soil moisture is (or perhaps was) substantially augmented in the submontane forests of the East Usambaras by fog-drip (Dowsett *et al.* 1954).

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Local climatic changes on the East Usambaras have enabled farmers to grow new types of crop, such as citrus fruits, but overall farmers and tea-planters consider the climatic changes very undesirable, especially because the rain is less reliable and less persistent.

The increased unpredictability of rainfall during recent years has affected not only the East Usambaras, but also a much wider area. In contrast to changes in mistiness and humidity, which could be more under the influence of local vegetation, this change cannot be due to deforestation on the East Usambaras, except as a minor contributory factor. Many factors could be responsible, one of which is widespread ecological degradation. In any case, regardless of the possible contributions of other factors, reduction in vegetation cover, with its various effects on energy and water budgets at the earth's surface, will certainly have some adverse influences on climate. It is in man's interest to try and control those factors influencing climate which he can, even though other, possibly more important, factors are outside his reach.

It is foolish to argue that, because we are largely ignorant of the influences of forest removal on climate, forest felling should be allowed to go ahead. In our view the body of theory and observations is sufficient to justify extreme caution. Those planning the use of resources in places like the East Usambaras have a responsibility to conserve the forests, not only because of local considerations, but for the probable benefits of these forests to climate on a much larger geographical scale.

9. The natural forests as sources of timber

Much higher yields of useful wood are obtainable from plantations than natural forests in Tanzania (Kalaghe & Kessy 1986). In the whole country, wood for all types of use should be increasingly obtained from plantations.

Wood has been obtained from the East Usambaras by both clear-felling and selective felling in the natural forests, using both mechanical logging and pit-sawing.

No more natural forest should be clear-felled on the East Usambaras. There is very little natural forest left in Tanzania and, apart from its value for gene conservation, natural forest is believed often to have other environmental advantages over plantations. There is evidence that some plantation species, chiefly conifers, deteriorate the soil (Reynolds & Wood 1977). We have established that nutrient cycling must be very different under *Maesopsis* than under natural forest on the East Usambaras. Soil under some types of plantations can also be more easily eroded, for instance under teak and, we strongly suspect, under *Maesopsis.* The open canopies of teak and *Maesopsis* result in warmer and less humid microclimates and probably more water is evaporated, aided in the case of *Maesopsis* at least, by a deep rooting system.

Such logging as is permitted in the forests should therefore be by selective harvesting. This should not be allowed everywhere; there should be no harvesting in areas specifically set aside for nature conservation and it should be prohibited on steep slopes and close to rivers. To avoid confusion, the boundaries of areas prohibited for logging because of steep slopes should be clear (Fig. 1.6) and could usefully include all those areas regarded as inaccessible in the recent Forest Division/FINNIDA inventory survey. There are local patches of more level ground within these areas, but in order to make control over logging more effective these should not be harvested.

The prerequisites for a sustainable logging industry are that forests should be managed to give continuing yields, that control over logging is adequate to ensure that plans are followed and that the environment is not unduly deteriorated. The importance of the concept of sustainable yield has been earlier emphasized by Eggeling (1951), once Chief Conservator of Forests. He believed that even in 1951 the cutting of timber in Tanganyikan forests was reaching the permissible maximum and that there should be no overall extension of exploitation allowed in the rain forests.

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Very little is known about how to obtain a sustainable harvest of timber from tropical forests anywhere in the world and indeed, according to some experts, no sustainable methods for selective harvesting of trees from tropical forests have for certain been developed anywhere. The recent mechanical logging on the East Usambaras has certainly not been based on any sound forestry theory and does not form part of a sustainable system. Given the serious environmental disadvantages, the destruction which mechanical logging has caused recently on the East Usambaras, and the relatively small amount of forest remaining, there seems to be no justification for further logging by mechanical means in natural forest.

Pit-sawing can be a more environmentally sensitive technique, provided it is well controlled. A study in Rwanda has suggested that pit-sawing can be more economic than mechanical logging (it certainly is on the East Usambaras if all direct costs, including massive 'aid' to the sawmill, are considered, and even more so if the indirect costs of environmental deterioration are included.) In the areas where it is to be allowed, pit-sawing should form part of a system of forest silviculture. Research is urgently needed to establish how the forests can best be managed to ensure a continuing harvest of wood, not only to supply pit-sawyers, but also to supply poles for villagers. Pre- and post-logging activities may be necessary, probably including gap-planting, for which only species native to the East Usambara forests should be used. It is fortunate that *Milicia*, one of the species favoured by pit-sawyers, often regenerates well from cut stumps, but it is less certain whether other desired species are maintaining their populations.

There is a need to undertake research into forest dynamics and the life-history strategies of individual species (Chapter 31). Additionally, more empirical studies of the effects of pit-sawing on tree regeneration and on the environment generally should be carried out to help develop efficient systems of exploitation. Forest regeneration is related to the formation of gaps, natural or artificial (Chapter 27), and any harvesting should be related to the gap pattern. The management of forests for sustainable pit-sawing will almost certainly require gap-planting.

The systems of controlling pit-sawyers need to be revised and strengthened. Pit-sawing should be allowed only in restricted areas (coupes) at any one time, to increase the potential of control and to make silvicultural treatments more efficient. At present licences are obtainable from different places for different parts of the forest estate or Public Land, making overall control difficult. Centralisation of licensing is desirable, possibly with the introduction of identity cards for all those involved. Since there are many people interested in making money from pit-sawing in the East Usambara forests, it will only be possible to license a small proportion of them: the method of selecting these should be fair and publicly known. The names of licensees should be public knowledge.

The Forest Division needs to be strengthened substantially to enable it to carry out its duties with greater efficiency. There are problems of morale and finance. Apart from basic pay, transport facilities, operating budgets, overnight allowances and housing should all be upgraded. Since basic pay is a matter for central government and cannot be influenced by a local management plan, thought should be given to the provision of fringe benefits to improve the material rewards for forest officers.

10. The *Maesopsis* threat

We have initiated studies to determine whether *Maesopsis* is a threat to the East Usambara forests, as has sometimes been claimed (Chapters 27–33). Work on forest dynamics has established that *Maesopsis* does invade gaps in natural forest, grows aggressively and will probably form a substantial proportion of the canopy if left unchecked. Probably the East Usambara forests are prone to biological invasions (see Section 5).

Maesopsis also changes the characteristics of the lower vegetation layers and of the soil. The lower vegetation beneath *Maesopsis* includes many pioneer tree species and weedy shrubs, but few individuals of species of the more mature natural forest (Chapters 27 & 28). The soil lacks the humus layer found

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in natural forest (Chapter 31) and contains a very different soil fauna (Chapter 32). *Maesopsis* forest has an open canopy and a much more dessicating microclimate than natural forest, and we suspect that the species dries the soil, which is also said to be the case by local farmers.

We believe that *Maesopsis* must be controlled and agree that it should be logged at Kwamkoro. Management should aim to replace *Maesopsis* with species indigenous to the East Usambaras, probably in mixed stands so as to lower risks of epidemic disease and to ensure fuller utilisation of soil and light resources. Research should be undertaken to establish suitable systems of management. *Cephalosphaera* has already been planted over extensive parts of the *Maesopsis* 'plantation' and its performance should be assessed.

11. Plantation forestry in the lowlands

Plantation forestry should play a big part in the development of the East Usambaras. Plantations of teak *(Tectona grandis)* and to a lesser extent *Terminalia* already exist in Longuza, Kihuhwi-Sigi and Kihuhwi Forest Reserves, where they have been established on land which once carried natural forest. It is recommended that there should be no further clearing of natural forest to create single-species plantations, which is in any case against government policy and was not recommended even as early as the 1930's (Troup 1936). In defence of the practice, it has been argued that lowland forests lie on land particularly suitable for teak. This is a poor argument since lowland forest, growing in places of higher rainfall and protecting the soil, will almost always be found on good sites. Following this line of reasoning, all lowland forests would soon disappear. Lowland forests are already uncommon in Tanzania (Chapter 21).

Extension of forestry plantations in the lowlands will have to be mainly on land which once carried forest, but which has suffered from some soil deterioration following forest removal. There is an opportunity and challenge to foresters to reverse environmental degradation. Plantation forestry using hardwoods is possible in many places to the east of the main East Usambara range and it is particularly recommended that the deforested escarpment on the south-east of the main range be afforested and that sisal estates within the Sigi and Mkulumuzi catchments be given over to this form of land-use (Chapter 16). The development of plantations can go ahead immediately at the north end of Longuza Forest Reserve. The possibility of establishing a plantation on an abandoned citrus estate near Segoma Forest Reserve should be evaluated. If a new forest reserve is established on the south-eastern escarpment of the main range, as proposed in Section 4, then this should be planted with trees useful directly to the local community; it should not be used for mechanical logging, because of the very steep slopes.

There are questions of ownership and finance of new plantations. Sikh Saw Mills has recently expressed interest in funding the establishment of teak plantations in forest reserves, but this opportunity should not be pursued since the ownership and management of the reserves by the Forest Division will become compromised. This is especially the case with Sikh Saw Mills, which unlike other sawmills in the area, is a parastatal organisation. Recent experience in the East Usambaras and also the forestry history of Uganda (Hamilton 1984) clearly demonstrate that the activities of publicly owned sawmills can pose particular problems of control for forest departments. Instead, the responsibility for establishment of plantations in forest reserves should rest solely with the Forest Divison. Sikh Saw Mills and others interested in starting plantations should do so on land which they own, though certainly with advice from the Forest Division where requested.

Various species and provenances should be tried in these hardwood plantations and extensive areas of one species or variety should be avoided, including of teak, which may seem a good choice at present, but perhaps its pests (such as the bee-hole borer *Xyleutes ceramicus*) have yet to arrive (Hedegart 1976). Teak increases erosion rates by 2.5 – 90 times compared with a good forest cover (Bell 1973) and should not be planted on steep slopes. Mvule *(Milicia excelsa)* could also be tried, though there could be problems with gall flies *(Phytoloma lata)*; it is usually regarded as unsuitable for close planting in pure stands (Borota 1975).

Exploitation of the lowland plantations could benefit from new technology, especially from the introduction of mobile sawmills, capable of utilizing small diameter trunks, and wood slicers, capable of producing a very highly priced product.

12. The land as a resource for the small-scale farmer

The last twenty years have seen a major expansion of small-scale agriculture on the upper part of the main East Usambara range. This has been mainly at the expense of leased land, but some forest reserves have been subject to marginal loss or even large-scale encroachment, particularly Lutindi and Kilanga Forest Reserves. The causes include movement of poorly paid labour away from the tea-estates, the financial attractions of cardamom and sugar cane and declining yields on land cleared of forest in the past.

The agricultural community places a heavy stress on the remaining forests through the gathering of forest produce. Some of the more minor uses, for example, the collection of medicinal plants (Chapter 20), are probably harmless, but fuelwood and pole-gathering are, or potentially could be, damaging influences on forest ecology (Chapter 19, 20). There are still enough trees on the East Usambaras to give a supply of fuel reasonably close to most inhabitants and fuelwood gathering, where it occurs in the forests, is mainly on the edges and does not involve the felling of live trees. It is important that the availability of fuelwood supply does not deteriorate as it has on the West Usambaras.

The gathering of poles for construction is a much more extensive activity and only the most remote forests are not affected to some extent. It has been estimated that, in 1986, the total wood volume gathered in the East Usambara area amounted to about 80,000 m^3 of fuelwood, 10,000 – 15,000 m^3 by pit-sawyers and 10,000 m^3 by Sikh Saw Mills (Maatta pers. comm.), but these figures are not really directly comparable because fuelwood gathering is expressed as gross removal and timber-harvesting as net removal, and no account is made for the massive incidental destruction of other trees, not harvested, during mechanical logging. The magnitude of pole cutting was not estimated, but is likely to be larger than the combined totals of pit-sawing and sawmill logging.

Fuelwood gathering in the forests is probably at present relatively harmless, though studies are needed for confirmation. It does, however, lower organic matter input into the soil and remove nutrients, and it can also encourage the spread of *Maesopsis* (Chapter 27). Pole-gathering is certainly already a major influence on forest regeneration in many areas. The problem of resource depletion through uncontrolled pole-cutting was earlier mentioned by Troup (1936).

Small-scale cultivation, as practised today, cannot be a viable long-term proposition at higher altitudes, where soils are very poor and easily eroded. Lowland cultivation has a better future, but even here the soils can be fairly easily degraded.

In an ideal world small-scale cultivation would never have taken place at higher altitudes and on the escarpments, but the existence of a large and growing population is a *fait accompli* and there is an urgent need to improve agricultural practices. Details are outside the scope of the present report but obviously entail the spread of methods of limiting soil erosion and maintaining soil fertility. Various methods of improving the agriculture or preventing soil erosion have been suggested by Milne (1944) and Lundgren and Lundgren (1979) for similar soils on the West Usambaras, where the Soil Erosion Control and Agroforestry Programme (SECAP) is now in progress. In the East Usambaras the IUCN/EEC project on agricultural development and environmental conservation aims to introduce some similar methods.

Plantations for fuelwood and poles should be established. Many farmers might be reluctant to establish their own plantations at present, since they perceive that supplies can be readily obtained from

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the forests. There may be a role for communal tree planting. The IUCN/EEC East Usambara project is presently working with local communities to promote tree-growing. The Forest Division can help by ensuring that the belts of planted trees around forest reserves are composed of useful species. Local governments, churches, schools and the tea-estates can all contribute.

The rugged topography of the main plateau leads to a repeated pattern of land units of different agricultural potential. Slopes, especially lower slopes, are the most suitable for cultivation. Ridges and upper slopes have less agricultural potential and are most suitable for fuelwood and pole plantations. Strips of land along rivers should remain under forest or be placed under a tree cover to help protect water courses: here fruit trees might be most suitable.

Superimposed on catenary variation is variation due to stages reached in soil degradation. This needs to be considered in tree-planting plans. There are still substantial patches of forest left outside the forest reserves. These would best be retained under natural forest, which is likely to be the best protector of the soil, but gradually enriched with the more useful indigenous species. Where the land is more degraded, then these locally managed forests should consist of more hardy trees, probably often exotics, with care taken to ensure that the species chosen are not likely to be capable of invading the natural forests.

There is a good case for encouraging farmers to plant cash, rather than food, crops on the upper parts of the East Usambaras. A small field of a cash crop can provide the same income as a much larger area of a food crop, high prices can serve as incentives to farmers to adopt soil conservation measures and some cash crops are trees and shrubs, providing a physical structure more akin to natural forest (Brown 1981). Some cash crops, such as tea and quinine, are also relatively well adapted to the poor soils. Every means should be sought to find ways of growing cardamom in a sustainable way; additionally, systems of controlled drying rather than sun-drying should be introduced as this would greatly raise the value of the crop (Slitz 1980).

13. Potential for tourism

Tropical forest tourism is a relatively new departure, which has proved successful in some parts of the world. If such tourism is permitted in the nature reserve, care should be taken to avoid ecosystem degradation. It may be possible to have educational tourism and specialized nature tourism, perhaps including visits to the sites of African violets (Chapter 18).

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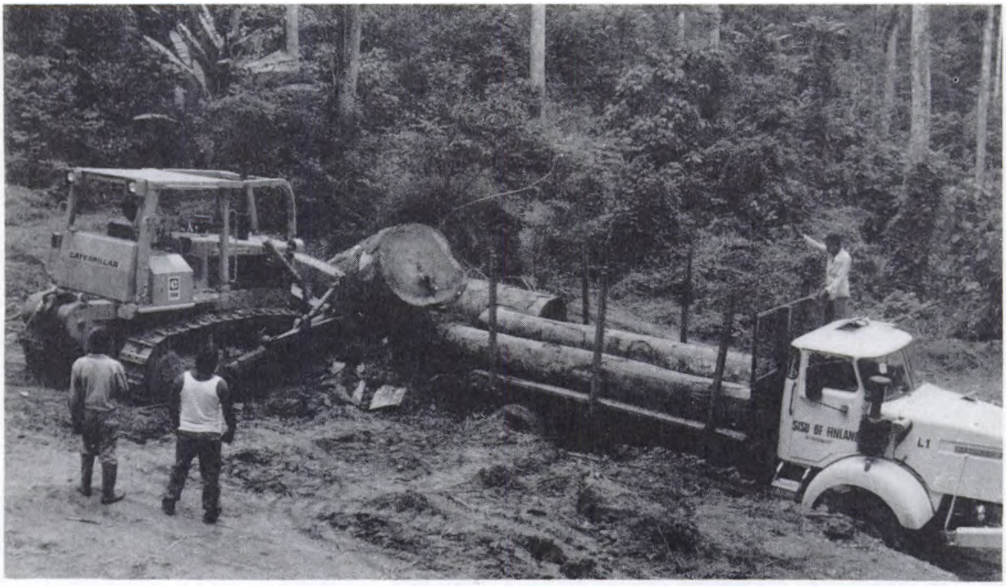
Large area of exposed subsoil exposed by poor road construction and landslides during industrial logging in submontane forest, Kwamkoro Forest Reserve, 950 m. July, 1986.



Loading logs on a truck at a landing site in submontane forest near Kilanga Forest Reserve. September, 1986.

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Section C

Technical Reports

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8. Early Exploitation and Settlement in the Usambara Mountains

by Peter R. Schmidt

Contrary to common opinion, many forests in East Africa have been exploited by man for at least 2000 years. There is evidence for Early Iron Age activity in the forest zone of the East Usambaras, probably dating to the first millenium a.d. and perhaps earlier. The Later Iron Age is also represented. Exploitation of the forests could have been intensive, at least locally.

[Editors' note: Years expressed a.d. or b.c. refer to radiocarbon years, which are approximately the same as calendar years for the period under review here.]

One of the foremost misconceptions in contemporary thinking about the forests of East Africa is that the present, well watered montane forests have only recently come under pressure and severe attack from human populations. This is an unproven assumption, which increasingly seems to be disputed by archaeological evidence. Archaeological research in Rwanda, Burundi, Kenya and Tanzania indicates that Early Iron Age (EIA) peoples encroached upon the East African forests between 500 b.c. and 500 a.d. and that their environmental impact can only be characterized as severe. The patterns of forest exploitation were not uniform, but there are definite regularities that appear to be common to EIA settlement and industry in ancient Tanzania.

Our focus here is the Usambara Mountains and the possible pressures the forest resources of this montane environment may have experienced during the EIA and subsequent periods. We know from archaeological surveys and excavations conducted during 1986 by the Archaelogy Unit, University of Dar es Salaam, that EIA populations were living above 1,400 m in a former forested zone in the West Usambara Mountains (Schmidt & Karoma 1987). These populations had cleared forested areas in the intermontane valleys to the south of Lushoto Town and were also living along and practising agriculture on the higher ridges overlooking the Maasai steppe to the west. The EIA populations of the West Usambaras were not an isolated group. Their material culture, particularly their domestic pottery, bears strong resemblances to that of other EIA populations to the north in the Pare Hills, the Taita Hills of Kenya, and on the slopes of Mt Kilimanjaro (Collet 1985; Odner 1971a & b; Soper 1967).

The affinities among EIA cultures in East Tanzania and Kenya are based on three criteria:

- the similarities of the pottery.
- the similarities in the iron industry practised.
- their permanent settlement in well watered montane environments..

The congruence between montane environment and industry is of particular interest. We see, for example, that the EIA industry practised in the Taita Hills and in the West Usambaras is highly similar.

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Both expressions of this industrial complex belong to what is called the 'Mwitu' or forest tradition. This is a distinctive industrial adaptation that is found only in East and Central Africa in forested environments during the earliest era of a settled agricultural/pastoral way of life that also practised iron production. The Kilimanjaro area supported intense EIA agricultural populations up to 1,700 m in altitude in what was a moist montane forest before being settled by these populations. Because it is a volcanic zone, iron ore resources were not available and consequently the Kilimanjaro area had to import iron goods throughout its entire Iron Age history. Most of the iron consumed in Kilimanjaro came from the Pare Hills, long known as a major iron-working area. Thus far we do not have evidence for the EIA industry having been practised in that montane zone, but this may simply be the result of incomplete investigations. The plentiful evidence for EIA settlements indicates that industrial sites must also be present.

It is particularly important to recognise that Kilimanjaro and Pare have been continuously occupied during the last 2000 years by settled agricultural peoples. This accounts for the significantly altered landscapes and the almost total forest clearance on the lower slopes of Kilimanjaro and in all of the Pare Hills. We believe that we see a similar, but less continuous history of occupation for the Usambaras. Our archaeological survey shows that there is EIA settlement and the practice of the Mwitu tradition of iron production, but much of the settlement and industrial evidence has been erased from the landscape because of the severe degradation of this fragile landscape during the last several hundred years of intense exploitation. In many areas of the West Usambaras that we surveyed, the A and B soil horizons have been removed from hillsides because of cultivation and house building on severe slopes (Ezaza 1985). We note that the only areas where evidence for EIA occupation is preserved is on the tops of ridges that have been cleared of forest during the last several decades.

The settlement history of the Usambaras is not only limited to the earliest and latest eras of the Iron Age. There is another occupational period that dates to the 900 – 1000 a.d. period, when there were a large number of villages, particularly on the small spurs that run perpendicular to the ridges within the intermontane zone. We know that communities making similar kinds of pottery were contemporaneous along the Indian Ocean littoral, the Pare Hills, and the Tana River in Kenya. This appears to be a widespread cultural system during the end of the first millennium a.d. and we can confidently say that it was generously represented during this time in the West and East Usambaras (Soper 1967).

We can conclude from the archaeological evidence that the montane environments of the Usambaras have experienced periodic, localized, but intense exploitation during three periods: 100 – 400 a.d., 900 – 1100 a.d., and probably 1600 or 1700 a.d. – present. We do not yet have sufficient evidence to suggest if such exploitation occurred in all sub-regions of the Usambaras, but we do know that it did consistently occur at higher and also lower altitudes, where moist montane forests were once found and where these forests appear to have undergone several cycles of regeneration. The task remains to expand upon the tentative survey results obtained by Soper (1967), who discovered four EIA sites in the northern zone of the East Usambaras. It would appear that the settlement history of the West Usambaras and the incidence of sites in the East Usambara Mountains strongly points to a high probability that the eastern montane environment also experienced significant, although possibly localized, forest exploitation during the earliest Iron Age.

The significance of the Mwitu iron tradition vis-à-vis forested montane environments can also be seen in the history of forest clearance in Kagera Region and in Rwanda/Burundi. The Mwitu iron producing tradition appears to have first developed in the forested zones of western Tanzania and Rwanda. Although Kagera is not a montane environment, it has several ecological peculiarities, wherein moist montane species are found in ground water situations, especially large swamps. These forests and the moist evergreen forests along the ridges west of the Lake Victoria shore were first exploited for agricultural and industrial purposes starting c. 500 – 200 b.c. The technological system that developed during this early period has been documented as one of the most technically complex in the history of metallurgy (Schmidt & Avery 1978; Schmidt & Childs 1985). The technological complexity of this early industry is attributable to its use of the preheating principle – in which a heated air blast creates high furnace temperatures and leads to the production of massive carbon steel. It is not clear if similar principles were employed in the EIA industry of Rwanda, but we can say with confidence that this enormously productive technology had widespread impact, along with agriculture, on the forested environment.

The Mwitu tradition in Rwanda awaits better documentation for such advanced principles, but we have clear evidence now that the EIA industry is unquestionably forest adapted and otherwise very similar to that of Kagera. The industry appears to have been well established by the time of Christ on the central plateau of Rwanda, and perhaps dates to the earlier 5th – 7th century b.c. era. However, the Rwanda industrial adaptation is different in that it utilized forest species from high altitude but from heavily wooded savanna. Some small riverine forests were also employed but the primary adaptation was to pristine wooded savanna (van Granderbeek *et al.* 1983). Research in the palynology and sedimentology of the area has shown that an intense erosional episode occurred in this industrial zone c. 400 a.d. Similar processes also occur as a consequence of EIA settlement in a wooded savanna environment in the western zone of the Kagera research area.

One of the more important developments of the Kagera research is that it demonstrates that, once the poor forest soils of a high rainfall zone are opened, they are occupied – given various conservation practices – until the forest resources necessary for a productive economy are depleted. Once the technological system experienced stress because of scarce fuel, then such developments appear to have caused the demise of the industry, abandonment of the land, and the re-establishment of the forests.

The presence of the highly productive Mwitu industrial system in the West Usambaras – evidenced in the preheated iron-smelting furnace excavated at Nkese village – shows that the forests of the Usambaras were being utilised for industrial (and agricultural) purposes some 1800 years ago. At this time we cannot say how widespread this industry was in the montane zone, nor can we yet say which forest species were favored by the EIA industrialists. However, the East Usambaras, with even better and more reliable rainfall, are an ideal environment for the practice of this technological adaptation. The survey evidence obtained by Soper shows without question that there was EIA occupation in the north-east sector of the Usambaras, with a cluster of four sites located at the base of the hills to the west of Mtai Forest Reserve. If sites are found at lower altitudes, then it is virtually certain that similar sites with an industrial component were located at higher altitudes in what today is a forest reserve.

Such a settlement history is also suggested by pottery and charcoal found in soils beneath apparently little disturbed or undisturbed forest selected for examining forest structure at both low (Kwamgumi) and high (Kwamsambia) altitudes (Chapter 25). Soil pits were dug along catenary sequences in these forests (Chapter 10) and topsoil samples for examining seed banks (Chapter 29) collected at the same sites. Charcoal and pottery occurred at one or more of these very small excavations at both low and high altitudes, suggesting that even forest selected as appearing little or not disturbed has in fact been influenced by man. A single sherd from a depth of 5 – 8 cm in the soil beneath apparently undisturbed ridge top forest at 980 m at Kwamsambia is undecorated; yet its fine texture and finish strongly resemble the EIA ware of the West Usambaras. The use of a slip finish and burnishing are both hallmarks of EIA pottery. Therefore I would confidently predict that there are similar patterns of exploitation in this area and that some of the forests that are extant today and appear to be relatively undisturbed did in fact undergo exploitation by a complex EIA technological system. Undecorated sherds recovered from Kwamgumi are of Later Iron Age (LIA) type and this together with earlier archaeological finds revealing the presence of LIA communities north of Amani suggest a history of exploitation on the East Usambaras roughly similar to that on the West Usambaras. These observations lead us to suggest, then, that the seemingly pristine forests of the East Usambaras have a much more dynamic history of human exploitation than the 'remnant' stands appear to suggest.

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9. Spatial Changes in Forest Cover on the East Usambara Mountains

by Idris S. Kikula

Comparison of air photographs taken in 1976, 1982 and 1986 and maps based on air photographs taken in 1957-58 shows that much forest clearance has occurred on the East Usambaras and that the amount of clearance varies greatly from place to place.

1. Introduction

This paper presents the results of an analysis of land-cover types during different years on the East Usambara Mountains. The analysis was undertaken in order to establish changes in the area covered by forests, as defined later in this paper.

There has been continuing interest in the monitoring and analysis of forests since the beginning of the century. This interest in forests has been partly stimulated by the global concern on the future of forests, a resource with a long list of values. For example theories suggest that forests have a stabilizing role in the atmosphere.

But even without the substantive evidence at hand on the relationship between forest and environment or the genetical potential of forests, our lack of knowledge on the resources stands out clearly. As such we cannot afford to destroy a resource of which, although we still have not explored its full potential, the known values are outstanding. It is therefore important that we continuously monitor forests to serve as an 'early warning system' against complete destruction of the resource. However, it has to be stressed that studies on forest change are not done merely to sensitise the issue of conserving forests at any price or for simply being against their use. On the contrary, it is hoped that these studies will provide a basis for a rational use of the forests i.e. conservation.

2. The mapping of forest cover

2.1 Some definitions

Both mapping and inventory raise the problem of definition of the land cover categories. It is unfortunate that the question of standardizing land cover legends is yet to be resolved in Tanzania, as in many other parts of the world.

It will have been realized from Section 1 that the mapping exercise was undertaken to establish changes in the area covered by forest. In this study, the term forest is based on Greenway's (1973) definition, as reproduced below:

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Figure 9.1 Land cover in the East Usambaras in 1957/58, from 1:50,000 maps.

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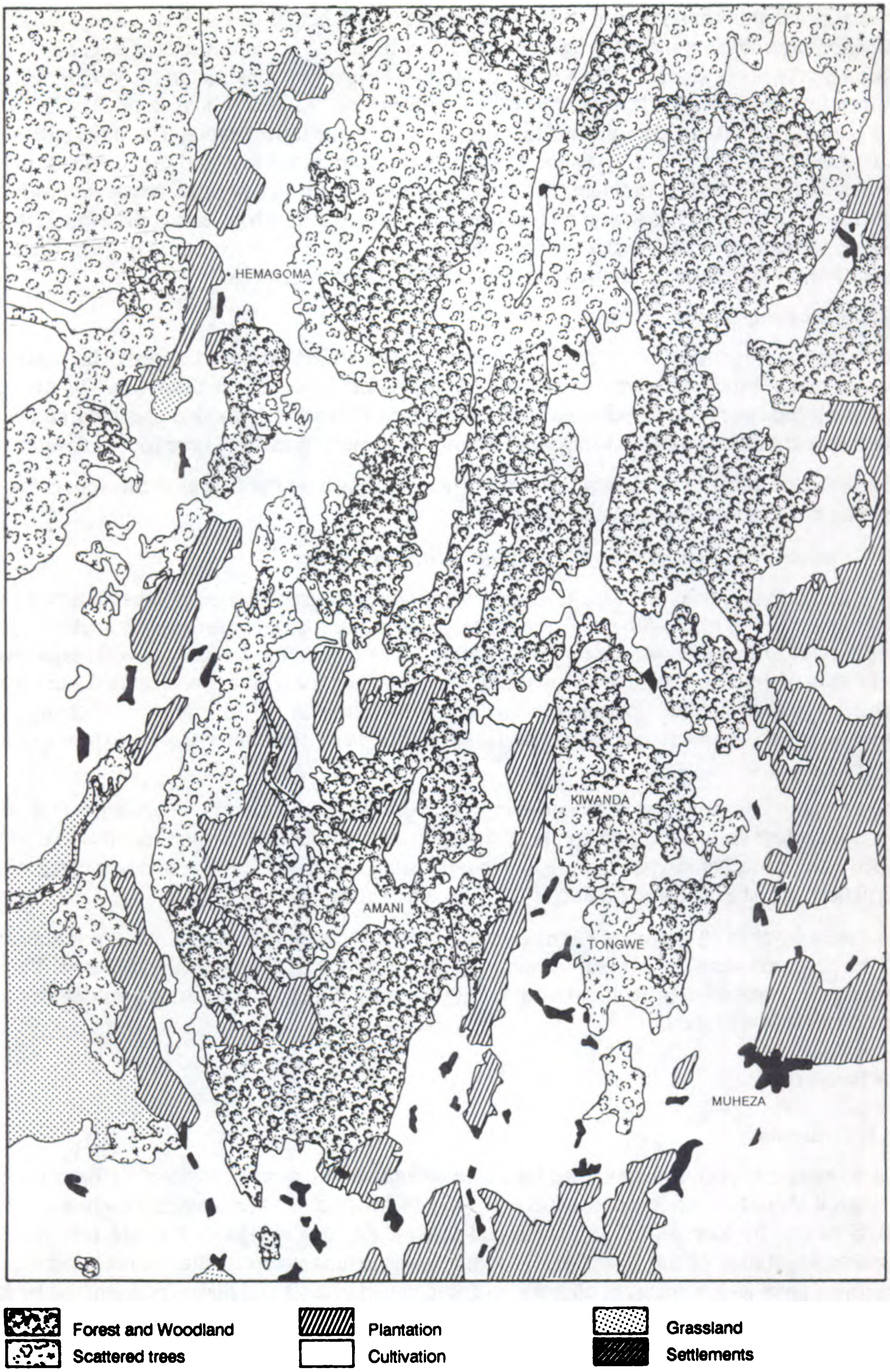

Figure 9.2 Land cover in the East Usambaras in 1986, from analysis of aerial photographs.

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"Forest is a continuous stand of trees, which may attain a height of 150 ft or more, with crowns touching or intermingling and often freely interlaced with lianes. The canopy may be of great thickness and usually consists of several distinct layers or storeys. Epiphytic plants, including orchids, ferns and giant mosses are characteristic, especially in the wetter types. Various lichens, especially Old Man's Beard (*Usnea*) are often a conspicuous feature especially in the upland types. The trees have simple or buttressed boles and in most types the majority of them are in full leaf all the year round. In a few types, deciduous species predominate. The forest floor may, where light permits, be covered with herbs and shrubs from a few inches to several feet high and interspersed with perennial climbers. If the tree canopy is particularly dense, excluding light, the ground is bare of herbs but may be covered with mosses. Grasses if present are comparatively localized and inconspicuous."

2.2 The mapping legend

Although the target land-cover type was forest (as defined in Section 2.1 above), the other land-cover categories in the area were mapped as well, to provide an idea of the dynamics. The categories used in the legend were forest, woodland, scattered trees and bushland, wooded grassland, cultivation, plantations, permanent swamp and seasonal swamp, settlement, grassland, bare rock and water body.

[Editors' note: Most of these non-forest types are not shown on the figures in this report but may be seen on maps in the possesion of the author.]

2.3 Air photo and other sources of information, and procedure

Air photographs (taken in 1976, 1982 and 1986) and topographical maps (sheets based on air photographs taken in 1957–58) were used for mapping the land-cover types with particular emphasis on forests. Unfortunately, however, only the 1986 photos and the 1:50,000 topographical maps covered the total area of the East Usambara Mountains. This lack of uniform data coverage for different years presented a special methodological problem in the presentation of the statistics of change. This problem, however, was overcome by using a grid system for measurements of areas, as will be explained in the section below.

The air photo interpretation was done using a mirror stereoscope and the information transferred onto a transparent sheet. The map compiled from the 1986 air photos was then reduced to a scale of 1:50,000 using a mechanical pantograph. Boundaries were also made for all land-cover categories on the 1:50,000 topo sheets, based on Porter (1973) methodology.

The forest cover in all the maps was measured by a digital planimeter. Aerial measurements for all the maps prepared were done by sub-dividing the entire area into 25 km^2 square quadrats. Thus, by measuring the forest cover in each square quadrat covered at different time periods, an idea of change in area could be established.

3. The forest cover

3.1 Distribution

Due to human impact, forests in the Usambara Mountains are mainly restricted to forest reserves. Even then it should be made clear that the Usambara Mountains have many micro-habitats. Early descriptions e.g. by Moreau (1935), Buchwald (1896), Engler (1894) etc. indicate that the most widespread vegetation of the Usambara Mountains was luxuriant forest. But on the most exposed ridges forest gives way, sometimes abruptly to ericaceous bushland and thickets dominated by *Erica arborea* or *Phillipia*. [Editors' note: Ericaceous bushland and thickets are essentially confined to the West Usambaras.]. In addition to this effect of habitat variation on the vegetation cover, in many places the rain forest has been replaced by various types of dry evergreen forest and semi-evergreen scrub forests. But as indicated in Section 2.3, the different forest types were not distinguished during mapping.

The distribution of forests in the 1950's is shown on Fig. 9.1 which was compiled from information on topographical maps. Fig. 9.2 is based on the 1986 air photos. When using these maps, the following

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points have to be borne in mind. First is that the information base of the maps is solely air photo interpretation. There was only a brief and casual visit to part of the area while the author was on a different assignment. Secondly, in some areas mapped as forest, there are a lot of activities under the forest canopy e.g. cardamom cultivation. However, these activities are not detectable from the air photos. Since cardamom loves shade, it is grown under the forest canopy after the undergrowth has been removed. Thirdly, comparisons between the air photo-based map and that compiled from topographical maps shows discrepancies in some places. This is attributable to differences in the level of interpretation and not necessarily due to change. For example, it is quite obvious that some areas with dense woodland were classified as forest on the topographical maps. Areas showing these discrepancies have not been considered during change detections. Thus, only those quadrats with absolute agreement have been used to provide an idea of change. In the end only 20 quadrats (29% of the total) were used.

Having pointed out the limitations of the maps it is probably important to clarify further the term forest. As has been indicated in Section 2.1, there are a number of types and subtypes of forests on the Usambaras. Stuart and Hutton (1978) recognized the following forest types:

- Highland Evergreen Forests: also sometimes referred to as Montane Evergreen Forest. This is a high altitude forest type occurring above 1,400 m.a.s.l. The flora of these forests is similar to that of other montane forests of East Africa (Lundgren 1980), with *Podocarpus* spp. and *Ocotea usambarensis* being dominant tree species. Co-dominants are: *Albizia* spp.; *Cassipourea* spp; *Chrysophyllum* spp; *Entandrophragma* spp.; *Ficalhoa laurifolia, Macaranga capensis, Olea* spp.; *Parinari excelsa, Polyscias* spp.; *Pygeum africanum* and *Syzygium guineense.* [Editor's note: It is doubtful whether this type of Stuart and Hutton really occurs; see Chapters 22-25 for more information on the forest types.]
- Intermediate Evergreen Forests: Also referred to as Submontane Evergreen Forests by some authors (e.g. Pocs 1975). The intermediate evergreen forests are the most luxuriant forest type in East Africa (Lundgren 1980). According to Moreau (1935) these forests are mostly found on the seaward slopes of the West and East Usambaras. But apparently similar types have been found on the Ulugurus by Pocs (1976). Examples of this forest type in the Usambaras are Kwamkoro and Amani-Sigi Forest Reserves. According to Polhill (1968) the intermediate evergreen forests have the greatest number of endemic species. They also have affinities to the Guineo-Congolian Formation (Polhill 1968; Chapman and White 1970). Lundgren (1980) lists examples of dominant tree species as *Allanblackia stuhlmannii, Isoberlinia scheffleri, Macaranga capensis, Cephalosphaera usambarensis, Myrianthus holstii, Newtonia buchananii* and *Parinari excelsa.*
- Low Altitude Forests: These forest types occupy what Moreau (1935) termed the lowland zone. They occur at the eastern foot of the Usambaras. Examples include Marimba Forest Reserve and a few others, many of which have no legal status and have been disappearing fast (Rodgers & Homewood 1982). This category includes riparian forests.

3.2 Magnitude of change

The area of forests (in km^2) in the twenty quadrats for different years is given in Table 9.1, which clearly demonstrates that there has been a significant depletion of forest cover through the years. Examples of most severe deforestation include areas covered by quadrats 13, 38 and 39. There was a 100% clearing in quadrat 13 between 1958 and 1986 (but note: this is Mazumbai Forest on the West Usambaras). In quadrat 38 there was a 77% decrease in forest cover between 1958 and 1986. In quadrat 39 there was a 24% decrease in forest cover between 1958 and 1982 and a further 22% decrease between 1982 and 1986. With a few exceptions, all the other quadrats have also experienced declines of various magnitudes. Those quadrats which have experienced no detectable change include numbers 43 and 45.

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Table 9.1 Changes in the area of forests in the East Usambara Mountains.

	STATUS (in km^2)			
Grid No.*	1958	1976	1982	1986
7	0.4	NC	NC	0
13	14.7	NC	NC	0
14	4.9	NC	0.4	0.1
15	NC	NC	5.5	4.0
20	1.3	NC	NC	0.9
25	1.3	NC	NC	0.9
27	18.8	NC	14.4	15.6
33	17.0	NC	11.1	15.7
38	9.0	NC	NC	2.1
39	17.0	NC	12.9	11.6
40	NC	NC	14.3	11.1
43	2.9	NC	NC	2.9
44	23.0	NC	13.6	14.9
45	11.0	NC	NC	11.0
46	NC	NC	11.7	9.4
49	2.2	NC	2.2	1.4
50	23.7	21.0	20.0	20.0
51	9.3	NC	NC	6.3
52	NC	1.8	NC	1.1
56	5.8	5.4	5.3	5.0

**The grids are 5x5 km.*
NC indicates not covered by air photos.

3.3 The factors of change

The factors of change in the forests of Usambara Mountains, not necessarily in their order of importance, are discussed as follows:

- Commercial and individual logging: These activities take place both in the gazetted forest reserves and ungazetted forests. Part of the area under forest reserves is reserved as water-shed and part of it is open for commercial logging. Commercial timber exploitation also goes on in the ungazetted forests. At the time of writing logging in the Usambaras is one of the biggest threats to the forests.
- Subsistence agriculture: This has expanded rapidly in ungazetted forests. Due to favourable rainfall and soils, the highlands of Tanzania have a higher potential for crop production than any other biogeographical region in the country (Lundgren 1980). The result has been high population densities and intensive cultivation of the highlands. This has put the highland vegetation under intensive pressure.The main food crop is maize. Other crops are beans, sweet potatoes, pumpkins, peas, Irish potatoes, cabbage, bananas and cassava. The Wa-sambaa or Shambaa also keep cattle, but in small numbers (the Wa-sambaa are the people of Usambara Mountains.)
- Commercial estates. The estates include tea and forest areas left as fuelwood reserves. Large areas of land were expropriated in the German times for coffee, mixed farms and forestry. During the British times large areas were put under tea plantations. Extensive cardamom agriculture is more recent (see below).
- Cardamom plantations: Cardamom is a high return cash crop which has been recently introduced to the area. The high price of cardamom has led to an influx of immigrants to the area, thus intensifying land pressure.

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- Population pressure: It has been stated above that the dominant people of the Usambara Mountains are the Wa-sambaa who in the 1967 census made up 78% of the population of the area (Lundgren 1980). It is also apparent that the Wa-sambaa have lived in the same area for hundreds of years. But with regards to resource utilization, the population of the area has grown many fold since the arrival of the first Germans in the 1900's. Thus this progressive increase of population has subsequently intensified pressure on agricultural land, leading to clearing of forests.

As a result of population pressure, even steep slopes have become cultivated and fallow periods have become shorter and eventually been abandoned. But this change in farming systems due to population pressure is not found only on the Usambara Mountains. Many other areas including the Southern Highlands of Tanzania have had a similar experience (Kikula 1986).

The effects of indiscriminate cultivation started to show in the 1930's, during which soil erosion was becoming a problem not to be ignored. The result was the establishment of soil conservation schemes and a few years later the Usambara Development scheme was started in the West Usambaras. The schemes aimed at modernizing agricultural techniques by introducing various conservation practices (Lundgren 1980). It is however unfortunate that these techniques were resisted by the local people. It seems likely that the introduced agricultural practices were not selectively chosen to include only those adaptable in the traditional social and cultural systems. The same story of failure of development schemes is repeated for many other parts of Tanzania (c.f. Kauzeni *et al.* 1986).

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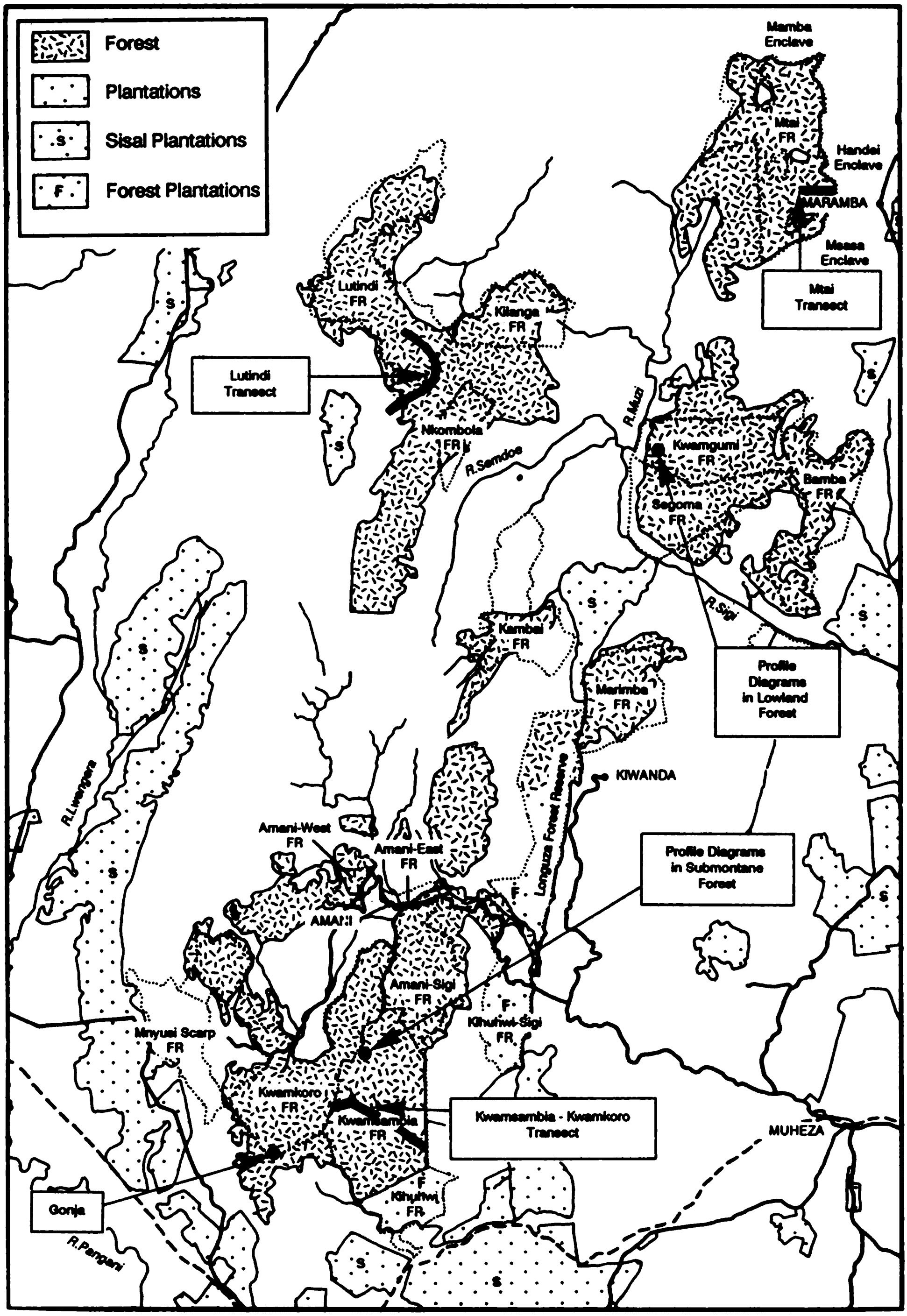

Figure 10.1 Locality map of the East Usambaras for profile diagrams, vegetation transects and soil sites. A few forest areas have been excluded from this map (see Fig. 1.3).

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10. Soils

by A.C. Hamilton

There are two main types of soil on the East Usambaras, found above and below 850-900 m. Higher altitude soils are very acidic and highly leached and cannot be used for sustainable agriculture without the use of very special precautions to avoid depletion of organic matter and nutrients. Lower altitude soils are less acidic and more fertile, but are still fragile.

1. Introduction

Soils of the East Usambaras have been described or commented on by Anderson (1963), Dowsett *et al.* (1954), Milne (1935, 1937), National Soil Service (1986), Nightingale and Steele (1963), the Tanga Water Master Plan (1976) and Walter (1971). Soils on the West Usambaras are described by Egger *et al.* (1980), Geissen (1984), Milne (1944), Lundgren (1980) and Pitt-Schenkel (1938). References to other studies are given in Rodgers and Homewood (1982). The comment of the National Soil Service (1986) that "no detailed information on the soils of the Eastern Usambaras is available" is misleading.

The country rock of the East Usambaras at both high and low altitudes is rather uniform and belongs to the Precambrian Usagaran system, consisting mainly of biotite-horneblende-garnet gneiss, with much quartz. There are local occurrences of granulite, amphibolite and pegmatite (Milne 1937). Rock outcrops are found mainly on summits around the plateau edges and on the escarpments, where there are some very large boulders. The soils are generally deep to very deep (often well over 1 m and sometimes over 5 m), usually red or otherwise brightly coloured, sandy clays or sandy clay loams. The forest soils are Ferralsols, according to the FAO/UNESCO system of classification.

Two types of soil have been recognized by earlier works. Soils at higher altitudes, such as on the Amani plateau, have been described as being highly leached and acidic with little inherent fertility; such fertility as exists is likely to be rapidly exhausted by continuous agricultural activity (Dowsett *et al.* 1954; Milne 1937). The clay fraction is composed of kaolin (Lundgren 1980) and has a low capacity to absorb bases (Milne 1937). Organic matter under forest averages about 4% in the upper 10 cm of soil, but is very low at greater depth; most of the soil nutrients are associated with the organic matter (Milne 1937). Soils at lower altitudes, on the escarpments and in the lowlands, have more or less the same visual appearance as the higher altitude soils, but are less leached, have more bases and are inherently more useful for agriculture.

The luxuriant submontane forest gave the impression to early settlers that the soils were very fertile and could sustain a wide range of plantations crops (Milne 1937). Arabica coffee was widely planted on cleared forest land by the Germans but gave disappointing results and was eventually abandoned. The forest had given a misleading impression. The forest is believed to be sustained by a very tight cycling of nutrients between vegetation and the soil; if this is broken through forest destruction, nutrients are likely to be rapidly lost, resulting in an impoverished soil.

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A number of soil pits have been examined during the course of the present work and we have also collected topsoil samples for pH and organic matter determinations. Studies have also been made of the influence of *Maesopsis* on soil properties (Chapter 31).

2. Soil profiles along catenary sequences

2.1 Introduction

Pits for examining soil profiles were dug in areas of apparently little disturbed lowland forest at Kwamgumi (210–260 m) and in submontane forest at Kwamsambia (920–980 m) (Fig. 10.1). The three profiles from each site are arranged along catenary series. Each profile is within or very close to the six plots used for examining forest structure by means of profile diagrams (Chapter 25). The pits were examined and laboratory analyses carried out by staff of the National Soil Service Project (Mlingano), Tanzania Agricultural Research Organisation. Some characteristics of the profiles are shown on Table 10.1.

Table 10.1 Some features of soil profiles on the East Usambaras.

Pit (Lab Code)	Altitude (m)	Position on Slope	Slope Gradient (%)	Soil Colour	Soil Texture	Classification (FAO/UNESCO System)	Depth of soil Sampled (cm)
A) Profiles along a catena in lowland forest, Kwamgumi							
KI	260	Upper slope (almost crest)	1-2	Dark reddish brown/ red to dark red	Sandy clay/clay	Rhodic Ferralsol	140
K2	230	Mid-slope	15	Dark reddish brown/ dark red	Sandy clay first 60cm, then clay	Rhodic Ferralsol	140
K3	210	Lower slope	2-5	Dark reddish brown	Sandy clay/clay	Rhodic Ferralsol	120
B) Profiles along a catena in submontane forest, Kwamsambia							
AF3	980	Upper slope, almost top	10	Dark reddish brown/ yellowish red	Sandy clay loam	Orthic Ferralsol	120
AF2	960	Mid-slope	67	Reddish brown/ yellowish red to red	Sandy clay	Orthic Ferralsol	185
AF1	920	Mid- to lower slope	70	Strong brown/ reddish yellow	Sandy clay	Xanthic Ferralsol	120
C) Profile from Gonja, submontane forest, Kwamkoro							
AF4	970	Edge of escarpment	27	Dark brown/ strong brown	Sandy clay loam/ sandy clay/ sandy clay loam	Xanthic Ferralsol	200

Information supplied by the National Soil Service, TARO.

2.2 Lowland forest soils (Kwamgumi)

The following comments have been provided by the National Soil Service (see also Table 10.2). These remarks refer to the top 20 cm of the soil.

"Organic carbon is low (0.7–2.0%). Total nitrogen is low to medium (0.09–0.27%), The soils are weakly acidic (pH 6.2–6.7). Cation exchange capacities are low to medium and very much related to organic matter content. Base saturations (70%) are high. Calcium levels are high, magnesium levels are medium and potassium levels are very low. Phosphorus is very low."

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Table 10.2 Results of analyses of soils from under little disturbed lowland (Kwamgumi) and submontane (Kwamsambia, Kwamkoro) forest on the East Usambaras.

			PARTICLE SIZE ANALYSIS				pH			ORG	TOTAL		EXCHANGEABLE BASES				
DEPTH (cm)	SAMPLE IDENT.	LAB.NO	< 2 (um)	2-20 (um)	20-50 (um)	50-2000 (um)	1:2.5 H20	KCl	BRAY1 Mg/Kg	C %	N %	CEC Me/100g	Na Me/100g	K Me/100g	Ca Me/100g	Mg Me/100g	B.S %
KWAMGUMI (Upper Slope) – 260m (Profile Code K1)																	
0-10	K11	4602	45	5	5	45	6.7	5.5	3	2.0	0.27	12.5	0.1	0.2	7.5	2.9	86
10-40	K12	4603	55	3	2	40	5.4	4.5	3	0.7	0.11	4.6	0.1	0.1	1.6	1.6	73
60-90	K13	4604	60	3	2	35	5.5	5.0	2	0.3	0.02	5.1	0.1	tr.	1.9	1.9	77
110-140	K14	4605	64	2	1	33	5.4	5.0	1	0.2	0.02	4.5	0.1	tr.	1.1	0.4	34
KWAMGUMI(Middle Slope) – 230m (Profile Code K2)																	
0-9	K21	4606	38	5	4	53	6.5	5.5	3	0.9	0.09	9.2	0.1	0.2	6.4	0.37	75
9-19	K22	4607	44	3	3	50	6.0	5.0	2	0.7	0.09	7.7	0.1	0.1	3.6	2.2	77
19-40	K23	4603	51	3	2	44	6.3	5.1	1	0.2	0.05	6.0	0.1	0.1	2.8	1.0	67
60-90	K24	4609	58	2	2	38	6.1	5.1	2	0.3	0.02	5.2	0.1	tr.	2.3	1.2	69
120-140	K25	4610	61	3	1	35	6.2	5.3	2	0.3	0.04	5.0	0.1	tr.	2.8	0.4	66
KWAMGUMI (Lower Slope) – 210m (Profile Code K3)																	
0-22	K31	4611	45	7	2	46	6.2	5.3	2	0.7	0.15		0.1	0.2	5.3	4.9	
22-44	K32	4612	55	3	4	38	6.1	5.2	1	0.5	0.07	13.7	0.1	0.04	2.0	1.6	27
50-70	K33	4613	56	4	2	38		5.3	2	0.1	0.02	6.8	0.1	tr.	1.6	2.0	54
90-120	K34	4614	57	4	2	37	6.2	5.6	2	0.1	0.02	6.1	0.1	tr.	1.4	1.2	44
KWAMSAMBIA (Upper slope) – 960m (Profile Code AF3)																	
0-15	AF31	4591	33	8	3	56	3.8	3.8	6	1.4	0.27	11.6	0.1	0.1	0.2	0.5	7
40-60	AF32	4592	29	9	2	60	5.0	4.7	6	0.5	0.10	5.1	0.1	tr.	0.3	0.3	14
100-120	AF33	4593	26	6	2	66	5.2	5.1	5	0.2	0.08	3.1	0.1	tr.	0.3	0.1	15
KWAMSAMBIA (Middle Slope) – 960m (Profile Code AF2)																	
0-5	AF21	4585	25	8	2	65	3.7	3.6	8	2.8	0.28	12.5	0.2	0.1	0.8	0.6	13
5-20	AF22	4586	34	6	4	56	4.3	4.1	3	1.7	0.17	7.7	0.1	tr.	0.4	0.2	9
30-50	AF23	4587	35	7	4	54	4.4	4.4	2	0.9	0.11	6.2	0.1	tr.	0.4	tr.	9
70-90	AF24	4588	32	8	4	56	4.6	4.5	2	0.3	0.10	4.7	0.1	tr.	0.4	0.1	14
120-140	AF25	4589	23	5	6	66	4.5	4.5	2	0.2	0.09	3.1	0.1	tr.	0.4	0.2	22
165-185	AF26	4590	19	5	5	71	4.4	4.3	2	0.2	0.08	2.1	0.1	tr.	0.2	0.4	37
KWAMSAMBIA (Lower Slope) – 920m (Profile Code AF1)																	
0-18	AF11	4615	37	8	2	53	4.7	4.2	3	1.4	0.13	7.4	0.1	tr.	0.5	2.3	41
20-40	AF12	4616	45	2	4	44	5.5	4.3	1	0.7	0.08	5.2	0.1	tr	0.5	0.2	16
60-80	AF13	4617	42	8	2	48	5.1	4.3	2	0.4	0.01	4.1	0.1	tr.	0.4	0.2	17
100-120	AF14	4618	36	8	4	52	5.4	4.4	1	0.2	0.01	4.0	0.2	tr.	0.4	0.3	24
KWAMKORO (Edge of Escarpment [top]) – 970m (Profile Code AF4)																	
0-5	AF41	4594	27	8	3	62	3.9	3.7	8	6.0	0.05?	14.2	0.1	0.1	0.1	0.1	15
10-20	AF42	4595	35	9	6	50	4.4	4.3	4	3.3	0.24	10.5	0.1	tr.	0.4	0.4	8
20-35	AF43	4596	41	7	3	49	4.5	4.4	2	2.2		9.8	0.1	tr.	0.4	0.3	8
40-60	AF44	4597	40	8	1	52	4.5	4.5	2	1.5	0.17	7.2	0.1	tr.	0.6	tr.	11
75-95	AF45	4598	29	5	tr.	66	4.7	4.6	2	0.5	0.10	4.2	0.1	tr.	0.2	0.4	17
110-130	AF46	4599	31	3	2	64	5.3	4.7	2	0.7	0.09	6.2	0.1	tr.	0.2	0.4	12
175-200	AF47	4600	23	3	4	70	5.2	4.9	1	0.3	0.08	2.4	0.1	tr.	0.2	0.3	26

tr. - indicates trace

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"The pH values are favourable for most crops. Most of the nutrient-holding capacity is accounted for by the organic matter, the inorganic fraction of the soil having very low nutrient retention. Clearing the forest will inevitably lead to a loss of organic matter."

2.3 Submontane forest soils (Kwamsambia)

The following comments have been provided by the National Soil Service (see also Table 10.2). These remarks refer to the top 20 cm of the soil.

"Organic carbon is medium (1.4 – 2.8%). Total nitrogen is medium to high (0.13 – 0.25%). The soils are strongly acidic (pH 3.8 – 4.7). Cation exchange capacities are medium and very much related to the organic matter content. Base saturations are very low (7 – 41%) due to the low pH of the soils; the absorption complex is thus dominated by aluminium and hydrogen ions. Calcium, magnesium and potassium levels are low to very low. Phosphorus is low."

"Clearing this forest for agriculture will result in immediate and fast deterioration of the soil, both physically and chemically. The top few centimetres, holding the organic matter, which accounts for the main nutrient capacity of the soil, will disappear when the forest is cleared. As slopes are very steep, soil erosion will become a very severe and inevitable problem. Besides, soils are so acidic that there exists a danger of aluminium and manganese toxicity. All other indispensable nutrients are very deficient. The only possible sustainable agricultural use will be the growth of tea, as tea is the only crop which tolerates such acid soil conditions and as it is a permanent crop, with a very good ground cover, preventing soil erosion and leading to an increase of the organic matter content."

2.4 Further comments on the profiles

All the soils were deep (1.5 m), especially in the lowlands (over 2 m in all three cases). Rotting rock was common at depth (c. 1 m) in the higher altitude soils, but only sporadic pieces were present in the lowland soils. The upper 20 – 30 cm of all the soils were browner than below and contained most of the roots, though some deeper roots occurred. No comments were received from the National Soil Service on possible variation associated with catenary position. However, the ridge soils seemed the most distinct in the field, being harder and differently coloured from the others. Earlier, Dowsett *et al.* (1954) had noted that soils on the upper slopes on the Amani plateau were relatively shallow and infertile and less suitable for tea. Charcoal was found in several of our pits and was especially abundant on the ridge site at Kwamgumi, where one side of the soil pit passed through a charcoal and daub-filled feature 70 cm deep, possibly an old post site for a house. Pottery was present in the mid-slope site at Kwamgumi and in the topsoil near the ridge site at Kwamsambia (Chapter 8).

2.5 Conclusions

These results support earlier views that there is a great contrast between the acidic infertile submontane forest soils and the more neutral, more fertile lowland forest soils.

3. Soil profile from Gonja escarpment edge, Kwamkoro

This site is under slightly disturbed forest, right on the edge of the southern rim of the escarpment in Kwamkoro Forest Reserve. Snails were found to be exceptionally abundant in the litter and an initial examination of the soil by Prof. Macfadyen suggested that the soil structure was different from that normally found in the submontane forest zone (Chapter 31).

Description of the profile and laboratory analyses were made by staff of the National Soil Service, who provided the following comments (see also Table 10.2). These remarks refer to the top 20 cm of the soil.

"Organic matter is high, about 4% (higher than in the Kwamsambia soils). The cation exchange capacity is slightly higher than in the Kwamsambia soils. In other respects, such as pH (3.9 – 4.4), the soil is similar to that at Kwamsambia."

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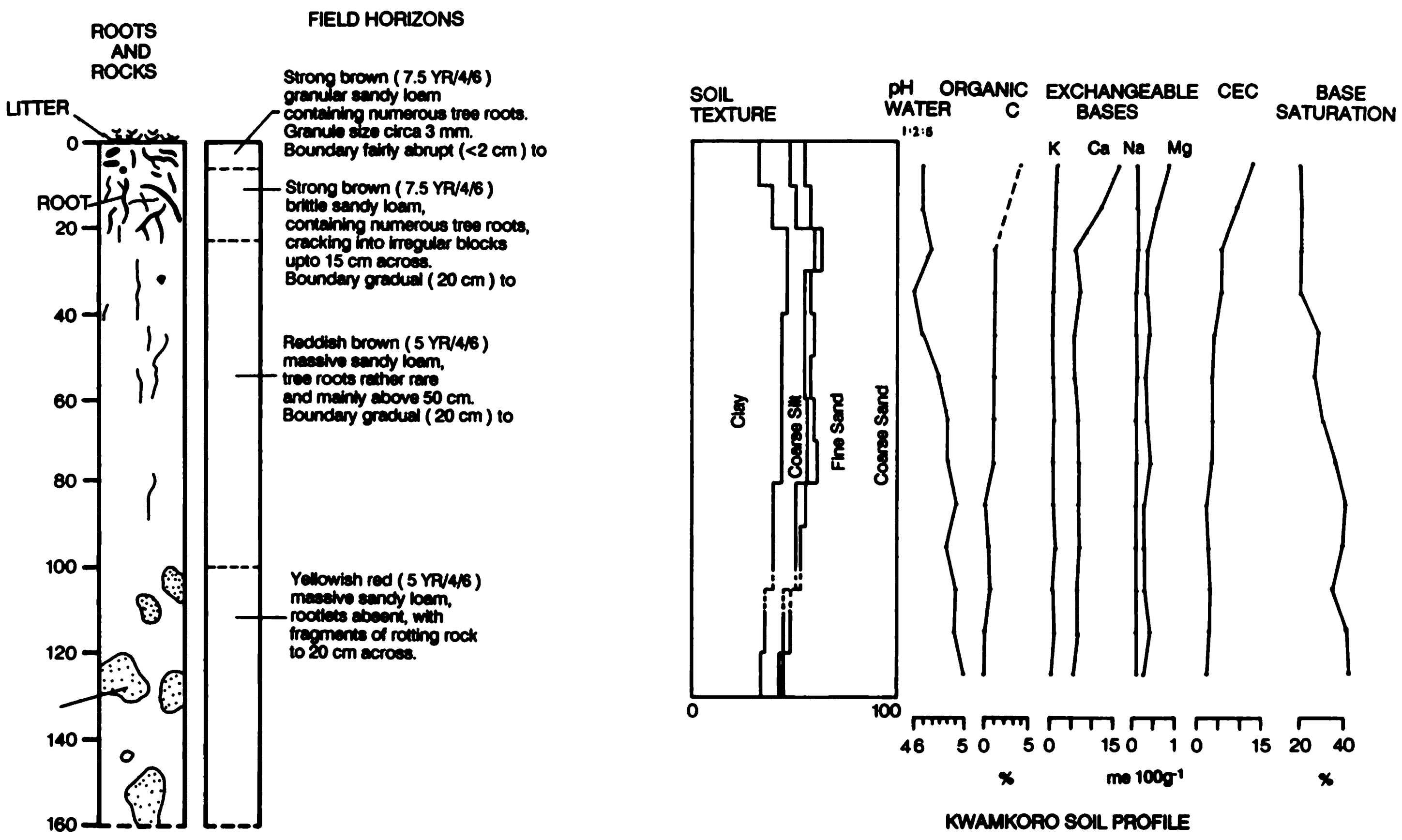

Figure 10.2 Soil under natural forest, exposed by very recent logging road. Rock: gneiss of basement complex; no rock outcrops near site. From a well drained slope of straight form. Altitude 940m, Slope 25°, Aspect 270°, Described by A. Hamilton 28/8/86.

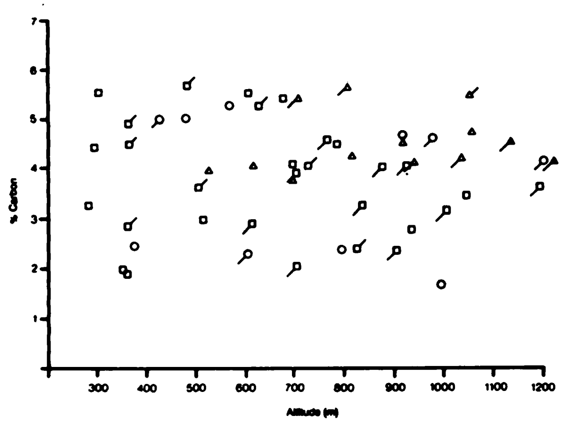

Figure 10.3 Relationship between altitude and organic carbon percentage in forest topsoils, East Usambaras. There is little variation with altitude; ridges tend to be more organic.

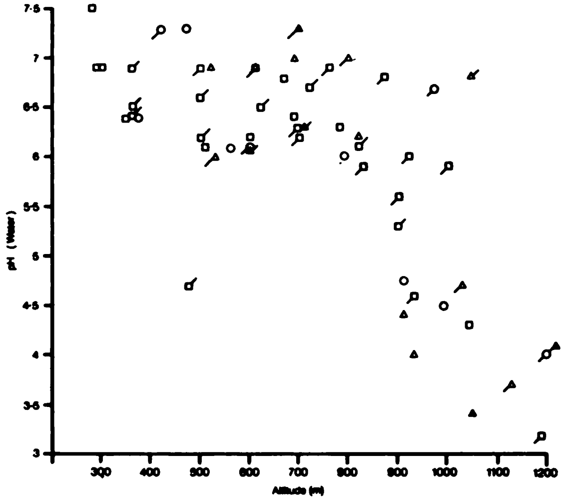

Figure 10.4 Relationship between altitude and pH of forest topsoils, East Usambaras. Note the large change at 850–900 m.

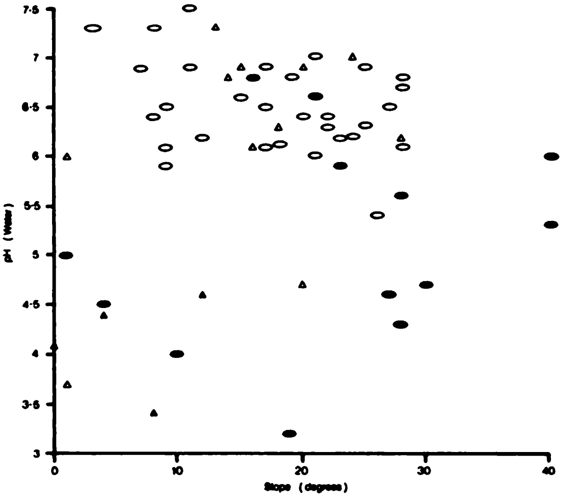

Figure 10. 5 Relationship between slope and pH of forest topsoils, East Usambaras. There is a tendency for soils to become less acidic as slope increases for sites above 850 m.

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It should be added that the soil is deep (2 m).

To conclude, nothing exceptional was discovered about the soil properties which could account for the exceptional abundance of molluscs, but this should not be regarded as conclusive since the methods of soil pit examination and soil sample collection used by the staff of the National Soil Service were not very sensitive from an ecological point of view.

4. Soil profile, Kwamkoro Forest Reserve

This profile (Fig. 10.2) was revealed on the side of a freshly cut logging track passing through virtually undisturbed natural forest. It is at 940 m, on the middle part of a slope, the slope angle being 25°. It was examined by A.C. Hamilton.

The soil is deep (160 cm), with rotting rock present below 100 cm. Roots are concentrated above 20 cm, with some seen down to 90 cm. The soil is mostly a strong brown to reddish brown sandy loam. There was little sign of the presence of soil animals (it was the dry season). Samples were collected in 10 cm slices for laboratory determinations, later carried out by the National Soil Service, who provided the following comments.

"The data indicate the presence of a clay bulge between 20–80 cm, which is typical for the soils of the region (Acrisols). The organic matter content decreases from 7.2% in the first 10 cm to c. 1.4% at 50–70 cm and 0.7% at c. 100 cm. Most of the nutrients are found in the top 20 cm and are associated with the organic matter. In the subsoil the amounts of exchangeable bases are very low, but, as the cation exchange capacity is also low, the base saturation values remain above c. 20%. In the deeper subsoil base saturation increases to c. 40% indicating an upward movement of nutrients from the fresh decomposing rocks below."

[This profile has presumably been termed an Acrisol because of the 'clay bulge', which is a feature of this soil group (Bridges 1978) and which can faintly be discerned on Fig. 10.2. This 'bulge' can also be discerned in the other profiles from submontane forest (Table 10.2), which are confusingly termed Ferralsols by the National Soil Service. Actually, all these profiles are very similar.]

5. Variations in acidity and organic carbon content of the topsoil

Samples of the top 10 cm of soil (beneath the litter) were collected from each of the 65 sites used for examining forest vegetation by variable-area tree plots (Chapter 22). These plots lie along three altitudinal transects in Mtai, Lutindi and Kwamsambia-Kwamkoro forests, stretching between 290 and 1,220 m.

Interestingly, there is no increase in organic carbon with increasing altitude, as might be expected (Fig. 10.3). It can be observed in the field that a thin (up to about 10 cm – see Chapter 31) humus layer is usually present in submontane forest, but absent from lower and medium altitude forests. The possible explanation for the analytical results is that the samples collected extend too deep to show the variation which has been observed in the field. Below the humus, the submontane forest soils are much less organic. It is also possible that organic matter is better distributed vertically in lowland soils.

Ridge sites tend to be more organic than slopes and valleys. This agrees with observations in the field. Ridges tend to have thicker accumulations of humus, perhaps partly because they tend to be flatter and there is less loss of humus through erosion. Ridge soils have particularly dense surface root mats.

Soil pH falls off from about pH 7 at 300 m to about pH 6.5 at 850 m and then diminishes rapidly to be typically below pH 5 at 900 m and to about pH 4 at 1,050 m (Fig. 10.4). All three transects, at the north and south of the main range and on Mt Mtai, show the same pattern. This result confirms that there is a major difference between soils at higher and lower altitudes and shows that the critical altitude

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is 850 – 900 m. This is an important result which confirms and helps to define the major difference between lowland and submontane soils.

6. Causes of soil variation

Two factors are considered here, rejuvenation and climate. The rock type is more or less the same everywhere (except for local amphibolites).

Milne (1937) has argued that the soils on the escarpments are less weathered because they have been rejuvenated by material coming from decomposing rock faces. This argument depends on the time-scales on which various processes such as leaching and soil movement are operating. Actually, with very few exceptions, none of the sites from which soils were collected either on the escarpments or elsewhere was situated near exposed rock, from which material might be supplied to soil surfaces nearby. The possibility might be raised that the escarpment soils have been enriched through the bringing up of material from depth through the action of gravity and other processes. Actually, slopes on the plateau tend to be just as steep as those on the escarpments and enrichment through soil creep seems inadequate as an explanation for the soil differences (see also below).

If soils on steeper slopes are being rejuvenated by soil creep, then it might be expected that steeper slopes would be less acidic. Such a relationship is not shown by the overall data set (Fig. 10.5). However, it is possible to consider the data in two sets, divided by altitude, in which case the pH of sites below 850 m appears to be little influenced by slope, but, above 850 m, soils tend to be less acidic on steeper slopes (as expected) (Fig. 10.5). The latter may not be a causal relationship; variations in the quantity and type of organic matter associated with slope are likely to be more important.

This result reinforces the view that the soils above and below 850 m are different, but does not adequately explain why the escarpment soils are not as acidic as those at higher altitudes.

Climate is probably the major factor responsible for altitudinal variation in the soils (Dowsett *et al.* 1954), the wetter climate of higher altitudes resulting in greater leaching and a tendency for the ecosystems to accumulate more acidic humus. The most interesting result emerging from the present survey is the rapid change in soil pH at 850 – 900 m. The most probable explanation is that this altitude marks a rapid climatic transition. During the rainy seasons it can be observed that low cloud frequently envelops the higher slopes, commonly with a base at just this altitude.

7. The importance of the soil as a resource

Four properties of the soil are of special interest in land-use planning: ability to accept water, ability to store water, erodibility and fertility. The first three of these are discussed in Chapter 15.

Fertility is fundamentally different in the lower and higher altitude soils, with soils below 850 m being potentially much more useful for agriculture. However, even these lowland soils should not be regarded as fertile in any absolute sense; they are quite highly leached and can easily be degraded through inappropriate land management.

Soils on the plateau are really of no use for sustainable small-scale agriculture, unless this is practised in ways very different from now. Only the narrow valleys, with alluvial soils (not described in detail in this chapter), are better, but these should not be cultivated since crops and soil are liable to be catastrophically destroyed during floods and because cultivation here can seriously deplete catchment values. When forest is destroyed, comparatively abundant nutrient reserves held in the soil and vegetation become available for utilization by crops, but these become depleted as leaching and erosion proceed, through burning and through the removal of crops (Lundgren 1980). Farmers have been described as being trapped in a vicious cycle, involving deforestation to increase the amount of arable land, followed by cultivation and later exhaustion of the soil and then more deforestation (Scheinman & Mchome 1986). Eventually only a low thicket with *Lantana* and *Pteridium* remains, useless to man

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and so depleted that the establishment of many trees is difficult and that of primary forest probably impossible. Using the submontane forest soils for agriculture without steps to conserve organic matter and nutrients diminishes the resource base in an irreversible way.

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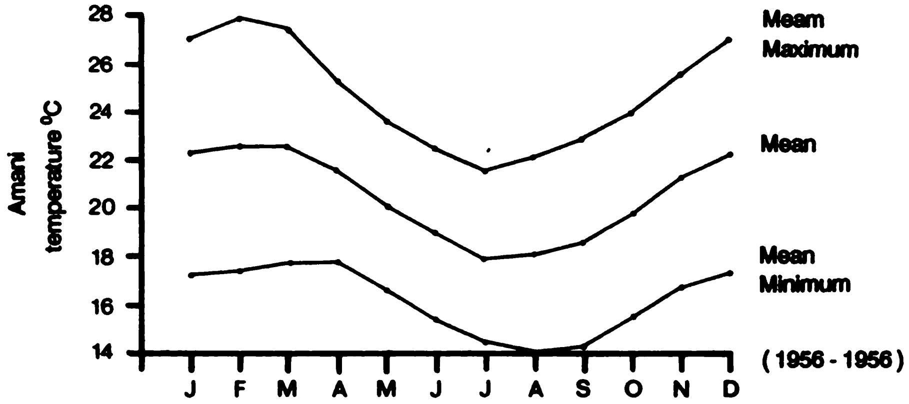
(Data from Tanga Water Master Plan 1976)



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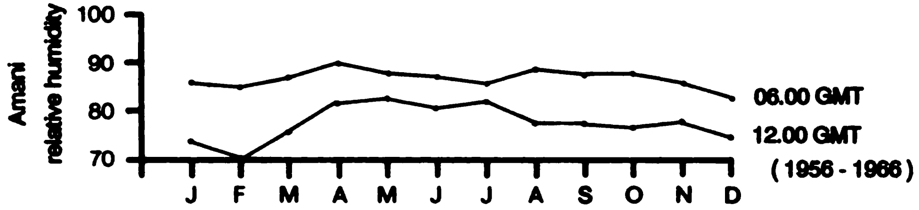

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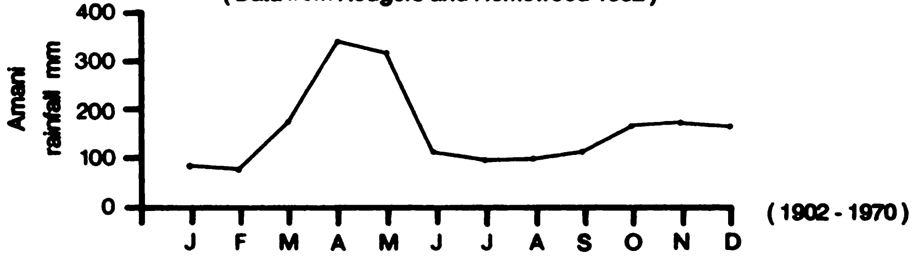

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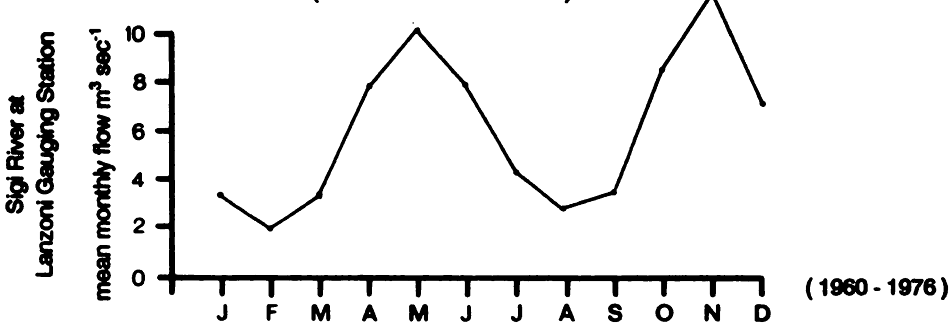

Figure 11.1 Some meteorological data from Amani (910 m) and river flow in the Sigi River.

11. The Climate of the East Usambaras

by A.C. Hamilton

The climate of the East Usambaras is monsoonal, with rainfall concentrated in two periods, especially the long rains (March-May). Rainfall is highest towards the south-east and at higher altitudes. Temperatures at higher altitudes are lower than in inland Tanzania. The humidity is high and mist is common at higher altitudes during the long rains.

Some climatic statistics for the East Usambaras are given in Table 11.1; yearly variations in some climatic parameters for Amani Meteorological Station are shown in Fig. 11.1.

The climate of the East Usambaras is monsoonal, being under the influence of the wetter south-eastern monsoon from April to October and the drier north-eastern monsoon from November to March. As elsewhere in tropical Africa, annual rainfall peaks are associated with the passage of the Intertropical Convergence Zone and, being near the equator (5°S), there are two such maxima, the 'long rains' (masika) from March to May and the 'short rains' (vuli) from October to December.

Table 11.1 Some climatic statistics for the East Usambaras.

Station (years of temp. readings)	Lat. (S)	Long. (E)	Alt. (m)	Mean annual rainfall(mm) (and no. of yr of records)	Mean max. monthly temp. (°C)	Mean min. monthly temp (°C)	Mean annual temp (°C)
Amani (1956-1966)	5 06	38 38	910	1918(66)	24.8	16.3	20.6
Magunga Estate	5 00	38 38	610	1315(41)	-	-	--
Kihuhwi Teak	5 12	38 39	215	1363(13)	-	-	-
Kizara	4 55	38 40	915	1654(13)	-	-	-
Kwamkoro	5 09	38 37	915	2262(39)	-	-	-
Longuza Forest Station	5 07	38 42	165	1484(12)	-	-	-
Marikitanda	5 09	38 37	975	1771(12)	-	-	-
Mlingano (1936-1974)	5 08	38 51	205	-	30.2	20.4	25.3
Muheza Agric. Office	5 10	38 47	200	1225(1,3)	-	-	-
Tanga Town Council (1956-1973)	5 05	39 04	35	1356(68)	30.4	21.9	26.2

(Data from various sources, especially Tanga Water Master Plan 1976.)

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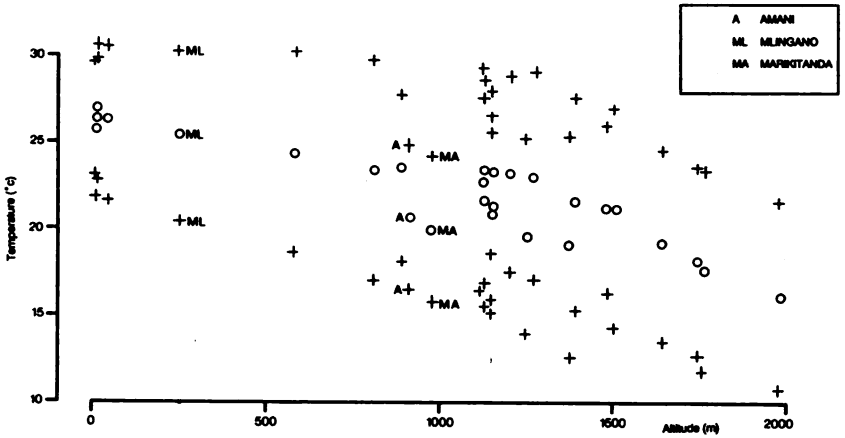
Mean monthly temperatures vary considerably during the year with a difference of 5°C between the hottest and coldest months (March and July respectively at Amani). On the basis of temperature and rainfall, four seasons may be recognized. January to March is hot and dry and is the most adverse season for plant growth. From March to May, temperatures are falling and rainfall is heavy, with typically 45% of the total annual rainfall falling during these three months. Temperatures are low during the second, but less severe, dry season from June to September. The short rains from October to December are a time of temperature increase.

Despite this marked seasonality, rainfall is reasonably well distributed over the year. At Amani, long-term averages show that no month receives less than 75 mm of rain, but of course no year is an average year and quite severe arid episodes do occur.

Judging by comparison with many places in Tanzania, mean maximum daily temperatures at higher altitudes on the East Usambaras are abnormally low (Fig. 11.2) though minimum temperatures are at most only slightly depressed. Maximum temperatures are around 4–5°C below normal and mean temperatures about 2–3°C below normal and are equivalent to those experienced in some other parts of Tanzania at altitudes about 700 m and 500 m higher respectively. It seems likely that the occurrence of many species of montane forest trees at unusually low altitudes on the East Usambara plateau is related to the unusually cold climate. Frost is unknown.



Mean, ○ and mean maximum and mean minimum, + temperatures for 25 main meteorological stations scattered through the country. Data from Moffett (1958) - except Mlingano (Tanga Water Master Plan 1976). Note the low mean and mean maximum temperatures at the two high altitude East Usambara stations, Amani and Marikitanda.

Figure 11.2 Temperature/altitude relationship in Tanzania.

Moreau (1934, 1935a & b) has written at length on the biological significance of the exceptionally low maximum temperatures on the Amani plateau. He was able to draw on data not only from the long-established meteorological station at Amani (910 m altitude) but also from short-term temperature records from a site in the Sigi (Zigi) valley (545 m) just below Amani. He also placed instruments under lowland and submontane forest in the Amani area and made comparisons between readings from these and readings from outside the forest. It is unfortunate that Moreau does not quote his temperature data from the Sigi station either fully or with a high degree of precision, but his general conclusion is that there is an exceptionally steep fall in mean maximum temperature up the East Usambara scarp. Moreau's study and temperature readings from Mlingano and Tanga do indeed show

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that mean temperatures in the lowlands around the East Usambaras are altitudinally normal, though towards Tanga the range between minimum and maximum temperatures is reduced due to the moderating effect of the sea (see Fig. 11.2). It is the plateau area of the East Usambaras which seems to be climatically exceptional.

Pocs (1976) has carried the debate about the altitude/temperature relationship further by pointing out that there is a difference in Tanzania in the relationship between places nearer the sea and those deep inland, where temperatures are raised by the 'plateau heating effect'. Temperatures are also lower in relatively wet places (where the natural vegetation is forest). A similar temperature/altitude relationship to that on the East Usambaras can be predicted to occur on the Ulugurus and other wet mountains near the coast.

Temperatures, as recorded at standard meteorological stations, give only a crude picture of the actual biological climate. Moreau's measurements from inside and outside forest on the East Usambaras show that at 1.2 m above ground-level maximum temperatures are reduced by 4°C under submontane forest (915 m) and 3°C under lowland forest (315 m) compared with measurements from shaded screens in the open. Minimum temperatures are little changed. Depressed forest temperatures lower evaporative stress on sub-canopy plants and on the soil surface, contributing to the maintenance of a humid forest microclimate. (Similar microclimatic studies have been undertaken on the Ulugurus by Pocs (1974), yielding similar results.)

A map of mean annual rainfall prepared for the Tanga Water Master Plan (1976) shows that, as expected, rainfall is highest on the south-east of both the East and West Usambaras, that is in the direction facing the prevailing south-eastern trade winds (Fig. 11.3). Maps of rainfall probability show the same pattern. The general pattern of rainfall distribution is clear, but the network of rain gauges is insufficiently dense to show much of the detailed variation which undoubtedly exists on the mountains.

In the lowlands rainfall decreases to the north of the Usambaras, resulting in a dry savanna environment towards the Kenyan border unsuitable for cultivation. Rainfall to the east and south-east of the East Usambaras is higher, and certainly high enough in places to support forest, but the exact limits of forest cover before clearance by man are uncertain. This is of some interest to those concerned with tree planting. There are scattered mvule *(Milicia excelsa)* trees over much of the area between the southern part of the mountains and the Tanga coast. This in itself is evidence of a formerly more extensive forest coverand, since mvule is essentially a lowland forest tree, often left on land cleared for cultivation and which can regenerate from suckers. Moreau (1935a) provides a map of forest distribution in the EastUsambara area in the 1930's, which shows many small forest patches between the mountains and the sea, but some of these patches were on slightly elevated ground where rainfall would have been relatively high and it cannot be deduced from this that there was once a continuous forest cover. Engler (quoted in Dowsett *et al.* 1954) mentions that at one time forest extended from Longuza to Muheza. This forest extension must have been before the time of Farler (1879), because by the time he lived on the mountain, this forest no longer existed. Farler (1879) mentions the presence of a forest patch near Mlingano.

Records from several stations on the main East Usambara range support the expected pattern of declining precipitation on the plateau to the north and west. Mean annual rainfall is highest at Kwamkoro near the southern escarpment (2,262 mm at 915 m alt.), lower at Marikitanda a few kilometres to the north-west (1,771 mm at 975 m alt.) and also lower at Amani (1,918 mm at 910 m alt.), which despite its south-easterly position, may be in a partial rainshadow from the elevated ground of the Amani-Sigi Forest Reserve. Kizara at the north end of the range receives only 1,654 mm (915 m alt.). A further indication of declining rainfall to the north is the statement by Dowsett *et.al.* (1954) that the climate becomes only marginally suitable for tea towards the north, the boundary lying somewhere within the Bulwa Estate. Rainfall over 1,525 mm per annum is regarded as necessary for good tea growth *(loc. cit.)*

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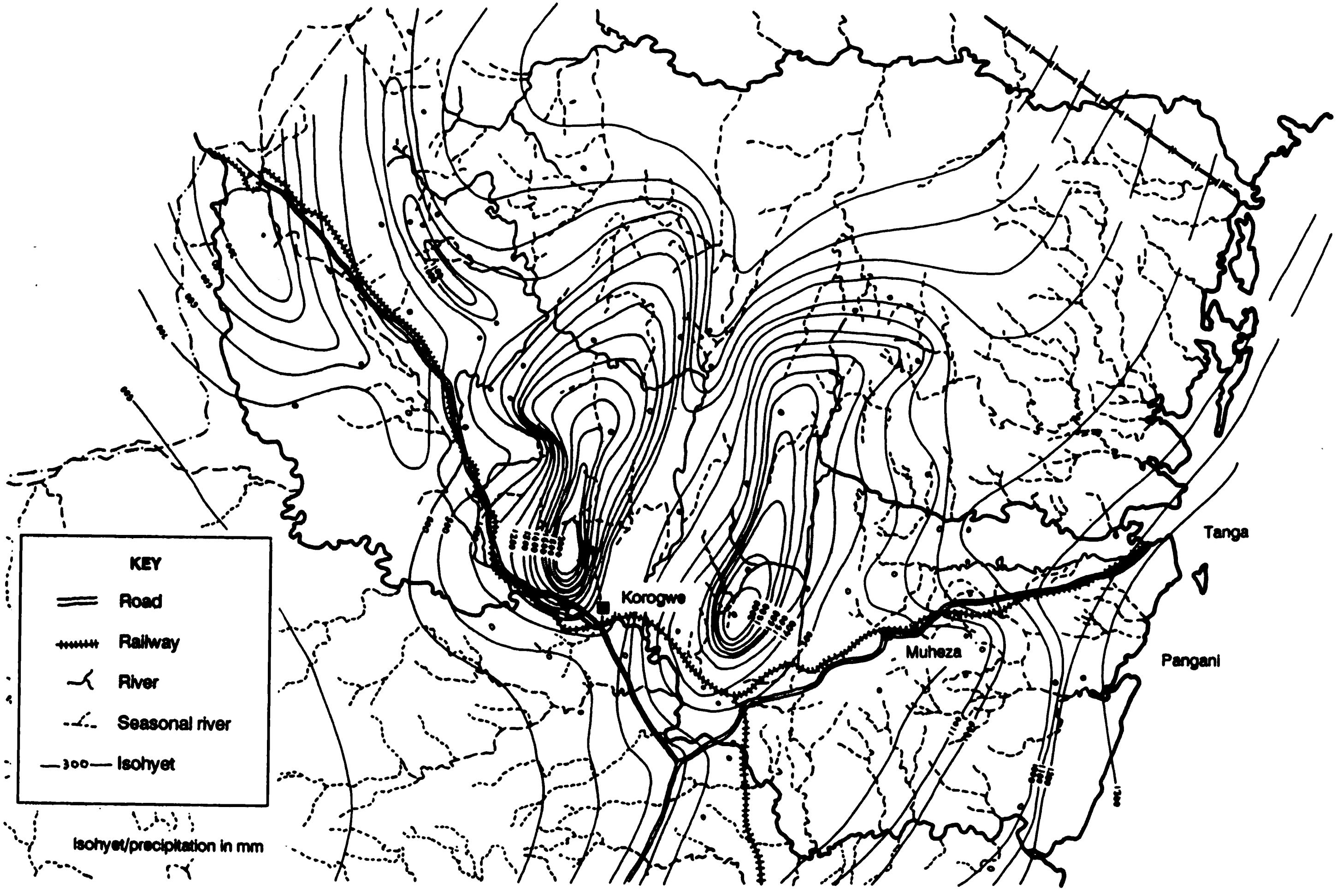

Figure 11.3 Map of rainfall distribution in the Usambara area, prepared for the Tanga Water Master Plan (1976).

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It can readily by observed that the greater part of precipitation on the East Usambara plateau must fall in localized storms. It is therefore of interest that there are high correlations between annual rainfall variations at the various stations on the plateau (Chapter 12), showing that over the course of a year, the irregularities produced by the local occurrences of particular storms are evened out to produce a small-scale geographical pattern of rainfall variation which is the same from year to year. Given this, and the observed considerable variation in annual rainfall between even closely situated stations on the plateau (Amani, Kwamkoro, Marikitanda), it seems likely that there is an intricate but annually constant pattern of rainfall variation related mainly to topographic peculiarities superimposed on the major gradient of declining rainfall away from the south-east.

A generalized isohyet map of the type produced for the Tanga Water Master Plant (TWMP 1976) must give only a crude guide to the actual distribution of rainfall in a mountainous area. For example, because there are no rain gauges on the isolated mountains east of the main range, these are not shown as areas of increased rainfall, even though they obviously are. River flow records and biological indicators can however add a bit more detail.

According to the TWMP (1976), the only permanent river on the East Usambaras is the Sigi, draining the southern part of the main range; all rivers flowing to the north are seasonal. However, the Kihuhwi river, rising on the south-eastern escarpment is also perennial as are (or at least were) various rivers coming from Mlinga (Dowsett *et al.* 1954). The permanency of rivers is however only a crude guide to climate variation in that it is also strongly influenced by non-climatic factors such as catchment area, topography and land-use.

Biological indications that the climate becomes wetter towards the south-east are the greater concentration of submontane species on this side of the mountains (Chapter 23) and the slight depression of vegetation zones towards the south-east as suggested by the variable-area tree survey (Chapter 22). Pockets of well developed submontane forest on Mtai, on Mhinduro and inand near Kilanga Forest Reserve are further suggestions of localized higher rainfall, though other factors such as high ground-water in steep-sided valleys may contribute in some cases. The presence of pendulous lichens and of bryophyte mats on isolated summits such as on Lutindi, on Mlinga Peak and on the rim of the southern escarpment of the main range in Kwamkoro Forest Reserve all suggest peculiarly moist local microclimates.

Moreau (1935a) and, following him, other authors have suggested that the unusual biological climate of the East Usambara plateau is related to exceptional mistiness and general wetness. Relative humidity at Amani is high throughout the year (Fig. 11.1) and (at least in the past) dews and mists were common. To quote Moreau (1935a) – "It should be added that on the plateaux, especially where large areas of forest remain, the rainfall is supplemented by so-called 'occult precipitation'. At Amani, for example, heavy dews form on nearly every night in the year and wet white fogs frequently envelop the ridges and permeate the forests, especially above Lowland Zone."

Observations and measurements of dew were made during the 1930's at Amani by Walter (1971) – "The high humidity in the virgin forests, which persists even after a number of days without rain is, according to my observations, to be attributed to the large quantities of dew that condense on the crown canopy. Dews occur every night in the humid tropics. The amount of dew was measured in a forest-opening at Amani during 40 nights without rain. The maximum amount recorded was 0.26 mm. The amount was over 0.15 mm on 14 occasions, 12 times between 0.15 and 0.1 mm and only during 3 nights was it hardly measurable. A dew precipitation of 0.1 mm corresponds to 100 ml per m^2. This quantity can quite possibly drip from the leaves, which usually show no residual wetness. The amount of dew condensing on the crown canopy is probably much greater."

As mentioned in Chapters 12 and 14, the incidence of dews and mists seems to have decreased during recent years and during 1986/7 they were noticeable only between April and May and then only occasionally.

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Potential evapotranspiration for Amani has been calculated at 1,540 mm (Lundgren & Lundgren 1979), resulting on average in an annual excess of precipitation (1,918 mm) over potential evapotranspiration. At higher elevations, especially in the south-east, potential evapotranspiration is likely to be less due to decreased temperatures and increased cloud.

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12. Climatic Change on the East Usambaras

Evidence from records from meteorological stations

By A.C. Hamilton & A. Macfadyen

Meteorological records from Amani, Kwamkoro and Marikitanda were examined to determine whether there have been any recent changes in climate. Much of the data is unreliable. There is however evidence for decreased annual rainfall reliability since about 1960 on a regional scale (including as far away as Tanga Town). There are more very dry years, with occasional very wet years. At most, this change is only marginally due to deforestation on the East Usambaras.

Many people who live on the East Usambaras say that the climate has changed during recent years, generally attributing this to forest clearance (Chapter 14). Some of these people are farmers who have to deal with the weather on a practical basis, but anecdotal evidence about climate always needs to be treated with caution, being liable to bias through selective recall and sometimes being deliberately biased for ulterior reasons. An attempt has thus been made to analyse some of the available meteorological data.

The Tanga Water Master Plan (1976) examined long-term rainfall trends for a few stations in Tanga District (though not including East Usambara stations) through calculation of moving averages. It was concluded that, for the period 1920 to about 1976, there were no general long-term trends. There are however periods of increased and decreased rainfall; for example the early 1940's were exceptionally wet and the few years before 1976 exceptionally dry.

As discussed below and in the next chapter, some of the data for recent years from meteorological stations on the East Usambaras are unreliable. There is however some reason to believe that annual rainfall totals are not too inaccurate. This is because there are high correlations between annual rainfall totals for different years between various stations on the East Usambaras (Amani, Kizara, Kwamkoro, Marikitanda) and between these stations and two stations in Tanga Town (examples shown on Figs. 12.1 & 12.2). These high correlations are unlikely to be produced by chance. An exception is the period before 1920 when a comparison of rainfall at Amani and Tanga Town Hall reveals a relationship different from that seen at later times. The early records are incongruous and rainfall seems to have been measured inaccurately either at Amani or Tanga, or possibly both.

Figs. 12.1 to 12.2 show that rainfall at Amani and other stations on and near the East Usambaras is variable from year to year. There seems to be a tendency since about 1960 to a greater number of exceptionally dry years, with a smaller number of exceptionally wet years.

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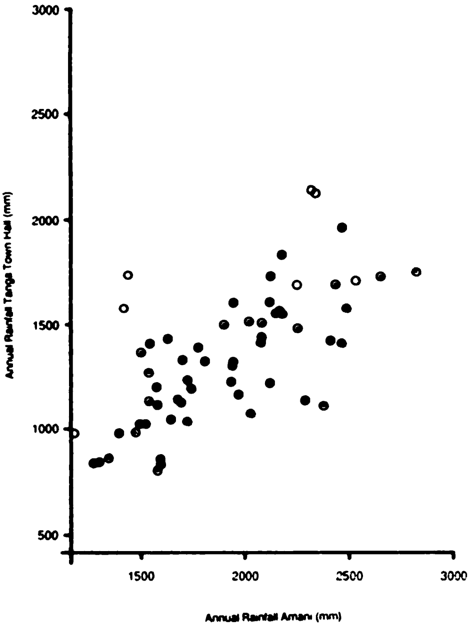

Figure 12.1 Relationship of annual rainfall at Amani and Tanga Town Hall. Altitudes: Amani 910 m, Tanga Town Hall 10 m. Note the good correlation, except for the early German records. There has been a tendency to have a greater number of very wet and very dry years since 1960.

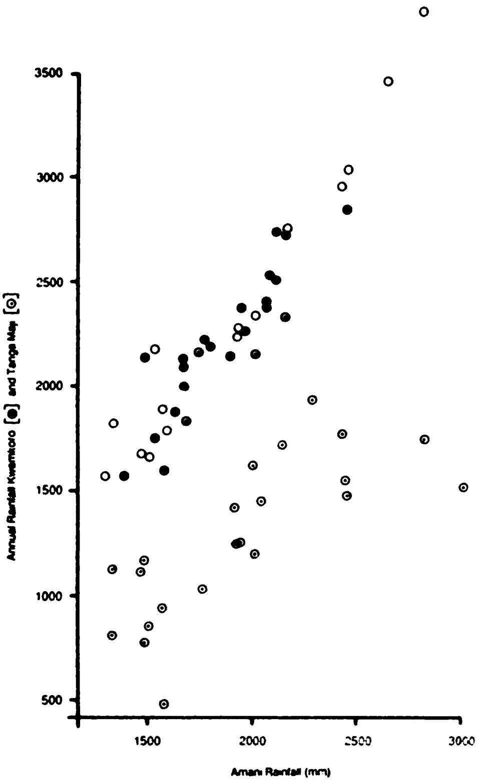

Figure 12.2 Relationships of annual rainfall at Amani, Kwamkoro and Tanga Maji. Altitudes: Amani 910 m, Kwamkoro 975 m, Tanga Maji 13 m. Note the good correlations, suggesting that the records are reasonably reliable.

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Rainfall has become more variable and less predictable, which will have created problems for the agricultural community. The high correlations between rainfall variations on the East Usambaras and at Tanga show that this trend is regional, not local, and thus at most is only marginally due to forest destruction on the mountains.

There are a number of possible causes of the change in rainfall pattern and analysis is outside the scope of the present study. It could be due to alterations in the surface properties of the Indian Ocean, in the positions and intensities of tropical high-and low-pressure areas or to large-scale changes in the surface characteristics of the East African land surface, most likely related to vegetational degradation by man.

Anectodal suggestions of a decline in mist and dew (Chapter 14) can hardly be examined through the types of measurement made at standard meteorological stations, but it was thought that it might be useful to examine the prevalence of raindays. (A rainday is a day on which precipitation in a raingauge exceeds a defined amount and is measurable.) The number of such days during the year might be expected to decline if cloudiness had declined, leading to more sporadic precipitation. Data from two stations, Amani and Marikitanda, were plotted (Fig. 12.3). At Amani the number of raindays shows a remarkable fall from about 1970 from a value of around 190 rain days per annum to values of often less than 160. However, no such trend is seen at Marikitanda. The date of the change at Amani corresponds to the time when measurements started to be recorded in metric rather than imperial units, possibly introducing a change in the definition of a rainday. In any case, little can be concluded from the readings.

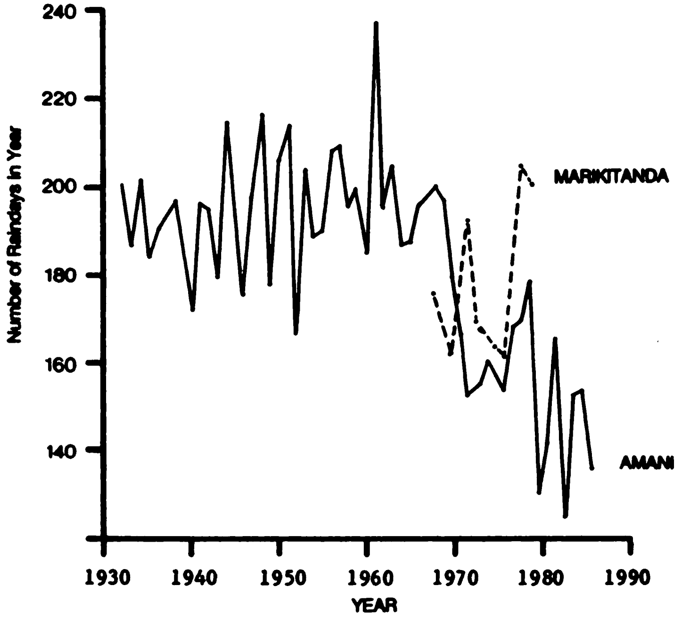

Figure 12.3 Raindays per year at Amani and Marikitanda.

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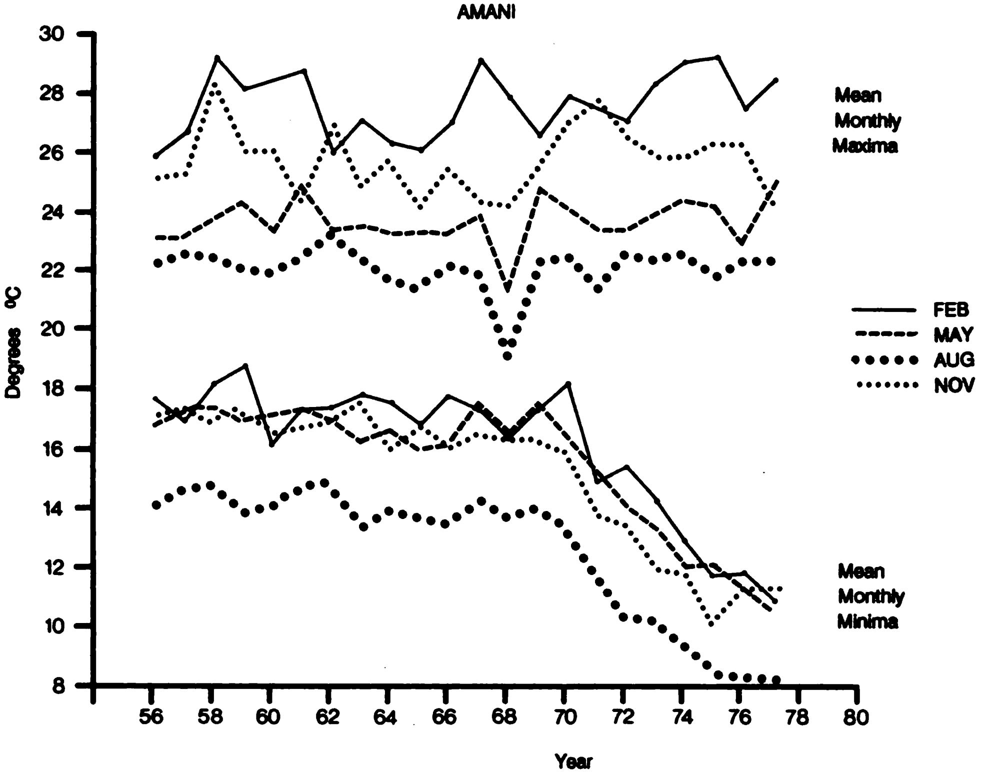

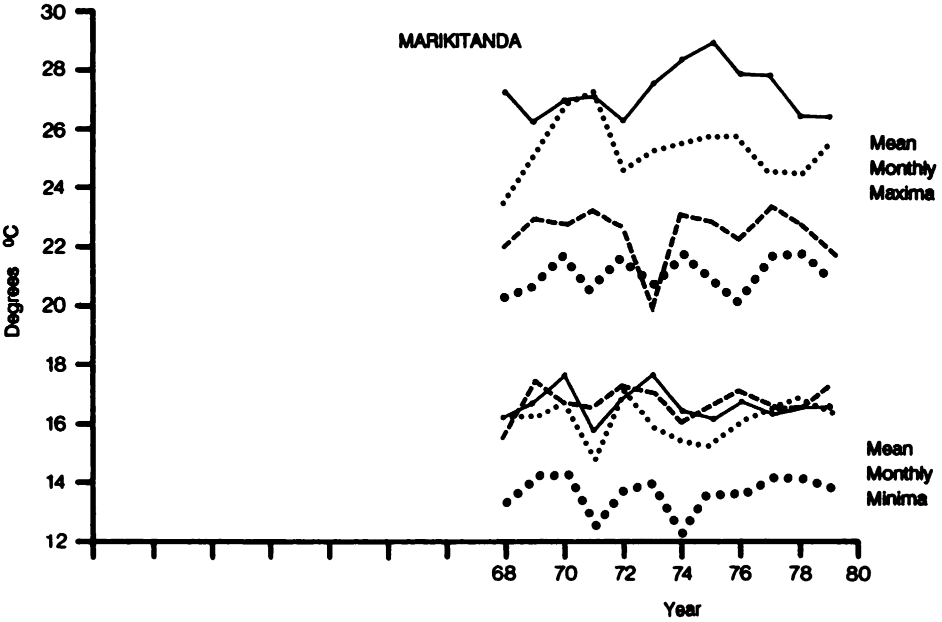

Figure 12.4 Maximum and mimimum monthly temperatures at Amani and Marikitanda. The huge falls in mean monthly minima at Amani are not seen at Marikitanda and are probably due to instrumental problems.

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Long-term residents around Amani report a warming in climate and temperature records from Amani and Marikitanda were examined for four representative months, February, May, August and September. Monthly means for Amani were obtained for the 1956–1966 period from the TWMP (1976) and were calculated for subsequent years from the original data by Professor Macfadyen who has provided the following notes:-

"Until 1977, records appear to be sensible and in Fahrenheit. From 1978 it appears (there is no note however) that a Centigrade thermometer was substituted for the minimum but misread (minimum temperatures around 30°C are impossible but down to 26°F are nonsense as frost does not occur). That situation continued until June 1979 when the maximum Fahrenheit readings cease. Minimum only is recorded and appears to be in Centigrade but at levels close to maximum levels. Perhaps a maximum thermometer in °C was being used for a minimum. There are no 1980 records. In March 1981 both maximum and minimum start, but column headings appear reversed (i.e. minimum means are impossible – from 5° to 10°C too high). Data are incomplete for January, February, November and December. There are no records for 1982 or 1983. 1984 records are realistic but lack precision; no decimals are recorded, which is very crude for °C. This continues for 1985 and 1986 except that occasional 0.5, 0.6 or 0.2 are scattered in the records, presumably without meaning. There are recordings for 29th February in 1967 and 1973, which are not leap years."

Temperatures as recorded at Amani for 1956 – 1978 are plotted on Fig. 12.4. There appears to be a slight rise in mean monthly maxima in February and May, but the most remarkable feature is a fall in mean monthly minima for each month examined by about 6°C. This is climatically impossible. Possibly, false readings were produced by progressive condensation of alcohol in the stem of the thermometer.

Monthly temperature averages for Marikitanda calculated from the original data for the period 1968–1979 (though not later) seem to be more reliable. There are no major falls in minimum temperatures as recorded at Amani, further evidence that this did not actually occur.

This study has brought to notice the poor quality of some more recent meteorological records from Amani and Marikitanda.

Reference

Tanga Water Master Plan (1976). Report prepared for the United Republic of Tanzania and GTZ by Agrar- und Hydrotechnik GmbH, Essen, W. Germany. 7 vols.

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Ocotea usambarensis on a ridge in submontane forest, Kwamkoro Forest Reserve, 960 m. The tree is leaning heavily, a common feature of this species. Ocotea in the East Usambaras is not regenerating, possibly because of climatic change. January, 1987.

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13. Climatic Change on the East Usambaras

Analysis of monthly extremes of temperature at Kwamkoro Tea Estate (1960–1983)

by Michael Bruen

Temperature data from Kwamkoro Tea Estate were analysed for the period 1960-1983. Temperatures increased from the late 1970's. In 1980 there is a remarkable fall in temperature maxima, possibly due to measurement error.

1. Source and quality of data

The management of Kwamkoro Tea Estate supplied values of maximum and minumum temperature, in degrees Fahrenheit, for each month for the years 1960 to 1983 inclusive. These were collected for me by Mr. I. Mwasha.

There were a number of years in which the reported temperature extremes are identical for three consecutive months. These are, for the maximum monthly temperatures:

- October, November and December in 1963.
- January, February and March in 1966.
- November, December in 1966 and January, February in 1967.

and for the minimum monthly temperatures:

- January, February and March in 1974.

These could be valid measurements, but as a series of three consecutive equal monthly temperature extremes is unlikely, the relevant values should be checked. If an error has occurred, it could be due to a malfunction of the measuring equipment, a faulty reading of the instrument or faulty transcription of the original records. If it is either of the first two, the error cannot be rectified.

The reported monthly maximum temperatures for the months of October, November and December 1965 are identical to the temperatures for the same months in the previous year. This is an unlikely occurrence, particularly since the minimum recorded temperatures for these months differ considerably from 1964 to 1965. This is very likely a transcription error and should be possible to rectify.

A yearly maximum temperature of 86°F is recorded for 12 years of the record. This is extremely unlikely and may be due to a fault in the measuring instrument limiting the maximum temperatures recorded for these years.

A minimum temperature of 90°F is reported for January 1963. This is an unlikely measurement.

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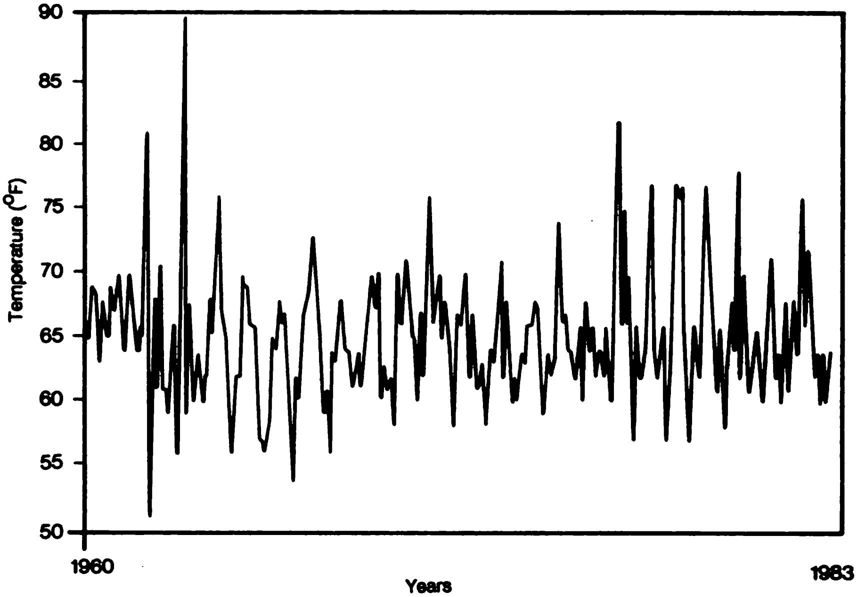

Figure 13.1 Kwamkoro Tea Estate: Minimum monthly temperatures 1960-1983.

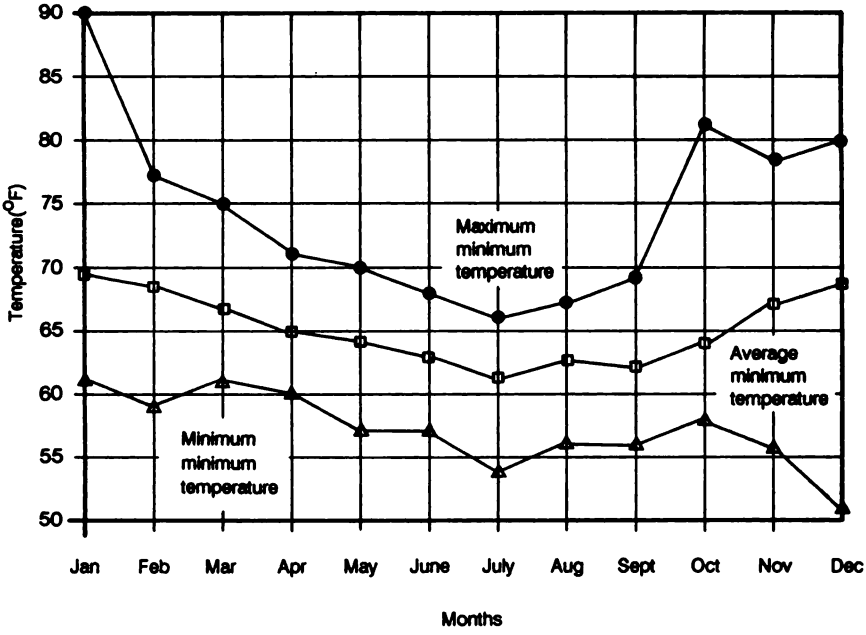

Figure 13.2 Kwamkoro Tea Estate: Statistics of temperature minima 1960-1983, showing the average minimum monthly temperatures and extreme values.

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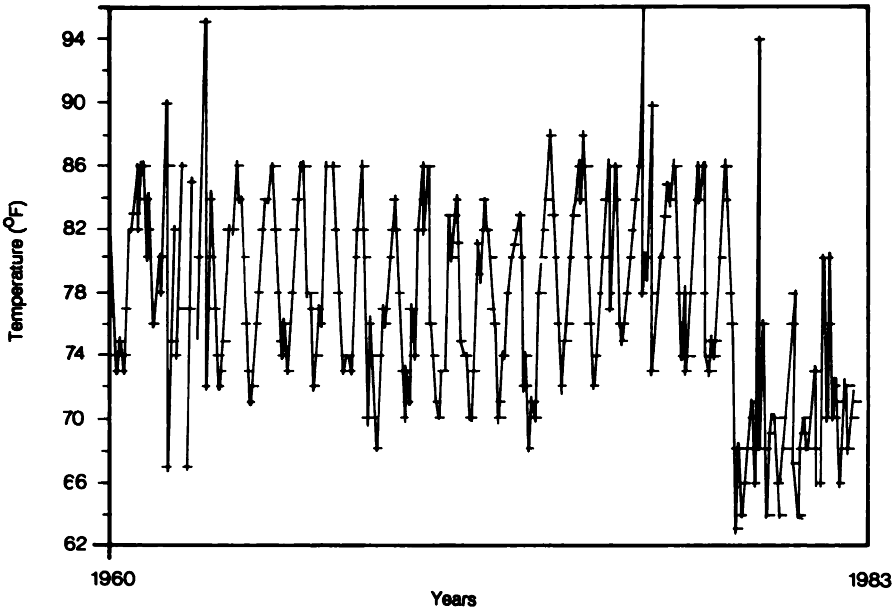

Figure 13.3 Kwamkoro Tea Estate: Maximum monthly temperatures 1960-1983.

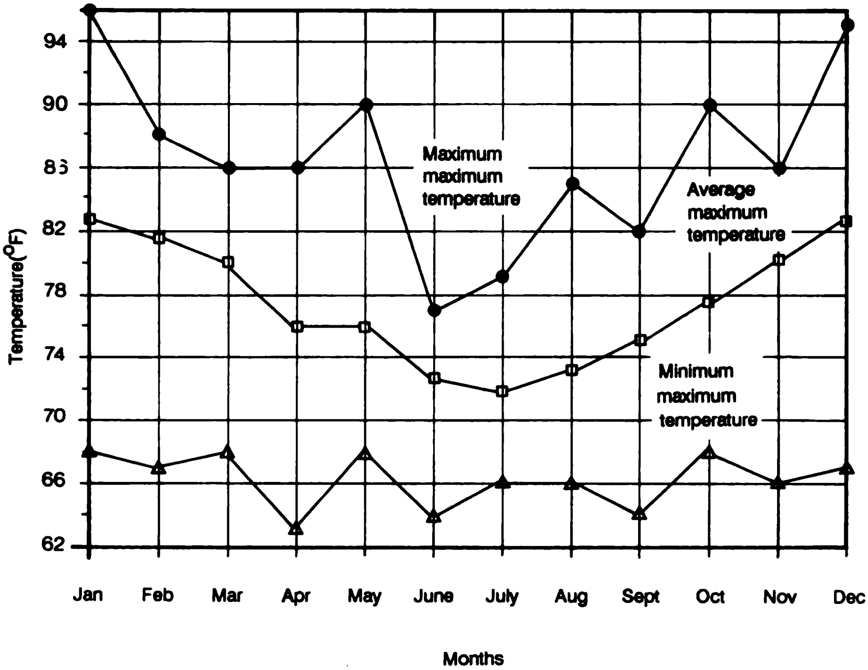

Figure 13.4 Kwamkoro Tea Estate: Statistics of temperature maxima 1960-1983, showing the average maximum monthly temperatures and extreme values.

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2. Analysis

2.1 Reservations

The following analyses have been done despite the apparent discrepancies in the data and thus the results should be interpreted with care. However, the results of most of the analysis would not be significantly affected by minor changes to a small number of data values.

2.2 Minimum monthly temperatures

The time-series of minimum monthly temperatures (Fig. 13.1) shows the expected annual cyclical variation and no strong trend. However, the first eight years and the last eight years of the record show a markedly greater annual variation in the range of temperature than does the middle eight years.

A linear regression analysis of all of this data, using a month index as independent variable, i.e. January 1960 is month No. 1, February 1960 is month No. 2 etc., gave the following equation:

$$\mathrm{MinTemp} = 64.91 + 0.0017\,j$$

(where j is the month index.)

The standard error of estimate of the slope, 0.0017, is 0.0035 and Student's t for the regression is 0.479. On the face of it this would seem to indicate a rise in minimum temperature of 12 x 0.0017 or 0.02 degrees per year. However, as the standard error of estimate of the slope is over twice the value of the slope, no confidence can be placed in this conclusion.

A similar regression, but using only the first 20 years of the data gives the equation:

$$\mathrm{MinTemp} = 64.73 + 0.0037\,j$$

The standard error of estimate of the slope is 0.0048 and Student's t is 0.761. Again a positive slope is indicated, but the standard error of estimate is still relatively high.

The distribution of average minimum temperature for each month (Fig. 13.2) is unimodal, with a peak in January and the lowest average minimum temperature in July. Superimposed on this graph are the curves of maximum minimum temperature and minimum minimum temperature for each month and this shows more deviation from the mean during the hotter months.

2.3 Maximum monthly temperatures

The time-series of maximum monthly temperatures (Fig. 13.3) does not show an obvious linear trend. It does show considerably more variation in temperature extremes in the first and last eight years of the record, compared to the middle eight years.

The most remarkable feature of the series is a sudden decrease, of approximately 10°F, in measured temperature maxima in 1980. This feature does not occur in the measured minimum monthly temperatures and in many cases brings the maximum and minimum recorded temperatures for a given month to within a few degrees of each other. Although it is possible, it is unlikely that these reported temperatures occurred, as it implies a temperature variation, within each month, of only a few degrees. The variation between the average maximum and minimum for each month is approximately 10 degrees, so the drop in temperature is quite a departure from normal behaviour.

It should be a simple matter to check if this sudden drop in temperature actually occurred, or is a measurement error. A similar series for another location, as near as possible to Kwamkoro, should be checked for a similar drop.

A linear regression analysis of the entire series gives the formula:

$$\mathrm{Max\ Temp} = 80.896 - 0.024\,j$$

The standard error of estimate of the slope is 0.0042 and Student's t vaue is -5.674. On the face of it, there appears to be an average decrease in temperature of 12 x 0.024 or 0.29 degrees per annum.

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However, most of this is due to the sudden drop at the end of the series, which also makes it difficult to interpret the value of Student's t. To illustrate this, a similar regression, using only the first 20 years of the data, i.e. up to the end of 1979, gives the formula...

$$\mathbf{MaxTemp} = 78.72 + 0.00096\,j$$

The standard error of estimate of the slope is 0.0051 and Student's t is 0.189. This shows virtually no slope in the first 20 years of the record.

The average maximum temperature for each month (Fig. 13.4) shows the same unimodal variation as the average minimum, with a peak in December/January, of over 82°F and a minimum, of 72°F, in July. More variation about this average occurs in the hotter months than in the colder months.

2.4 Temperature difference within the month

A time-series of the difference between the maximum and the minimum recorded temperatures for each month was calculated.

A linear regression analysis of the entire series gives the formula:

$$\mathbf{Difference} = 15.98 - 0.0258\,j$$

The standard error of estimate of the slope is 0.0033 and the Student's t value is -7.807. This would indicate a gradual reduction in the difference between the monthly maximum and minimum of 12 x 0.0258, or 0.31 degrees per annum. However, this particular result is greatly influenced by the last four years of record, for which the series of maxima is suspect.

A regression, excluding the final four years of the data, gives the results:

$$\mathbf{Difference} = 13.987 - 0.0027\,j$$

The standard error of estimate of the slope is 0.0039 and Student's t is -6.686. This cannot be confidently interpreted.

So these particular results are inconclusive until it is determined if the sudden decrease in temperature is an actual decrease or merely measurement error.

3. Conclusions

Another temperature time-series, from a location as near as possible to Kwamkoro, should be examined to determine if the sudden drop in the Kwamkoro temperature measurements from 1980 onwards is a valid result or is due to measurement error.

If the analysis of another series confirms the drop in temperature, then a physical reason for this drop should be sought.

No significant trends can be detected in the first 20 years of the data, i.e. prior to the sudden drop in maxima. Thus, if this drop is only due to measurement error, then the final conclusion is that a significant trend cannot be inferred from this data.

[Editors' note: In statistical analyses carried out after the receipt of the manuscript for this chapter, Dr. Bruen has concluded that both maximum and minimum temperatures were relatively high in the early 1960's, low in the late 1960's and early 1970's, and have been increasing from the late 1970's. A much longer set of data is needed to establish if there are climatic cycles, or whether the recent temperature increases are due to deforestation.]

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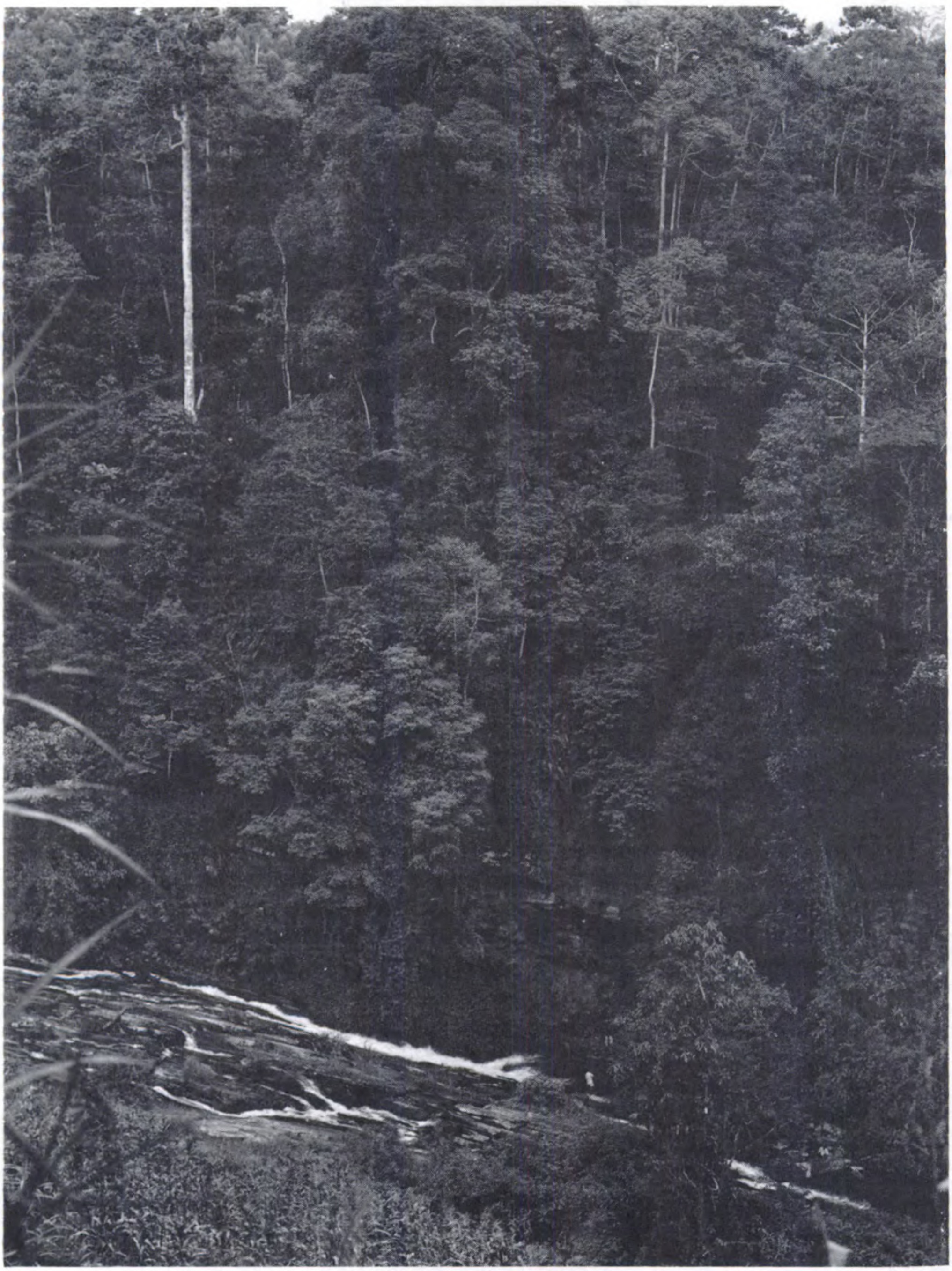

The torrential Sigi descends the escarpment near Amani. February, 1987. Credit PH.

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14. Climatic Change on the East Usambaras

Statements on climatic and environmental change

recorded by A.C. Hamilton

Long-time residents of the East Usambaras report that the climate on the Amani plateau has changed greatly during the last 10-15 years. There is now much less mist, rain is less predictable and more concentrated in particular episodes, and it is warmer.

These statements were recorded with as little prompting as possible so as not to bias the accounts. The statements are invaluable as a record of climatic change, given the inadequate data recently coming from meteorological stations.

1. **By Mr. M. Kimweri**, long-time resident of Amani. He is now employed as a watchman at the Medical Research Institute. (Taken on 12 March 1987.)

"People started cutting trees on a big scale in 1964. There used to be mist every day of the year at about 6 a.m. and it used to form in the evening at about 6 p.m. In 1978, the early morning mists lifted. It started to get much hotter in 1983. There was a lot of rain in 1954 and 1976, but afterwards not so much rain."

2. **By Mr. M. Kibaja** His family home is at Tongwe in the Amani-Sigi Valley. He worked at Amani Agricultural Research Station 1944 – 1951 and since 1981 has been Librarian at the Amani Medical Research Station. (Taken on 13 March 1987.)

"The climate has changed completely. Between 1944 and 1951, the climate at Amani was very good because of the presence of the forest. The climate was cool. Heavy rain came in May. From June to September, the place was very cold and fires were used in the laboratories, main office and homes for comfort; this is not necessary now. At the time there was heavy rain. Much mist occurred almost every day of the year. This mist was present in the early mornings and evenings, sometimes during the days and occasionally at nights, which were usually clear. It was impossible to produce citrus fruits and mangoes on the plateau at the time; today they are common. Even coconuts are now produced at Mlesa; they could grow in the past but would not produce fruits. Many streams and springs, for instance near Bomole and near Amani, are now dry; they used to have permanent water. Today I sometimes don't cover myself at night, but this could not be done in the past. I left Amani in 1951 but sometimes returned to my home and saw that a good forest cover was maintained up to 1964. There were only a very few and small villages before 1964 attached to the estates. Today there are many villages. Many people came here for commercial reasons to grow cardamom and have now settled. Some managed to cut many trees and shrubs. In about 1964 citizens of this country were told that they must cultivate. Some people did not understand and thought they could cultivate anywhere, even in forest reserves.

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There was an Area Commissioner in about 1964/5 called Mr. Issa Mntambo. When he heard that everybody should cultivate he came and gave people shambas. He thought it was his right to give away the land to the people, though this was not the idea of Government which wanted to keep the forest. There is no Public Land here according to the Law; even Amani Agricultural Station was only given 550 acres. Big forest destruction started in about 1967. Today mosquitoes are plentiful because of the climatic change: there were no mosquitoes before, because the larvae could not survive. Now there are many open places where they can breed. The European staff left Amani in 1966 and standards of cleanliness declined, leading to many suitable breeding areas for mosquitoes. There used to be no malaria at Amani — now there is plenty. Another factor is shade trees, which used to be present on the tea plantations; these have been cleared and this is another reason why the climate has changed. There are more tea-estates these days and estates have expanded."

3. By **Mr. S. Osman**, since 1967 Manager of Marvera Tea Estate, north of Amani. Taken on 15 April 1987.

"Temperatures, both in the night and during the day are definitely warmer than 10—15 years back. In the past mangoes and citrus could not be grown — these fruits are available now."

"Rainfall has changed to a certain extent, in that it was formerly more continuous with many rainy days each month. Nowadays, we get heavy showers with dry days in-between."

"Total rainfall at Marvera is not much different, but it has declined on the tea-estates further to the west and north, where there has been more forest destruction."

4. By **Mr. R. Mtoi**, a Senior Laboratory Technician at Amani Research Station. His home is about 15 miles from Amani, towards Muheza. He has worked at Amani since 1975, with an earlier visit in 1968. Taken on 9 June 1987.

"I came to Amani in April 1975. That year and 1976 the weather was very different from now because mornings were misty almost all through the year. The situation changed dramatically in 1977/78 and has deteriorated ever since. What has happened is that the rain has become concentrated in certain periods rather than being well distributed. The mist has actually disappeared except during the rainy seasons — previously it was almost throughout the year and the rain was more continuous. It was the evenings after about 5 p.m., the nights and the mornings up to about 9.30—10.00 a.m. which were misty, after which it cleared. It was an unpleasant place because it was always wet and misty. It used to feel colder than now. Places like Monga were very cold."

"In the Bombani area (in the lowlands to the east of Amani, towards Muheza) the rainy seasons used to be very predictable, but from the 1970's farmers have been in trouble, it being difficult to predict the weather, for instance concerning the right time to plant maize. Rainfall nowadays has a much more patchy distribution from place to place in a small area."

"There was a boom in cultivation of iliki (cardamom), after which sugar cane was grown. There has also been an upsurge of interest in timber. The cardamom started on a big scale in the 1970's; in 1975 there was a peak and everybody was talking about cardamom. Cardamom was a restricted crop to be sold only to a government institution (GAPEX). Now, this institution was failing to pay the farmers who became angry and thought it was better to cultivate a crop which they could cultivate easily and get money — sugar cane. Then there was an upsurge of pit-sawing in 1978 due to an appreciation of people from outside the region that money could be earned easily here and it has been paying handsomely ever since. The whole thing exploded when the government allowed people to export timber and other crops without restriction (before about 1980 — previously timber had to be exported through TWICO). There was a very severe shortage of foreign currency at the time, causing a great interest in exports, so that people could buy goods not available here. This changed the attitudes of people towards ruthless exploitation of the trees."

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15. Hydrological Considerations for Development in the East Usambara Mountains

by Michael Bruen

The East Usambara catchment and climate are described. A summary is given of the processes which influence the hydrology of a forest catchment and the ways in which they may be influenced by changes in land-use practices. Areas on the East Usambaras are identified which make large contributions to soil-water storage or which are vulnerable to erosion. Forest should be retained in these areas until it can be ensured that forest removal will not result in damage to the catchments.

1. Introduction

This chapter has three main objectives:

- to describe the important hydrological processes operating in a forest catchment.
- to suggest how changes in land-use might affect these processes and thereby alter the hydrological characteristics of a forest catchment, and, in the East Usambaras, to identify the areas most susceptible to such changes.
- to determine if serious changes in the hydrological characteristics of the East Usambaras have already happened.

Much of the work is of a descriptive nature, but the results of field studies and data analysis are also presented. The field studies formed part of the M.Sc. dissertation project of Mr. A.K. Inima, who also played a major role in the collection of the rainfall data, analysed herein.

2. Description of the Usambara catchment

2.1 Location

The East Usambara Mountains are located in the north-east part of Tanzania at 38°35'E 5°5'S. They are in Muheza District, Tanga Region, approximately 50 km west of Tanga Town. The main range is oriented in a nearly north-south direction.

2.2 Topography and relief

The mountains rise steeply from the coastal plain at 250 metres above sea level (masl) to form a plateau region at about 1,000 masl. Some of the individual peaks reach 1,400 masl. In places, the escarpment may rise by 700 m, in distances of only 1.3 km. The plateau region is not uniformly flat, but consists of steep-sided valleys and ridges, and the ground may rise or fall by up to 100 m in quite short distances.

Contour maps, showing the topology in detail, were produced by Finnmap from an aerial survey of the area. These maps are to a scale of 1:10,000, cover most of the study area and show contours at 50 or 100 m intervals.

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2.3 Soils

The soil type varies very little throughout the mountains. The thickness of soil cover varies from 3 to 10 m. The entire region is classified by Hathout (1972) as sandy loam, which includes coarse gravel and small stones, and having a number of (unspecified) limitations to agricultural development. The results of recent soil analysis are given in Chapter 10.

2.4 Vegetation

There are a number of different vegetation types in the Usambaras, including:

- forest. The distribution of species of trees and plants varies greatly, particularly with altitude (see e.g. Chapter 22).
- tea-estates. There are a number of tea-estates in the region.
- smallholder cultivation. The principal crops include bananas, sugar-cane, cassava, cardamom and arrowroot.

2.5 Drainage

The western slopes of the East Usambaras drain into the Lwengera river, which flows into the Pangani. The eastern slopes are drained by the Muzi, Semdoe and Kihuhwi rivers which flow into the Sigi, which itself drains most of the Amani plateau region. The Sigi is the main source of the water supply for Tanga Town.

A Basic Gauging Station at Lanzoni Sisal Estate has measured daily discharge in the Sigi since 1957. Prior to then, it was a Tertiary Level Station and only a small number of intermittent gaugings are available for periods before 1957. It is the only reliable gauging station in the catchment. Some gauging of the Muzi river has been done for the Tanga Water Supply Scheme, but the rating curve, and thus the measurements, are unreliable (Litterick pers. comm.).

The Tanga Water Master Plan claims that the Sigi is the only one of the eastward-draining streams which is perennial. However, the Kihuhwi is also perennial and, while the Muzi may have dried up in the very dry spell of 1969, local information indicates that it, and a number of other such streams, are also essentially perennial (Hamilton pers. comm.).

3. Climate

3.1 Wind

As the mountains are relatively close to the East African coast, and there are no intervening obstructions, wind directions are governed by the monsoons of the Indian Ocean. The predominant wind direction from March to August is from the south-east, and from September to the following February, from the north-east. The wind direction greatly influences the distribution of rainfall in the mountains.

3.2 Rainfall

The spatial distribution of rainfall over the Usambara Mountains is primarily related to altitude and aspect. In general, the higher areas receive more rain than lower areas with a similar aspect. Areas on the south-eastern side of the mountain range tend to receive more rainfall than areas of similar altitude on the northern or western slopes (Fig. 11.3). Average annual rainfall amounts exceed 2,000 mm in the higher areas of the south-east, while the plains at the foothills receive an average of 1,200 mm annually (Hydrological Year-Book 1965 – 1970).

The average annual distribution of rainfall in the area is bimodal, with a rainy period in November – December, called the 'short-rains' and a, generally much wetter, rainy period from March to June, called the 'long-rains' (Fig. 11.1). This distribution, determined by the movements of the Inter-Tropical Convergence Zone, is typical of the East-African coast in the vicinity of the equator.

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Rainfall is usually due to orographic lifting of the moist monsoon winds from the Indian Ocean. Showers are usually intense, but of short duration and highly localised.

Measurements of daily rainfall amounts are available from most of the tea-estates in the Usambara region. Tea production requires a considerable amount of moisture and thus the management of tea-estates requires data on the amounts and distribution of rainfall. The data are of mixed quality, as both the siting of the gauges and measuring procedures are inadequate at some locations (Kenyani 1987). Data from gauges at Lanzoni, Kwamkoro, Amani, Marvera, Marikitanda, Ndola and Derema were used in this study. Rainfall measurements for the lowlands are available from a raingauge at Lanzoni Sisal Estate.

3.3 Temperature

Temperature influences the amounts of water evapotranspired from a catchment. Analysis of measurements of minimum and maximum monthly temperatures at Kwamkoro Tea Estate showed no significant long-term trends in temperature regime over a 24-year period, although a marked deterioration in the quality of the measurements was detected (Chapter 13). However, temperatures have been rising over approximately a decade, possibly part of a slow cycle.

3.4 Humidity

No data on humidity were available for this study.

4. Hydrological processes in a forest catchment

An understanding of the various physical processes involving water as it moves through a forest catchment is essential to the arguments used below to identify the areas of the Usambaras which are most vulnerable to changes in land-use.

4.1 Precipitation

Water enters the catchment mainly in the form of precipitation, which includes rain, hail, sleet and snow. In the tropics, rainfall is generally of the convective or orographic type, rather than frontal, and is highly variable in both space and time.

The quantity of water entering the catchment can be measured with raingauges. These collect the precipitation falling on a small fixed area for a specified period of time. They may be inspected manually at set times, or may record the rainfall automatically. Manual raingauges are integrators and give only the total quantity of precipitation falling in a particular time interval. From this the average precipitation rate for the interval may be calculated, but the peak precipitation rate cannot be determined and this has some serious implications when analysing overland flow and soil erosion. Certain types of automatic recording raingauges do give instantaneous precipitation rates.

Siting a raingauge is a problem in a forest. If it is located at or near ground-level, then it should be sufficiently far from trees not to be sheltered and to catch the full amount of rainfall coming from the atmosphere. This generally means that a gauge must be placed at a distance from the base of a tree at least as great as the height of the tree. This is impossible within tall forest. Alternatives are:

- The gauge may be placed above the forest canopy, so that it is higher than any obstruction. This is the only way to get an accurate measurement of the amount of water entering a small area. This would require construction of tall platforms within the forest which for this study is impractical. In any case both the extreme height above the ground and exposure to the wind alter the amount of rain caught by a gauge, so such measurements should be interpreted with care.
- Rainfall measurements from gauges surrounding the forest, but not in it, can be used. Because of large spatial variations in the rainfall, particularly in mountainous areas, care must be taken to ensure, as far as possible, that the measured rainfall is indeed representative of that falling on the catchment.

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The second method is used here and the rainfall records from the various tea-estates are used in the analysis. In certain circumstances, fog-drip or condensation of moisture from clouds and fog banks may add water to the catchment which is not recorded by raingauges. Opinions vary on the importance of this effect. Penman (1963) concludes that this is generally a minor effect in a forest, except where fogs and mists are prevalent, and is confined to the periphery. Other studies indicate some significant contribution from fog-drip.

In very large forest basins there is the possibility that moisture evaporated by the trees in one part of the catchment may contribute to precipitation in other parts of the catchment, introducing a feedback loop into the water-balance calculations. While the moisture evaporated by any forest eventually is precipitated somewhere, the East Usambaras is too small an area for this to have a significant effect.

4.2 Interception

A certain amount of precipitation falls onto the foliage of plants. In the case of a forest with a dense canopy, virtually all of the precipitation encounters the foliage first. A part of this water wets the surface of the foliage and collects in pools in the leaves and branches, from whence a portion evaporates directly back into the atmosphere without ever reaching the ground. This is called interception and, naturally, the water thus intercepted plays no further role in the catchment. It is not practical to measure directly the quantity of water which is intercepted and it is usually included with evapotranspiration and the combination is estimated from water-balance calculations.

4.3 Throughfall and stemflow

Precipitation which is not intercepted reaches the ground in either of two ways:

- It drops from leaf to leaf until it eventually drops from the forest canopy onto the ground. This is called throughfall. Its kinetic energy as it hits the ground is a measure of its ability to detach exposed soil particles and make them available for transport by overland flow. Although the forest canopy absorbs the kinetic energy of the original raindrops, the drops from the canopy, if it is far from the ground, can still acquire considerable kinetic energy. Drops from the canopy also tend to be larger than natural raindrops and thus carry more kinetic energy for the same velocity.
- Water also moves along the surface of the branches which act as collectors, directing water inwards towards the trunk. This water then flows down the trunk onto the ground and its impact on the ground is thereby considerably lessened. This is called stemflow and the magnitude of this effect depends on the leaf-shape and the structure of the framework of branches and of the canopy. It is thus species-dependent. While the soil is not subjected to impact damage by it, stemflow does concentrate the water flow into a small area of ground around the trunk, which may lead to local erosion, or the formation of gullies, if it does not infiltrate immediately.

No data on the relationship between throughfall and stemflow for species indigenous to the East Usambaras could be found, but the formulae for some American pines (Appendix 15.1) gives a rough idea of the magnitude of the effect.

4.4 Evapotranspiration

Transpiration is the process by which plants transport water, against gravity, from their roots to the stomata on their leaves. On its way it is involved in the many chemical reactions which enable the plant to grow. Once it emerges from the stomata the water evaporates in the same way as water from any other source, including the ground surface, and the combined effect is called evapotranspiration. The rate of evapotranspiration is determined by whichever of the following influences is limiting:

- Energy, provided by the sun, is required to convert the water from a liquid into a gas. Temperature is a measure of the quantity of heat energy available, and thus directly controls evapotranspiration.

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- The evaporated water increases the moisture content of the air. There is a limit to the quantity of moisture which a given volume of air can carry under a given set of conditions. When this limit is reached, evaporation ceases. However, if the air, after gaining some moisture, is moved and replaced with drier air, then evapotranspiration can continue. Wind provides such movement.
- Even if the energy and transport conditions are favourable, water can only evaporate as quickly as it is delivered to the evaporation surface. Thus, the rate at which water is supplied to the leaves is also a limiting factor. This supply-based limit applies equally to the rate at which water evaporates from a bare ground surface. If the surface is not saturated, then the limit on evaporation is the rate at which water can move upwards from the water-table. Transpired water must have been originally absorbed by the roots of the plant. If the plant has a shallow root system then the water available in the upper soil layers may be reduced considerably, by transpiration, in periods of drought. Trees, on the other hand, generally have roots which may go very deep, in some cases even below the soil into decomposed rock. The root systems of submontane forest trees studied on the East Usambaras all include deep roots (Chapter 30). These can tap deeper, more permanent sources of water, even groundwater. The transpiration of trees is less likely to be limited by the availability of water in the soil than that of other plants, including grasses and cultivated crops. Moisture loss from a forest through evapotranspiration is generally higher than for any other form of land-use.

4.5 Infiltration

Some of the water which reaches the ground may enter the soil, displacing air, and this is called infiltration. Gravity is the driving force, sometimes supplemented by the, potentially more powerful, soil capillary suction. The maximum rate at which soil in any given condition is capable of absorbing water is called its infiltration capacity. The actual infiltration rate can be less than this if the supply of water to the ground-surface is lower than the infiltration capacity. The main influences on infiltration are:

- The moisture content of the soil, which, for a given soil, affects both its capillary potential and hydraulic conductivity.
- Soil macrostructure. Burrowing insects and animals and the roots of plants create comparatively large flowpaths through the soil. Cracking of the soil, when dry, is another source of macro flowpaths.

The water which enters the soil may be held by capillary forces to the soil particles or may move through the soil in the direction of the hydraulic gradient. Water which moves through the soil either percolates to groundwater, re-emerges at the ground-surface in a different location, causing overland flow, or drains directly through the soil into a channel.

For a given soil, the infiltration capacity is greatest when the soil is dry, as the ingressing water is first absorbed by the soil particles and then held to the particles by capillary action. As the soil becomes wetter, the infiltration capacity reduces and is eventually limited, at saturation, by the rate at which moisture can be transported through the entire soil profile. This is called the saturated infiltration capacity and is determined by the least conductive soil horizon. This may be below the ground-surface, in which case most of the infiltrated water flows laterally above it and may re-emerge at the ground-surface. The soil surface itself may sometimes be the least conductive horizon. In soils, exposed to the direct impact of raindrops, the capacity of the soil-surface to transmit water changes during a rain-storm, as the soil is compacted, reducing its hydraulic conductivity. This is called surface sealing and some experiments conducted elsewhere by Edward & Larson (1969), on agricultural land, indicated the possible magnitude of the effect. They report a reduction in conductivity from 1.9 cm hr^{-1} to 0.2 cm hr^{-1}, a nine-fold decrease, after 2 hours of rain. The final infiltration rate was reduced from 2.5 cm hr^{-1} to only 1.0 cm hr^{-1} because of increased soil suction at the sealed layer.

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This effect is generally more pronounced in soils consisting of smaller, rather than larger particles. In pasture land, overgrazing by animals can also reduce the infiltration capacity of the soil. The weight of the animals compacts the upper soil layers and, if the plant cover is reduced, so is the root network which facilitates infiltration. This effect is discussed by Gifford & Hawkins (1978). This is generally not the case with undisturbed forest soils.

Some soils, when they are dry, are hydrophobic when first wetted and repel water. As water accumulates on the ground, this behaviour ceases and infiltration begins.

In theory, single infiltration measurements are quite easy to make. In practice, however, it is difficult to make reliable inferences about actual infiltration during natural rainfall over a large area from such measurements. In a natural soil, infiltration capacity can vary greatly over comparatively small distances (Berndtsson & Larson 1987; El-Kadi 1987). In addition, it is not easy to reproduce natural rainfall in an experiment. Effects, such as surface sealing, which change the capacity of the soil-surface to transmit water, are thus not reproduced during the measurement. Sprinkling infiltrometers attempt to overcome this difficulty. Simpler double-ring infiltrometers are used when the surface sealing effect can be neglected.

Infiltration capacity was measured, using double-ring infiltrometers, in the West Usambaras by Lundgren (1980) and in the East Usambaras in the course of the present study. Lundgren (1980) reports mean infiltration capacity in the range of 704 to 1,049 mm hr^{-1} after a 90-minute experiment. Individual experimental values are highly variable because of differences in root structure of the soil at each site. The present study confirms that high infiltration capacities, of the order of 700 mm hr^{-1} also occur in the East Usambaras, but reveals that a 90 minute experimental period is, in many cases, too short to measure saturated infiltration capacity in the East Usambara soils. In some cases, saturation was not reached after 2.5 hours indicating the high capacity of the sandy loam to transmit water (Kenyani 1987). In general, forest soils may be expected to have a high infiltration capacity and, worldwide, figures as high as 5,000 mm hr^{-1} have been reported (Dryness 1969; Webster 1977). The generally high saturated hydraulic conductivities of forest soils have been attributed to the macropore network and to organic soil horizons (Sidle, Pearce & O'Loughlin 1985).

Repeated measurements at the same locations in the Usambaras indicate only a slight reduction in infiltration capacity due to surface sealing, even when the soil surface is exposed to the direct impact of raindrops. As infiltration capacity depends very much on soil moisture amounts and on soil macrostructure, it exhibits the seasonal and annual fluctuations of these quantities.

4.6 Direct or storm runoff

The discharge hydrograph for a catchment can be considered as composed of two parts, a slowly varying part called baseflow and, superimposed on this, a component, called direct or storm runoff, which can change rapidly in response to individual rainfalls. There are no rigid criteria for distinguishing between these components, which vary from catchment to catchment. A response time of days may be considered quick for a large catchment, while a response time of a few hours might be considered slow for a small catchment.

There are a number of different mechanisms by which direct runoff may be produced. They are complementary and the response of a catchment may involve any or all of the mechanisms.

4.6.1 Infiltration excess

If the rate at which water reaches the ground-surface exceeds the sum of the infiltration and evaporation rates, the excess, after depression storage is filled, flows downhill as overland flow (Horton 1933). Flow velocities can be between 10 and 500 m hr^{-1} (Dunne 1978), so that this water reaches the channel network very quickly, resulting in a very rapid increase in discharge. An equally rapid decrease in discharge occurs when the rain stops, since the dynamic storage is small.

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Overland flow rarely occurs uniformly over the whole catchment and generally only a fraction of the catchment contributes to this type of response. This idea was called the partial-area concept by Betson (1964). Nor can all the overland flow be expected to reach the channel network immediately, as it infiltrates if it flows over ground where the infiltration capacity has not been exceeded. Overland flow is unlikely to occur frequently on freely drained forest soils, which have high infiltration capacities. However, Dunne (1978) reports overland flow on access roads, skid trails and loading landings in logged forests in the United States. Similar observations were made on the logging roads and landings of the East Usambaras during the course of this investigation.

Direct runoff, i.e. the local excess of throughfall and stemflow above the infiltration rate, was measured on small-scale runoff plots in the West Usambaras by Lundgren (1980). The maximum percentage runoff (based on throughfall only) reported was 2% for a steep forest slope and was of the order of 1% for mild slopes. The mean annual rainfall in that study area, Mazumbai, is 1,200 mm. Parts of the East Usambaras receive considerably more rainfall than this, and a higher percentage runoff can be expected.

4.6.2 Subsurface stormflow

If infiltrating water encounters a layer of soil with a low hydraulic conductivity, much of the water may be forced to move laterally through the soil rather than percolate vertically. An extreme case occurs when the infiltrating water reaches an impermeable stratum or solid bedrock. Many soils are likely, due to their origins, to be anisotropic and layers of different conductivity must be expected. Subsurface flow may occur above any lateral interface at which the conductivity decreases with depth. Sometimes much of the lateral flow can occur in the highly permeable upper organic layer of soil, especially if it overlies a less permeable clay layer. Although macropores facilitate the movement of water through the soil, subsurface flow is still comparatively slow.

To determine if this mechanism operated in the East Usambaras, a cutoff trench was constructed on a typical hillside to intercept subsurface lateral flow during the short rains of 1986. No appreciable amount of water was collected from the upper 0.5 m of the soil profile, but the observation period was too short to draw firm conclusions from this.

4.6.3 Saturated overland flow

A combination of infiltration, percolation, lateral subsurface flow and rise, local or otherwise, of the groundwater table may saturate the soil surface at certain locations in a catchment during a rainstorm. When this happens, water, which had previously infiltrated, may emerge from the soil and flow over the ground. This is called return flow. Direct precipitation onto these areas then contributes to the total overland flow. This generally happens in the bottoms of valleys in hilly catchments which have some soil cover. Generally small areas around the streams in the valleys, or flat areas contribute in this manner to the storm response. The stream network is considered to expand dynamically into these saturated areas and this is called the variable source area mechanism (Hewlett & Hibbert 1967) and is used in a catchment model by O'Loughlin (1981). Burch *et al.* (1987) use the idea to interpret the response to logging of a forest catchment in New Zealand.

4.7 Baseflow

Except in catchments where there are a significant number of lakes, the contribution to streamflow from direct precipitation onto the water surface can be neglected. This leaves direct runoff, described above, and baseflow as the two major components of streamflow. Water, which does not contribute to the direct response, is stored in the soil, either in the groundwater or as an increase in the moisture content of the unsaturated zone, from which it flows gradually to the streams. The baseflow component in a discharge hydrograph is easily isolated as it varies more slowly than the direct response and continues long after rainfall has stopped.

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4.8 Erosion

Erosion is the process whereby soil particles are detached from their original position in the soil matrix and transported to another location. Both activities require a source of energy. When the erosion is caused by water:

- The energy required to detach the soil particles from the original soil matrix may be provided by:
    - the kinetic energy of falling drops of rain. The total amount of soil detached then depends on the size of the raindrops (i.e. their mass) and the intensity of rainfall. This is the mechanism of detachment for most areas of a watershed.
    - the energy of flowing water, and of particles already carried by the water. This may dislodge particles from the surfaces in contact with the flow. This is the mechanism of detachment which leads to the formation of gullies and river channels.
- The energy required to transport the detached soil particles to another location is generally provided by flowing water or by the successive impact of raindrops.

Determination of erodibility requires consideration of all the factors which may influence either of these physical processes. The Universal Soil Loss Equation, developed by Wischmeier & Smith (1960), gives the following relationship

$$A = RKCLSP \qquad (1)$$

(where A = average annual soil loss, due to erosion, in tons ha^{-1}, R = a rainfall/runoff factor, which describes how much of the annual rainfall runs off as overland flow, thereby causing both detachment and transport of soil particles, K = a soil erodibility factor, which, for a given soil type, describes how easy or difficult it is to detach soil particles from the soil matrix, C = a crop management or plant cover factor, L = the length of the particular slope, S = steepness of the particular slope, P = a conservation pratice factor.)

The equation was developed for cultivated fields in humid areas and, for arid areas, gives lower estimates of soil loss than actually occur.

At the moment there is insufficient information on soil loss in the Usambaras to calibrate this equation in order to produce actual estimates of soil loss under changed conditions. However, the equation identifies the effects of all the major factors involved in soil loss and is used, in Section 7 below, to distinguish between areas of greater or lesser susceptibility to erosion.

5. Storage and water yield of a catchment

5.1 Types of storage in the catchment

A catchment may store water in a number of ways:

- The water may be stored in a lake or reservoir. A barrier, be it natural or man-made, holds back the flow until the water rises sufficiently to flow over the barrier. In the case of a lake, the barrier is the bed of the stream leading from the lake. In the case of a man-made reservoir, the barrier is a dam and a spillway is constructed at its lowest point to allow water to escape without harming the dam. A small quantity of water is also stored temporarily in the channel network in the catchment.
- Water may be stored in the ground, between the soil particles. The water may be below the groundwater table, in which case it is called a groundwater store, or it may be stored as the excess of soil-moisture above field capacity in the unsaturated soil zone. Water in the groundwater store and the excess over field capacity in the unsaturated zone flow slowly, under the influence of gravity, to the streams, producing baseflow.
- Water may also be stored within the biomass of a catchment.

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5.2 Effects of storage

The distribution of rainfall throughout a year is highly uneven, with many high intensity peaks separated by long periods of little rainfall (Fig. 15.1). Although some rain is likely to fall in every month, there are two main rainy seasons and much of the annual rainfall falls within a period of two or three months.

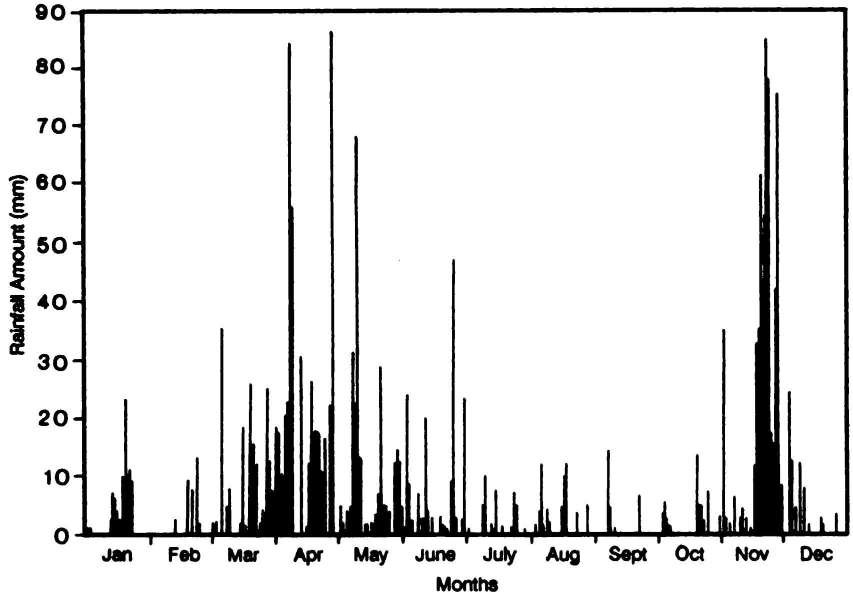

Figure 15.1 Daily rainfall totals at Amani, 1978.

The population of a town generally requires a reliable supply of a reasonably constant amount of water per day throughout the year. There are, of course, seasonal variations in the demand for water, particularly if much of it is used for irrigation, but these variations are of smaller magnitude than the variations in rainfall. In addition, peaks in water demand tend to coincide with periods of little rainfall and low flows in the rivers.

A reservoir is a device which stores water during periods of high streamflow and delivers it later at a constant or slowly varying rate, as required. The size of the reservoir needed to provide a particular constant supply, depends mainly on the variation in the streamflow feeding the reservoir. If a reservoir is made too small, it will not be able to store sufficient water during the rainy season to supply the constant demand during the dry period. If a reservoir is made too big, a constant supply would be assured, but a lot of resources would be wasted in unnecessary construction.

The role of a reservoir can be easily seen by considering two possible extreme cases. If the flow in the river was always constant, then that river could provide a town with a reliable supply of water equal to its constant flow. If, on the other hand, the entire annual discharge in the river always occurred on one day of the year, then a reservoir capable of storing a full year's supply of water would be required in order to provide the town with the same constant water supply. This is despite the river having the same long-term mean annual flow in both cases. Evaporation losses and compensatory flows are neglected here for simplicity. Of course neither of these extremes actually occurs, but the behaviour of any given river may be closer to one or the other and storage requirements for water supply from different rivers with the same average annual flows may be quite different. Such is the effect of variability in the discharge time-series.

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For a given rainfall pattern the storage required to deliver any given constant supply of water with a given probability of failure can be determined. If any form of natural storage is available within the catchment itself, the size of the man-made reservoir required to supply a given demand for water is correspondingly less. The various storages within a catchment ensure a streamflow time-series which is much smoother than the corresponding rainfall time-series. Man-made storages are then required to smooth only the streamflow series and not the original rainfall series.

6. Effects of development on forest hydrology

A proper understanding of the consequences is important in planning changes in any particular area. Good planning involves a proper balance between the beneficial and the harmful effects of the development. This section sets out the possible hydrological effects of removal or opening up of forest areas. The extent to which any of them occur in a particular development depends on the care exercised in managing the various stages of development. Most of the possibilities described here are harmful ones and will occur if they are not taken into account in a development plan. If they are allowed to occur, the situation cannot be reversed, as it would take thousands of years to replace a depleted soil cover. Thus, it is vitally important not to permit such changes until their proper management can be assured.

6.1 Influences on discharges from forest

It is generally accepted that forest clearance increases the magnitude of flood peaks and decreases the dry-season low flows downstream of the catchment. However this hydrological effect is not a direct consequence of the removal of trees, but follows indirectly and only in certain circumstances. It is clear from the descriptions in Section 4 that the water which enters the catchment is either:

- evapotranspired, either immediately from the canopy or ground surface, or later from soil-moisture through the root system of the plants, or
- stored as soil moisture for gradual release as base-flow in the streams, or
- discharged from the catchment quite soon after its arrival as the direct storm response.

The quantity of water involved and the speed with which it can be transported to the catchment determine the magnitude of the resulting flood peaks. Both of these factors depend critically on the quantity of soil in the catchment and on its infiltration capacity which, in turn, depends on its moisture content and the type of soil cover. If the soil is already saturated, then rainfall infiltrates only at a rate equal to the saturated infiltration capacity, and the excess becomes surface runoff. If the groundwater table is high in some locations, the subsurface flow of infiltrated water from another area may raise it to ground level and thereby also produce overland flow. Thus, the quantity of soil available to store water is a major factor in determining the quantity of runoff. In areas with a thin soil cover, the infiltration capacity, if not limited by any particular layer, is likely to be lower than for a thicker layer of the same soil. Also, the water table, if any, in a thin soil layer is likely to be closer to the surface than in a thicker layer and may rise to the surface quicker during a rainstorm. Thus, a greater quantity of direct runoff is produced from a thin soil layer than from a thick soil layer, under the same set of circumstances.

The same arguments apply to the baseflows, which are the chief components of the dry season low-flows. These flows are produced by the gradual emptying of the reservoir of moisture in the soil. The slowness of this release is due to the resistance of the soil to water movement. At a first approximation, baseflow may be considered proportional to the quantity of water in live storage. Baseflow occurs all year round, including the wet season, during which it is sometimes masked by the much larger quick responses to rainfall. The decay rate of the base flow during the dry-season gives a heuristic indication of the size of the reservoir of water. If there is a large amount of soil in the catchment, then a large groundwater reservoir may exist which can provide sufficient water to maintain the flow in streams throughout the dry season. This reservoir may be in deep soils on the mountain slopes, if they exist, or, more usually, in the deeper layers of soil in the valleys.

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The soil is thus the major internal determinant of the streamflow characteristics of the catchment. Apart from its interception and transpiration, the forest itself influences streamflow mainly by its effects on the soil. The trees protects the soil from erosion in a number of ways and thus preserve the soil moisture reservoir. However, it would be wrong to conclude from this that the forest was essential to the maintenance of streamflow. As long as the soil mantle is maintained and its infiltration characteristics unaltered, it will continue to act as a reservoir. Thus, change of land-use to, for instance, a tea-estate might still preserve the favourable streamflow regime if proper soil conservation measures were maintained (Edwards & Blackie 1981). The critical period is immediately following the clearing of the forest, when the soil is exposed before the alternative cultivation systems become sufficiently established to provide protection. Even crop cultivation may be undertaken in areas where erosion protection measures are feasible. The main difficulty here is to ensure that the proper conservation measures are strictly adopted. In very few areas, the character of the soil may be such that no soil conservation measures are necessary. In one such area, in Mbeya, this was attributed to the highly stable ash-derived soils (Edwards & Blackie 1981). Such cases are the exception, rather than the rule.

A forest transpires at a greater rate than grassland or cultivated land. Because of its normally deeper root-system a forest has access to a greater part of the soil-water reservoir and its transpiration is less inhibited by soil-moisture deficits than grasses or most crops. Thus, in a period of drought, its transpiration continues for a longer time when plants with shorter roots wilt. This means that more water is lost through evapotranspiration from a forest than from any other land-use for a catchment.

The implications of this for water-supply are twofold. First, virtually any other land-use gives a larger total annual yield of water from the catchment than a forest. However, this larger quantity of water is delivered in a much more variable way, more closely related to the temporal distribution of rainfall. If sufficient reservoir storage capacity is available downstream to store the large quantities of water involved, then this greater yield can be utilised. However, if the storage available in the reservoir downstream is not sufficient then large amounts of water are lost over the spillway during the rainy season and the full yield of the catchment is not available for water supply. In this case, there may be an advantage in allowing this water, which would otherwise be lost over the reservoir spillway, to remain in the catchment soil-moisture reservoir. Although evaporation losses from the water surface of a reservoir are always much less than those from the forest catchment supplying it, in this case the quantity of water lost over the reservoir spillway can be much greater than the difference in evapotranspiration losses. Thus, although the forest continually transpires a large quantity of water, a greater amount is actually available for water-supply, because the slower rate at which the remainder is released from the catchment soil-store causes less loss over the spillway of a small reservoir.

Nortcliff & Thornes (1981) suggest that the very rapid response to rainfall of discharge hydrographs in the wet season is due to saturated overland flow on the floodplains and not due to overland flow in the mountain catchment itself. If the upper layers of soil are destroyed by forest clearance, the saturated hydraulic conductivity of the exposed soil may still be large enough to allow all the rainfall to infiltrate. In this case, flood peaks would not be significantly affected by forest clearance. (Their experimental area had average slope angles of 20° and slope lengths of 40 – 60 m.)

Zadroga (1981) quotes reports in FAO (1977) and United States Forest Service (1976) which assert that the 'temporary' increase in streamflow in temperate climates by logging is approximately proportional to the basal area eliminated. This is supported by Hibbert (1967). This probably refers to forest clearing rather than thinning. However Zadroga (1981) says that destruction of montane cloud forests may cause a decrease in yield of water. This is because moisture from the fog, mist or clouds condenses on the surfaces of the leaves and this 'leaf-drip' provided, in his particular case, a significant contribution to yield.

6.2 Erosion effects

The forest protects the soil from erosion in a number of ways. The initial kinetic energy of the rainfall is absorbed by the canopy. However this effect may be mitigated by the larger size of the drops which eventually fall from the canopy. The forest provides a layer of leaf-litter and humus over the bare soil which protects it from the impact of the water drops. The forest maintains this layer and protects it from removal by wind. In addition, the stem-flow diverts a portion of the rainfall to the ground without appreciable impact. The deep rooting system of the trees reinforces the soil structure and, incidentally, increases the infiltration capacity, thereby reducing surface runoff.

Deforestation generally increases the rates of soil erosion. However, if careful anti-erosion measures are employed immediately after deforestation, the effects can be satisfactorally controlled. Blackie (1972) describes the effectiveness of such measures in clearing a forest to produce a tea-plantation. In this case evapotranspiration losses decreased by 13% when the forest was cleared, but, once the tea-shrubs became established, the water-balance returned to its former state.

The increased erosion leads to increased sedimentation in reservoirs downstream of the catchment, and their useful life-times are shortened. It is extremely difficult to predict the sediment inflow into a reservoir from a catchment. Even the best current techniques give only an order of magnitude result and are not reliable. In the case of the Usambaras it is likely that the transport capacity of the streams is quite large and the actual sediment outflow is limited only by the sediment available for transport. Thus any increase in the rate of detachment of soil particles would indeed result in increased sedimentation in the reservoir downstream. Most of the sediment transport takes place during the relatively short periods of very high flows and thus no regular stream sampling procedure will give a true picture of the quantity of sediment removed. There is an added complication in the case of the East Usambaras because of the extensive sediments deposited each year on the banks of the streams in areas of low slopes. When the high flows commence, much of this is carried further downstream and this extra load masks any difference due to land-use changes, making it impossible to associate reliably the changed activity with any change in sediment transport by the major streams. It may be possible, but it would certainly be difficult, to do this for some of the smaller steeper streams, which have no littoral sediment deposits. Rapp (1972) reports on the erosion and reservoir sedimentation problem in Tanzania, but does not consider deforestation.

The nutrient cycle, which in the forest is virtually closed, is disrupted with a net nutrient loss unless the forest is replaced with an alternative cycling system (see Chapter 10).

The increased sediment load in the water damages irrigation works, water intakes, pump impellers and bearings.

Leaf-litter prevents soil detachment by the energy of raindrops. In addition, the layer of humus acts as a filter, preventing the transport of any detached soil particles. Erosion from a typical area of forest near Kwamkoro was found to be negligible.

Leaf-litter prevents soil compaction by raindrops. In certain soils the direct impact of raindrops compacts the soil, forming a harder crust on its surface. This reduces the infiltration capacity of the soil, which is then determined by the rate at which water can penetrate this upper crust. Surface runoff is more likely under these circumstances, with a consequent increase in flood peak and less water entering the soil store. In the forest, the natural leaf-litter protects the soil from the direct impact of the raindrops. On agricultural land, mulch spread in sufficient quantities provides similar protection (Mannering & Meyer 1963).

By concentrating the rainwater into larger drops, the forest canopy may increase the soil detachment and soil compaction effects, unless the soil is protected by the litter. Logging removes this protective layer from the soil, as well as removing the protective canopy. The area affected on the ground is generally much larger than the area of canopy removed. This is because the falling trees and the subsequent processing activities damage a considerably greater area than that of the crown removed.

Leaf-litter increases the total amount of interception losses, since it can hold water, as a layer of wetness and in small pools in the leaves. Although the leaf litter has a field capacity of up to 250% of its weight, the losses are usually only of the order of 5% of the annual rainfall (Helvey 1971). Where

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only selected species are logged the logging rates may not reflect the amount of damage done to the ground surface. Logging rates of 1 in 50 or 1 in 100, if evenly spread throughout the forest would probably not alter the hydrological balance of the catchment. But if these average logging rates were only of a small number of species and these species tended to occupy definite habitats then it is likely that considerable damage may be done in small isolated areas.

Transport of detached material: Detached sediment particles do not leave the catchment unless transported by water. The major distances are traversed in the streams, but it is the short distances which must be travelled by the particles before they enter the streams which are important in this case. The sediment must be carried these short distances by overland flow or raindrop impact. Overland flow is most likely to occur on steep slopes and on the flatter slopes in the valleys where the water-table is higher, near the streams. It is essential that these areas of ground be protected by leaf litter otherwise any material detached from the surface in these areas will eventually be transported to the streams.

Sediment is also produced by the erosion of the banks of streams. The roots of the neighbouring trees protect the bank from this erosion.

6.3 Effects of roads

Heavy machinery compacts the soil and reduces its infiltration capacity. Experiments performed on temporary roads in a logged area near Kwamkoro revealed negligible infiltration, of the order of 10 mm hr^{-1}, through the surface of the road (Inima 1987). Runoff rates from the surfaces of the roads during heavy storms are very high and lead to erosion of the road surfaces. The water collected by the roads discharges into the forest at a small number of outlets, which may, because of the quantity of water involved, initiate gully erosion.

Logging roads open access to the forest to shifting cultivators. This is not a direct hydrological effect, but the consequences of uncontrolled cultivation without soil conservation measures may be serious.

Unpaved roads, with their exposed soil and lack of proper drainage, become a prime source of sediment. The surface of the roads and their embankments are subjected to the direct impact of raindrops, either from the sky or from the canopy. This loosens the soil particles and makes them available for transport.

By collecting water from the slopes above it, and discharging this at a small number of locations, roads act as collectors and may produce gully erosion downslope. Even roads built along contour lines collect water from the catchment areas above them and discharge it at a fixed outlet. These outlets may become the focus for erosion because of the high discharge rates. Gullies may be eroded downslope of these outlets, even though this would not have occurred in the absence of the roads. The roads behave as drains, collecting water seeping harmlessly through the subsoil, which, once brought to the surface, regains the power to erode and transport material. The cumulative effect is to quicken the response time of the catchment which results in earlier and greater flood peaks. It also reduces the amount of water which percolates into the soil to recharge the groundwater and this reduces the dry-season low flows.

6.4 Stability of slopes

Landslides and mudflows may occur on steep slopes, especially during periods of extremely heavy rainfall. Temple & Rapp (1972) report that, in theUluguru mountains, these occur with much greater frequency in cleared and cultivated areas than in forest and woodland. Bishop and Stevens (1964) report that the number and area of shallow landslides increased over fourfold within ten years of clear-cutting in the United States.

The factors affecting the stability of the soil on hillslopes are:

- slope gradient
- slope shape
- properties of the soils

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- amount of soil water
- amount of subsurface flow
- evapotranspiration, in so far as it affects soil moisture
- vegetation.

The last five of these are usually altered when the land-use is changed. Slope failure is generally associated with a rise in pore water pressure in the soil as its moisture content increases during rain. Shallow, rapid slides are associated with single, but very intense, rainstorms, especially when the soil is already wet before the storm begins. Slower and deeper soil movements are associated with prolonged periods of wet conditions. The rooting systems of vegetation, especially of trees, reinforce the soil and resist movement, in addition to reducing soil moisture by improving the drainage and by transpiration. It has been established that a substantial increase in landslides and mud flows generally follows within ten to fifteen years after clearfelling. Meghan *et al.* (1978), cited by Sidle *et al.* (1985), suggest that, for partial removal of trees, few additional landslides occur until more than 90% of the crown cover has been removed. This is probably because, for removal figures less than this, the rooting systems of the developing understory at least partially compensate for the loss of the roots of the original trees. As the roots of cut trees take a number of years to decay and lose their strength, the understory has time to develop before its protection is required.

A number of studies indicate an increase in landslide frequency where forest on hillslopes is converted to pasture. A greater number of landslides were reported, during a very intense rainstorm, in a tea plantation than in an adjacent forest (Starkel 1972).

7. Identification of critical areas

For the purposes of this report, a critical area is one which provides a significant contribution to the water flowing in the Sigi River and which is especially vulnerable. Critical areas are determined using two separate criteria.

7.1 Areas susceptible to soil erosion

The soil provides the primary reservoir which stores water from rainfall and releases it slowly to the streams. It follows that as large a soil reservoir as possible is desirable. The size of this reservoir is reduced by soil erosion, which not only removes a quantity of the soil, but also, by the creation of gullies, allows a larger quantity of water to run off directly to the streams, effectively by-passing the soil reservoir and its moderating influence.

The factors which influence erosion are given in the Universal Soil Loss Equation, above. Soil conditions are fairly uniform throughout the East Usambaras and thus the K value in this equation remains constant. The factors C, P and, to a certain extent, R, can be changed by development or other forms of management of the area. This leaves the topological variables of slope length, L, and steepness, S. These are the only important soil erosion influences which are effectively outside the control of a management plan, which must therefore take them into account.

The steeper the slopes, the greater the amounts of surface runoff and thus of detachment and transport of soil particles. The detailed contour maps of the region allow areas of steep slope to be readily identified (Fig. 15.2). The area to the south-west of Amani village requires a special mention. Although, on a map with large contour intervals, this area appears to be a plateau, the detailed contour maps reveal that the area consists of steep-sided hills and valleys and thus is included in the critical region.

7.2 Areas with large contributions to soil-moisture storage

The simplest way to identify most of the areas with large effective soil-moisture reservoirs is to map the catchments of the perennial streams. A perennial stream is an uncontestable indication of a valuable soil-moisture reservoir. These areas are easily identified on a large scale map. However, not all of these

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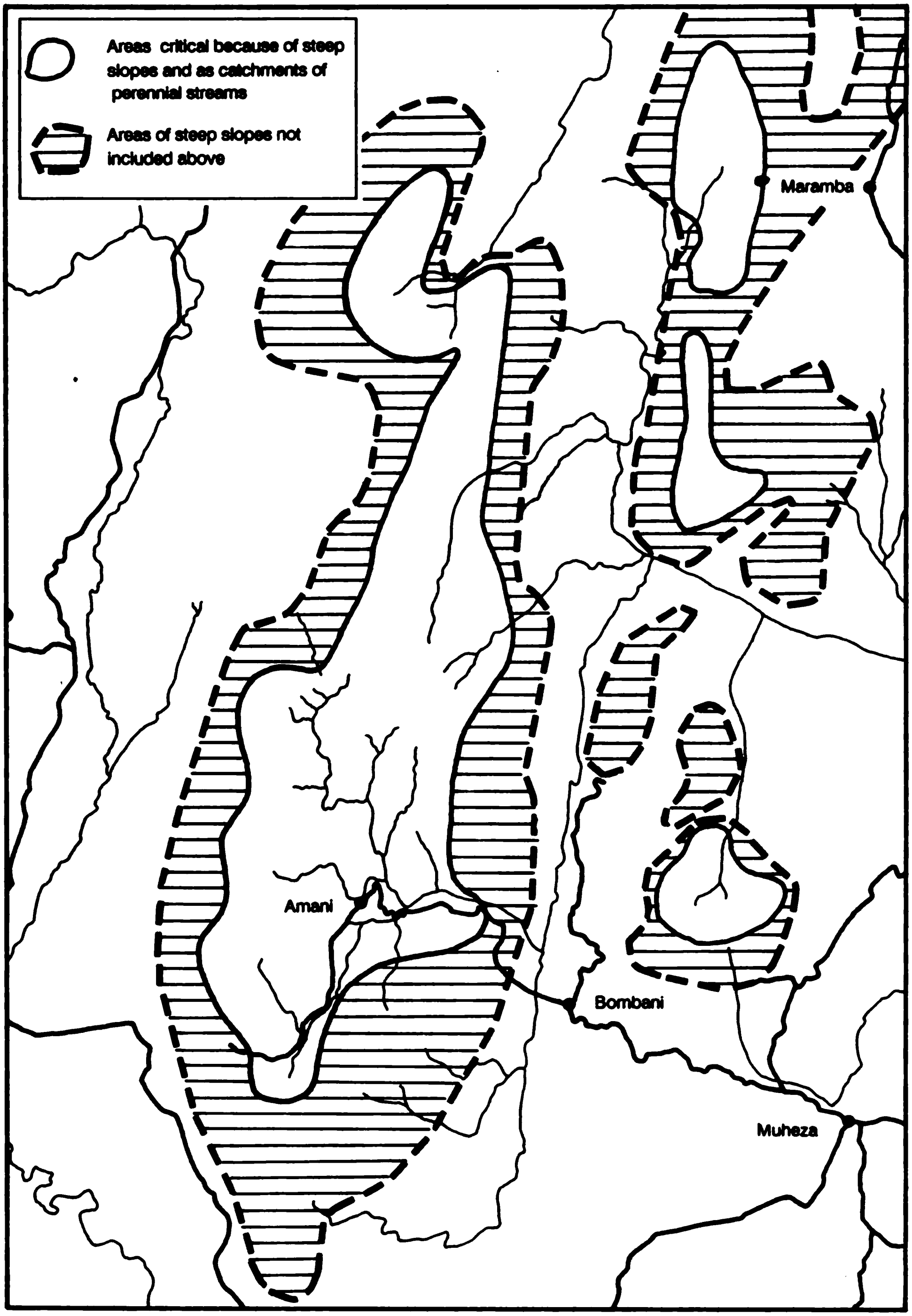

Figure 15.2 Critical catchment areas on the East Usambaras.

reservoirs are seriously threatened by land-use changes. Areas of low slope and low rainfall are unlikely to be seriously threatened by soil erosion, although gully formation in areas of serious mismanagement could still allow much water to by-pass the soil reservoir. Since rainfall amounts are strongly correlated with altitude, low-lying, gentle-sloped areas are not considered to be critical. The critical areas are the soils of the steep-sloped catchments feeding the major tributaries of the Sigi (Fig. 15.2).

7.3 Most vulnerable areas

Care must always be taken, in any development plan, to minimise soil erosion and the following areas are particularly vulnerable.

The most critical areas are those which are identified as vulnerable under both the above criteria. On the map (Fig. 15.2) these can be seen to include much of the central area of the East Usambaras and a small part of Mtai mountain. These are the areas where soil erosion, if it is allowed, will have the greatest effect on the flows in the Sigi River and thus on the Tanga Town water supply. Surrounding the most critical areas is a band of land which is vulnerable because of steep slopes. Care is still necessary if this area is developed. The widest parts of this band are around the southern slopes of the mountain, because of the steepness of the escarpment and the higher average rainfall.

8. Data analysis

In the preceding sections are described the hydrological processes operating in a forest catchment and how they are influenced by changes in land-use. Such changes have occurred in the West Usambaras and the Ulugurus. However, the East Usambara forests have not yet been reduced to the same extent, and the expected changes in hydrological regime may still be slight. In this section, the available data on rainfall in the East Usambaras and discharge in the Sigi river are examined to see if significant changes in behaviour have occurred. The discharge measurements in the Sigi are especially important here, but unfortunately values are available only since 1957, so that changes in behaviour which occurred before that time cannot be inferred from the analysis.

8.1 Double mass-curve analysis

The double mass-curve is a useful technique for checking the constancy of a relationship between two quantities, both of which vary with time. A time-series of values for each quantity is required. From each of these a time-series of cumulative values of each quantity is calculated and a graph of the corresponding cumulative values is drawn. If there is a linear relationship between the variables then the resulting curve is a straight line.

In the present study, such a relationship is sought between total monthly (or annual) rainfall and the total volume of water in the Sigi passing through Lanzoni. If a relatively constant proportion of the rain falling in the Usambara catchments eventually reaches Lanzoni then a double mass curve of discharge volume versus rainfall volume should be essentially a straight line. Seasonal variations are expected in the proportion of runoff and these appear as fluctuations in the graph about the general straight-line trend.

The double mass-curve relating rainfall at Amani with discharge in the Sigi, Fig. 15.3, shows the straight line trend for much of its length. The initial portion of the graph is almost a straight line, while the later part shows greater fluctuations. But, as these are fluctuations about the same trend line, there is no reason to infer a change in the relationship between rainfall in Amani and discharge in the Sigi.

However, the double-mass curve relating rainfall at Marvera with discharge in the Sigi, Fig. 15.4, does show a change in behaviour. An average straight line, drawn through the initial portion of the graph has quite a difference in slope from an average line drawn through the final portion of the graph. The change in general slope of the relationship suggests an increase in the fraction of the rainfall at Marvera which reaches the Sigi. This could be caused by an increase in direct runoff and/or by an expanding drainage network, either of ditches in cultivated land or of eroded gullies.

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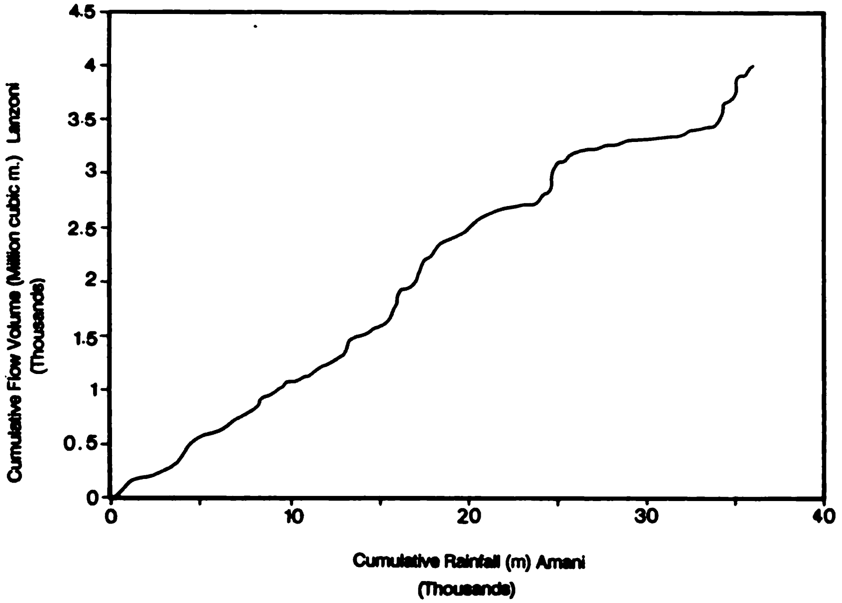

Figure 15.3 Double mass-curve analysis relating flow volume of the Sigi River at Lanzoni with rainfall at Amani.

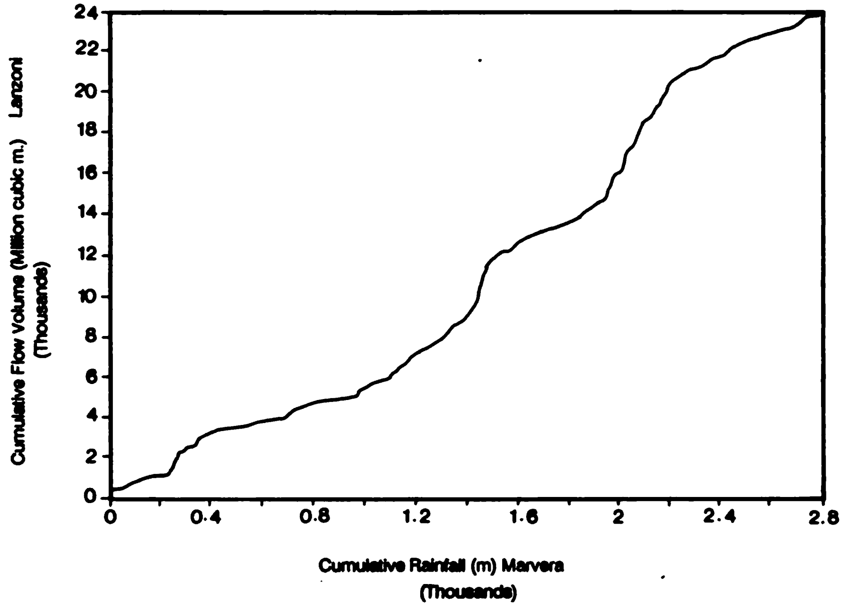

Figure 15.4 Double mass-curve analysis relating flow volume of the Sigi River at Lanzoni with rainfall at Marvera.

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This apparent increase in runoff from Marvera does not necessarily imply that more water can be extracted from the Sigi throughout the year. The extra water is available in the rainy season only and, unless a dam stores this extra water for use in the dry season, it is wasted as floods in the Sigi. The increase in runoff means that a smaller proportion of the rain percolates into the soil-moisture store and the dry-season flows are likely to be decreased. The net result is a lower usable all-year-round supply from the Sigi, unless a reservoir of sufficient capacity to store all the flood flows is constructed.

Ideally, the double mass curves should cover as long a period as possible. However, discharge values are available for the Sigi only from 1957 onwards and rainfall values after 1980 are not so reliable. This limits the period for which the curves can be drawn. The results presented here show no change in the relationship between rainfall at Amani and Sigi discharge, but do suggest a change in the relationship between rainfall at Marvera and discharge in the Sigi. It is quite likely that some parts of the Sigi catchment have experienced more development than others and that the hydrology of these parts only has been noticeably affected.

8.2 Analysis of recession curves

8.2.1. Background

The response of a catchment to a rainfall event can, for convenience, be divided into two distinct periods. In the first period, the catchment receives rainwater and the discharge in its rivers usually increases, forming the rising limb of the flood hydrograph. The second period begins when the rainfall ceases and all further discharges in the river are due to the 'drying out' of water already received by the catchment. A graph of the decreasing discharge versus time in this second period is called a recession curve.

The recession curve itself can be considered to have a number of components. In the period immediately following the cessation of rainfall some of the direct runoff still flows to the rivers. The mechanism here is still surface runoff and shallow subsurface flow. However, this source of water is quickly depleted and the hydrograph decreases relatively rapidly. Thereafter, in the absence of further rainfall, much of the water flowing in the river comes from the draining of moisture which had infiltrated into the soil during the rainstorm or which remained in the soil after previous storms. This subsurface reservoir of water can be very extensive and drains comparatively slowly. Thus the discharge hydrograph flattens and eventually becomes the base-flow curve.

The first part of the flood hydrograph depends very much on the intensity and distribution of the rainfall as well as on properties of the catchment. However the second, lower, part of the recession curve, representing water draining from the soil, depends mainly on properties of the catchment only and on the quantities of moisture infiltrated into the soil. Its shape does not depend directly on the characteristics of the rainfall. In many cases, the lower parts of the recession curve may be adequately modelled by an exponential decay curve:

$$y(t) = y(0).\exp(-t/k) \tag{2}$$

(where $y(t)$ = the discharge at time t, $y(0)$ = the initial discharge, when $t = 0$, k is a decay constant)

This corresponds to the behaviour of an idealised linear reservoir. In this case the curve can be characterised by two parameters, its initial value, $y(0)$, and a decay constant, k. The former should depend on the quantity of moisture in the soil, while the latter should depend only on properties of soil and its drainage. Some authors consider the recession to be composed of a number of different exponential decays, each with a different decay constant (Raudkivi 1979). The earlier parts of the recession are still influenced by drainage of surface water and have larger decay constants, but the later parts are determined by drainage from the soil alone and have lower decay constants.

Changes in the size of the soil-moisture store or in the effectiveness of the channels which drain it should cause changes in the character of the recessions in the discharge hydrograph. The records of discharge for the Sigi River were examined to see if such changes could be detected.

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8.2.2 Method

The method was as follows.

Records of daily mean discharge in the Sigi River at Lanzoni were examined and the recession periods noted.

Rainfall records for the stations, Amani, Kwamkoro, Marikitanda, Marvera and Ndola, were examined to determine if rain fell in the catchment during each of these recessions. If a significant quantity of rain was measured at any of these stations during a particular recession then that recession was eliminated from the analysis. The additional rain would have added to the discharge in the river and flattened the natural recession.

For the remaining 'true' recessions, the natural logarithm of the discharge was plotted as a function of time. If the recession is given by Equation 2, above, then taking logarithms of both sides gives:

$$\log(y(t)) = \log(y(0)) - t/k \qquad (3)$$

This indicates a straight-line relationship between the logarithm of discharge and time. The slope of the line is the inverse of the reservoir decay constant.

8.2.3 Results

The selected Sigi recessions for the year 1970 are shown in Fig. 15.5a. The recessions vary in duration from four to seven days. The starting dates of each recessions are 3rd February, 25th February, 27th May, 17th June and 22nd October. The latter parts of each curve are straight and have similar slopes, i.e. they are parallel to each other. The average slope is approximately 0.05. The steepness of the early part of some of the curves is due to the influence of the direct runoff from the rainstorms.

Selected recessions for the years 1981/1982 are shown in Fig. 15.5b. The starting dates are 8th January 1981, 3rd February 1981, 26th October 1981, 12th February 1982, 15th July 1982 and 29th July 1982. Again the latter parts of the curves are straight lines and are parallel to each other. The average slope for this period is 0.06, indicating a slight increase in steepness during the decade from 1970.

To check this apparent steepening, some recessions for the period 1957 to 1959 were analysed in the same way. The starting dates were 15th October 1957, 21st September 1957, 5th May 1958, 14th July 1958, 21st March 1959, and 24th August 1959. Daily rainfall data were not available for that period so that the recessions could not be properly screened. However the results (Fig. 15.7), show the expected parallel structure with an average slope of approximately 0.06. Thus, despite the 0.05 slope value for 1970, no great change has occurred in the character of the Sigi recessions within the period 1957 to 1981.

Over the whole catchment, the capacities of the effective soil water reservoir and of the channel network draining the soil has not changed sufficiently to alter the character of recession flows in the Sigi.

No daily discharge data are available for the Sigi prior to 1957, so this analysis cannot determine if the recession characteristics changed before then.

8.3 Analysis of catchment lag times

The time lag between the centre of mass of the effective rainfall series and the direct runoff series for a storm indicates the average response time of the catchment. If the hydrological characteristics of the catchment change, a corresponding change should occur in this value. Data for the Sigi catchment were examined to determine if such changes could be detected. The time lag can be examined in a number of ways:

- Unit Hydrographs are derived for a number of different rainstorms over a long period of time and are examined for systematic changes in character. Unit Hydrograph estimation is

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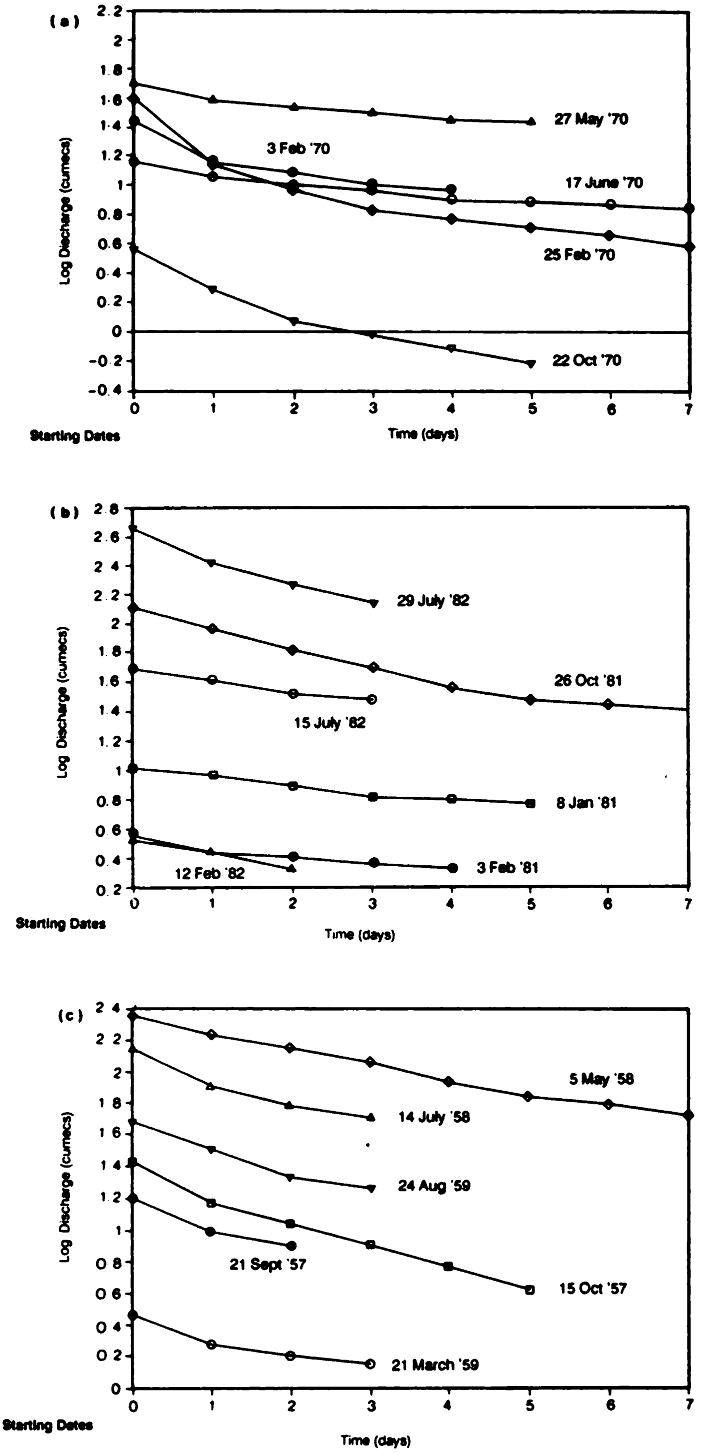

Figure 15.5 Sigi River recession curves for (a)1970, (b)1981–82 and (c)1957–59.

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inherently a numerically unstable procedure, but, if stable UH's can be derived, they give information on the lag and on recessions as well. Inima (1987) derived a number of UH's over the period 1970 to 1980 and reports a small decrease in lag time.

- Catchment lag may also be examined by comparing the statistical moments of the effective rainfall and direct runoff time-series. A preliminary analysis of this type indicates that the lag of the Sigi catchment varies from less than a day (0.7 day) to slightly over a day (1.2 days) and is related to pre-rainstorm river discharge, which is an indicator of catchment wetness. With this magnitude of inherent variation, it is difficult to isolate an effect of smaller magnitude.

In order to detect reliably changes in this lag, measurements of rainfall and discharge at time-intervals considerably less than the catchment lag are required. In the case of the Sigi, this would mean measurements should be taken every 2 or 3 hours. Unfortunately, this type of data is not yet available.

9. Conclusions

This report is a qualitative description of the processes which influence the hydrology of forest catchments and how they may be affected by changes in land-use practices. Little attempt is made to put absolute values on the amounts of erosion to be expected under various types of development. The variety of conditions obtained in the Usambaras and the wide choice of development options would make this an extremely arduous task and the results, given the current state of knowledge on soil erosion, would be at best of order of magnitude accuracy only. The approach adopted here is rather to rank the various parts of the Usambaras into areas which are more vulnerable or less vulnerable. It is a simple but effective approach. The figures shown here indicate three different types of regions: those which are not vulnerable under either of the criteria used, those which are vulnerable under one criterion only and those which are vulnerable under both criteria. It stands to reason that, while great care should always be taken in any development, the greatest care should be taken in altering conditions in the most vulnerable regions. Therefore the recommendations are as follows.

10. Recommendations

- If development of any sort is to occur, it should begin in the areas designated here as least vulnerable.
- The effects of the development in these areas should be continuously monitored in order to detect problems before they become too serious and to develop models which can be used to predict more accurately the possible effects of development of the more vulnerable areas. Measurements of rainfall and discharges are required at 2 to 3 hourly intervals for adequate detection of catchment changes.
- Although no major change in the hydrology of the Sigi catchment could be detected in the analysis of the available daily data, some evidence of a disturbance in part of the catchment could be discerned in the mass-curve analysis.
- Only when the effects of the development of the more vulnerable areas can be predicted more accurately, should such development be allowed to proceed, with continuous monitoring of the results.
- Management of any development should have the authority, resources and commitment to modify the course of the development to take account of adverse effects as they are detected.

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Appendix 15.1 Formulae for throughfall and stemflow for some American Pines, from Helvey (1971).

Species	Throughfall (inches)	Stemflow (inches)
Red Pine	0.87P - 0.04	0.02P
Loblolly Pine	0.80P - 0.01	0.08P - 0.02
Shortleaf Pine	0.88P - 0.05	0.03P
Ponderosa Pine	0.89P - 0.05	0.04P - 0.01
Eastern White Pine	0.85P - 0.04	0.06P - 0.01
Spruce-Fir-Hemlock	0.77P - 0.05	0.02P

Where P is the total areal precipitation expressed in inches.
Precipitation which fails to reach the ground as throughfall or stemflow is regarded as interception.

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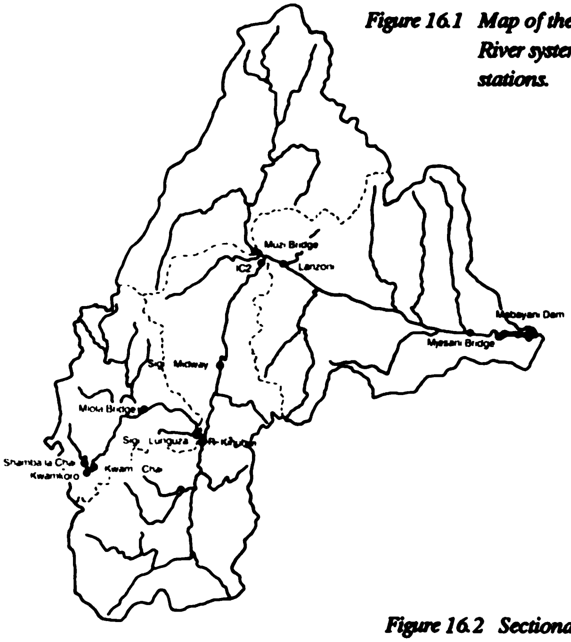
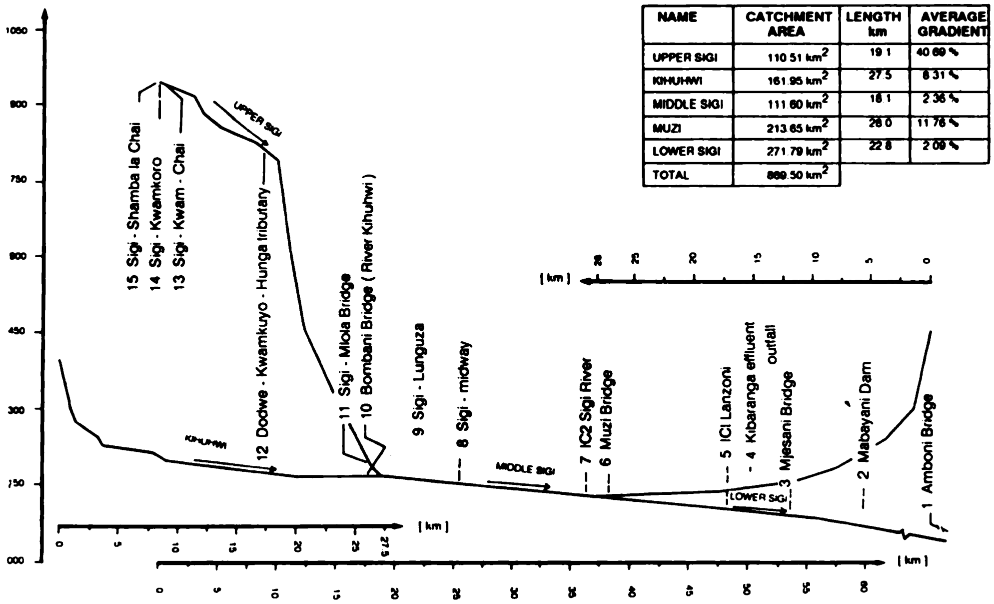


Figure 16.1 Map of the drainage basin of the Sigi River system, showing location of sample stations.

Figure 16.2 Sectional elevation through the Sigi River system, showing location of sample stations



NAME	CATCHMENT AREA	LENGTH km	AVERAGE GRADIENT
UPPER SIGI	110.51 km²	19.1	40.69 %
KIHUHWI	161.95 km²	27.5	8.31 %
MIDDLE SIGI	111.60 km²	18.1	2.36 %
MUZI	213.65 km²	26.0	11.76 %
LOWER SIGI	271.79 km²	22.8	2.09 %
TOTAL	869.50 km²		

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16. Assessment of Water Quality of the Sigi River

by Malcolm Litterick

The catchment of the Sigi River is described and threats to water quality assessed. It is concluded that forest clearance on the East Usambaras will have only marginal effect on water quality,but that rehabilitation of the run-down sisal estates in the Sigi catchment is likely to result in serious problems. The sisal estates could usefully be converted to forest plantations.

1. Catchment area description

1.1 Area and topography

The Sigi River catchment lies between latitudes 4°48'S and 5°15'S and longitudes 38°34'E and 39°03'E in north-eastern Tanzania (Fig. 16.1). The river is perennial, rising in the East Usambara Mountains at an elevation of about 920 m above sea level. It has two primary branches, the Sigi which flows initially eastward and then northward and the Muzi which flows southward. After their confluence, the combined Sigi flows eastward out of the Usambaras near Lanzoni, and onward to the sea.

Approximately 22 km below the Sigi-Muzi confluence a dam was constructed at Mabayani in the late 1970's to provide water storage for abstraction and supply of potable water to the coastal town of Tanga. Prior to this time the town had been able to draw adequate supplies of water from boreholes, but growth of the town's population and industry exceeded the borehole capacity leading to the need for a reservoir and a growing dependence upon the Sigi River. Today Tanga is totally dependent upon supplies from Mabayani Dam.

The total catchment area of the Sigi is approximately 1,100 km^2 and that above the dam about 900 km^2 The upper catchment is mountainous to steep and the lower catchment hilly to undulating. The main water course has a generally moderate to low gradient falling through 950 m along its 70 km length to the sea. The upper 15 km of the Sigi above Longuza is steep and torrential.

A sectional elevation through the sub-catchments, together with details of length, gradient and area of river segments and location of the sampling stations, is presented in Fig. 16.2.

1.2 Geology and soils

The upper and middle Sigi catchments comprise metamorphic rocks of the Usagaran System that have been extensively migmatised and consist of pyroxene and hornblende granulites and gneisses. The Eastern and Western Usambara mountains are separated by a graben valley, the main tectonic direction of faulting trending north-north-east to south-south-west. The soils of the upper and middle

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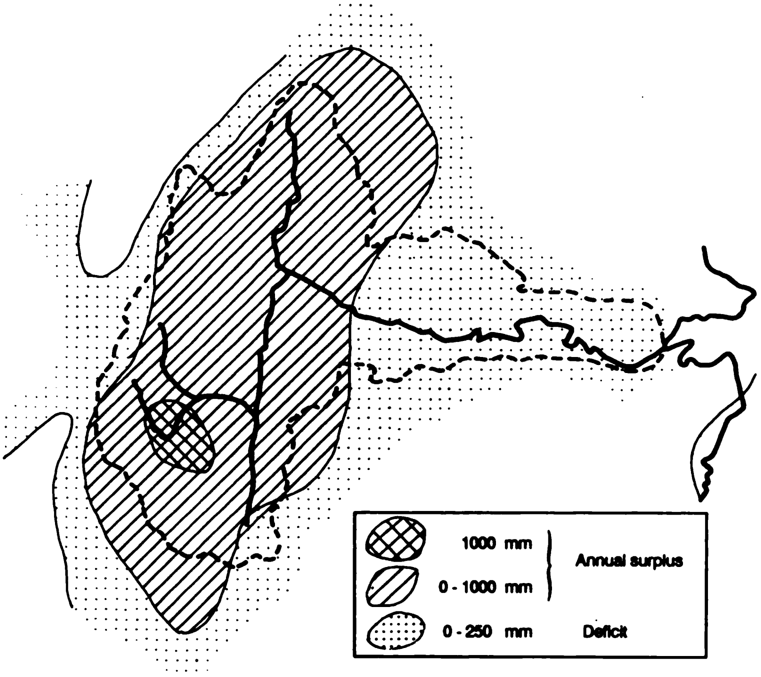

Figure 16.3 Map of the average annual evaporation deficit in the Sigi catchment.

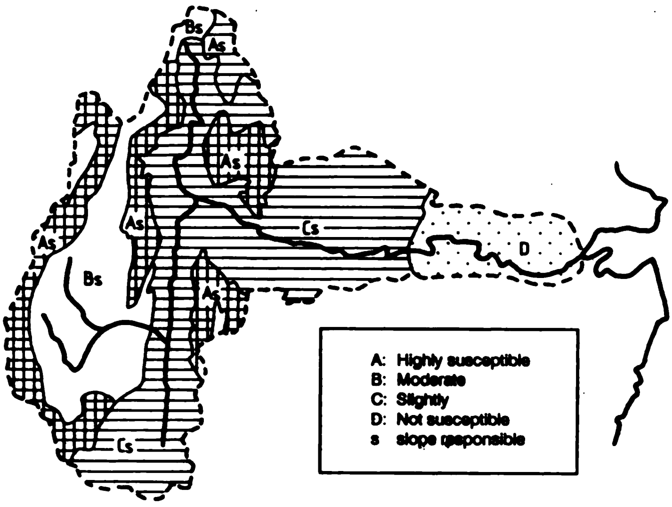

Figure 16.4 The distribution of erosion hazard in the Sigi catchment.

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Sigi catchment are well drained, deep to moderately deep, red and yellowish red clays, sandy loams and clays (Chapter 10). Topsoils contain moderate amounts of organic matter.

Geologically, the lower Sigi catchment is made up of a sedimentary succession of rocks from Karroo to Quaternary in age, that form a sequence of sandstones and shales giving way to Jurassic marine marls and Tanga limestones. The older Neogene coastal sediments consist of sands, gravels and fossiliferous rubbly limestones, whilst younger Neogene sediments consist mainly of raised coral reef deposits. The overlying soils are well to moderately drained, deep greyish brown sands with loamy subsoils often overlying impermeable mudstone.

1.3 Rainfall and evaporation

An isohyetal map (Fig. 11.3) indicates that the annual rainfall across the catchment shows a marked variation, but on average varies around 1,200 mm at the coast, reduces to about 1,000 mm per year some 20 – 25 km inland then rises rapidly to approximately 2,000 mm per year over the southern end of the East Usambaras around Amani and including the headwaters of the Sigi.

During a dry year with a probability of non-exceedance of 10% the lower catchment can be expected to receive between 600 mm and 800 mm of rain during the year rising steeply to about 1,400 mm around Amani. At a similar return period, during the three driest consecutive months the rainfall would be expected to vary from about 20 mm at the coast to 70 mm in the foothills of the East Usambaras, rising to about 120 mm at Amani.

In the lower 30 km of the Sigi evaporation exceeds precipitation by between 0 and 250 mm per annum in an average year (Fig. 16.3). In a 20% dry year this same area experiences an evaporation deficit of 250 to 750 mm but the hazard of meteorological drought is stated to be low by GTZ (1976).

1.4 Vegetation and land-use

Vegetation cover in the catchment varies from good to excellent. The catchment has been considered to have a varied potential for erosion, varying from highly susceptible (on steep slopes) to only slightly susceptible (Fig.16.4).

In the upper catchment of the Sigi within the Usambara mountains, vegetation comprises dense forest interspersed with tea plantations and areas of traditional cultivation (Fig. 16.5). These give way progressively down slope to sisal plantations, dry savanna bush, grazing land and eventually to coconut palms along the coastal strip.

Because of the depressed state of the sisal industry many of the estate areas have been abandoned or are only subject to intermittent cropping and natural savanna vegetation is returning to such areas, providing good ground cover. Active sisal production of low intensity is now confined to the lower Sigi catchment and to small areas in the Kihuhwi River catchment.

2. Water quality

2.1 Introduction

Water quality is determined by the nature and quantities of materials dissolved and suspended in it. There is no pure water in nature and therefore no absolute definition of 'good quality'. The assessed quality of the water is dependent upon the requirements of the end user and the purposes for which the water is needed.

Four factors are important in determining the chemistry (or salinity) of the water draining from a catchment. These are:

- **Parent rock type:** The gradual weathering of the parent rock provides elements directly to the run-off water. Generally streams draining upland regions, where hard igneous and metamorphic rocks frequently predominate, have a water chemistry similar to that of the local rainfall, since these hard rocks are resistant to weathering and erosion and contribute

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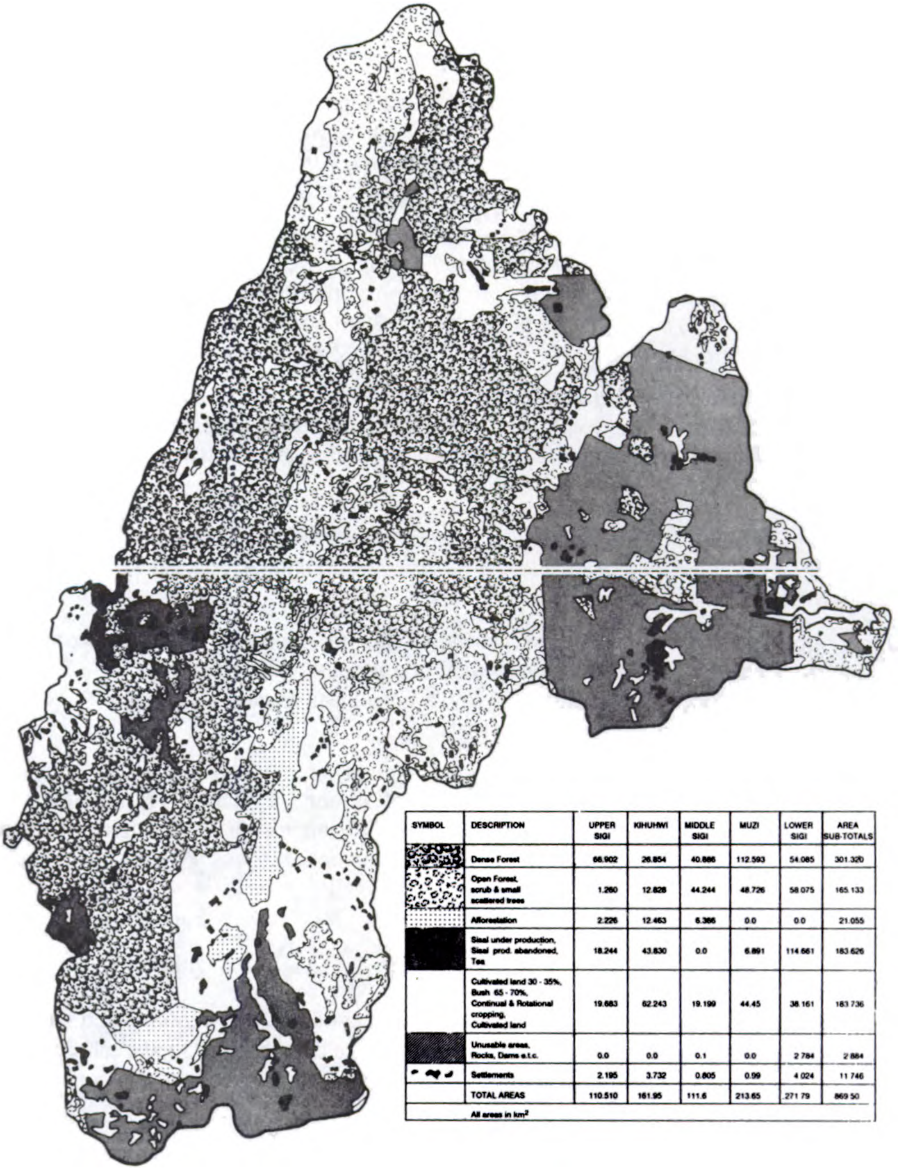

SYMBOL	DESCRIPTION	UPPER SIGI	KIHUHWI	MIDDLE SIGI	MUZI	LOWER SIGI	AREA SUB-TOTALS
▩	Dense Forest	66.902	26.854	40.886	112.593	54.085	301.320
▒	Open Forest, scrub & small scattered trees	1.260	12.828	44.244	48.726	58.075	165.133
░	Afforestation	2.226	12.463	6.366	0.0	0.0	21.055
■	Sisal under production, Sisal prod. abandoned, Tea	18.244	43.830	0.0	6.891	114.661	183.626
□	Cultivated land 30 - 35%, Bush 65 - 70%, Continual & Rotational cropping, Cultivated land	19.683	62.243	19.199	44.45	38.161	183.736
▨	Unusable areas, Rocks, Dams e.t.c.	0.0	0.0	0.1	0.0	2.784	2.884
●	Settlements	2.195	3.732	0.805	0.99	4.024	11.746
	TOTAL AREAS	110.510	161.95	111.6	213.65	271.79	869.50
	All areas in km²						

Figure 16.5 Vegetation and land-use of the Sigi River catchment. Information from GTZ (1976).

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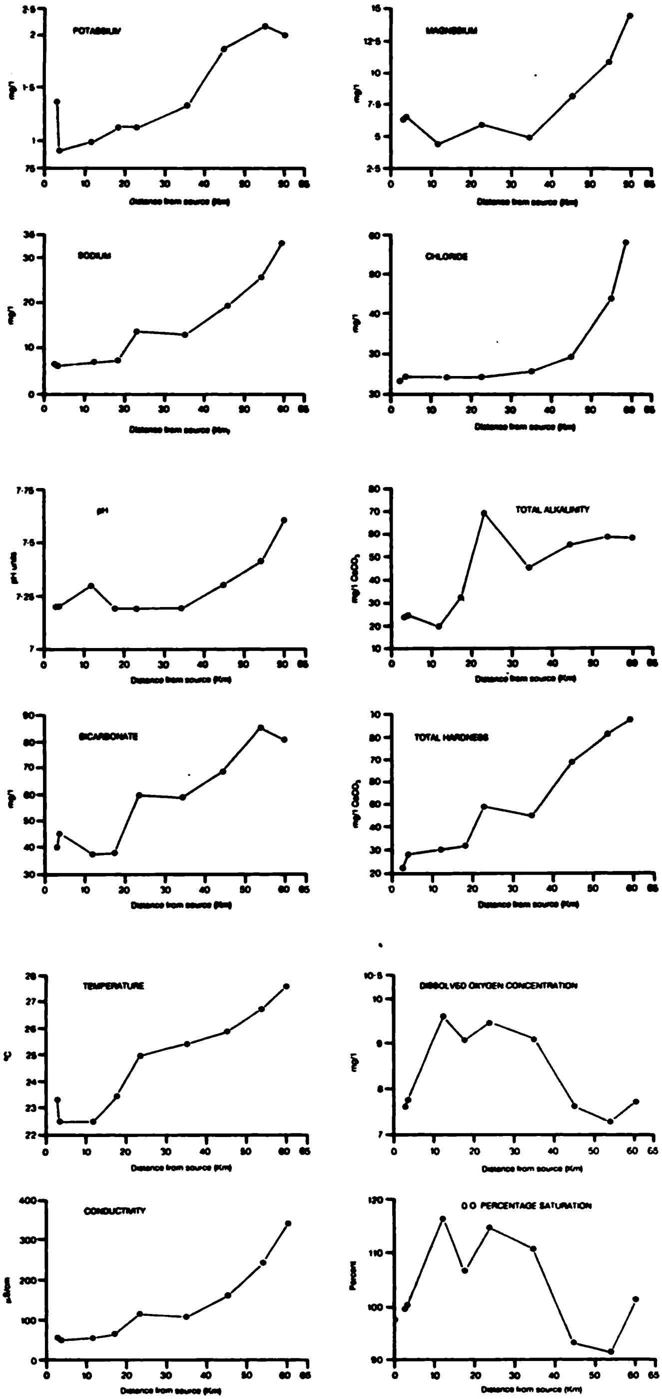

Figure 16.6 The Sigi River transect: Physical and chemical parameters.

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few ions to the water. In consequence the run-off is ionically poor (with low electrical conductivity, usually less than 50 microS/cm) and is characteristically soft i.e. low in calcium and magnesium salts. Sedimentary rocks, in contrast, are usually more easily weathered and more soluble, producing drainage water high in dissolved materials. The water is frequently hard, being rich in calcium and magnesium salts.

- **Climate:** Climate strongly influences the rate of weathering and dissolution of minerals from the parent rock. Extreme fluctuations in temperature speed weathering by cracking rocks and changing soil conditions. The balance between rainfall and evaporation affects the overall ionic concentration and chemical composition by sequential precipitation of salts as concentration increases. Rainfall is a significant source of ions in many areas especially to waters of low ionic concentration and to those in coastal regions where salts from sea-spray are carried inland and precipitated. Rainfall is also a primary agent of rock and soil erosion and thus further responsible for the transportation of material into water bodies. Areas with abundant rainfall are also usually well vegetated and the cover thus provided influences water chemistry as described below. In more arid areas, dry precipitation of dust particles can contribute significantly to the mineral content of inland waters.
- **Topography:** The degree of slope or steepness of the land controls the stability of the site and regulates both erosion and the exposure of soil and rock to the water passing over it. With steeper slopes, run-off is faster, erosion is greater, more suspended eroded material is transported, infiltration is reduced and there is decreased duration of contact between the water and the substrate, lessening the quantities of materials going into solution.
- **Vegetation cover:** Vegetation protects the soil from erosion by providing a physical barrier to the force of the rain-drop impact and by binding the soil with its rooting system. Fallen plant debris supplies nutrients to the soils and helps to maintain soil fertility. Forests provide particularly efficient protection, especially in steep mountainous areas and are important conservators of nutrients. Frequently, when forests or individual trees are removed using modern highly mechanized equipment which require the construction of access roads, the harvest of timber may also lead to very high yields of sediment and dissolved nutrients. These represent losses of fertility and topsoil from the forest and are a potential source of pollution to the water courses in the drainage basin.

2.2 The Sigi River Catchment Study 1984–85: introduction

From March 1984 through June 1985, the Sigi River, its principal tributaries and Mabayani Dam were studied (Anon. 1986). Samples were collected from 15 stations at approximately two-weekly intervals and analysed to provide baseline data on water quality throughout the entire catchment. Selected data from this earlier study are presented here to highlight conditions within the Sigi River and Mabayani Dam in relation to land-use activities in the catchment, especially logging and sisal decortication.

The key issue in question here is whether present land-use practices in the catchment, or any others currently under consideration, will in the foreseeable future render the Mabayani reservoir unusable as a source of raw water for treatment and supply to Tanga Town.

2.3 The Sigi River Catchment Study 1984–85: the present situation

2.3.1 Physical and chemical parameters

To illustrate the longitudinal changes which occur in water quality in the Sigi River, nine stations along the main channel from the upland region around Amani to Mabayani Dam have been analysed. The transect data are presented in Table 16.1 and selected parameters shown in Fig. 16.6. The locations of the sampling stations are given on Fig. 16.1.These same data have been regrouped in Table 16.2 to enable comparisons to be made between the six main components of the Sigi system, namely the upper, middle and lower Sigi River sections, the Kihuhwi River, the Muzi River and Mabayani Dam.

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Table 16.1 The Sigi River transect: longitudinal variation in physico-chemical parameters along the Sigi River.

Station number	02	03	05	07	08	09	11	12	13	14
Temperature (^oC)	27.6	26.8	25.9	25.4	25.0	23.5	22.5	22.4	22.5	23.4
Conductivity ($\mu S/cm$)	347.0	244.0	160.0	109.0	114.0	66.0	59.0	73.0	50.0	54.0
pH	7.6	7.4	7.3	7.2	7.2	7.2	7.3	7.2	7.2	7.2
Dissolved oxygen (mg/l)	7.7	7.3	7.6	9.1	9.5	9.1	9.6	8.5	7.8	7.6
D.O. % saturation	101.5	91.3	93.4	110.9	115.0	107.1	116.6	106.0	100.5	99.6
Alkalinity-total (mg/l $CaCO_3$)	58.6	59.1	54.9	45.7	69.0	32.6	19.9	28.7	23.1	24.0
Hardness-total (mg/l $CaCO_3$)	87.1	80.6	68.3	46.4	50.0	32.0	30.5	30.0	28.7	22.0
Bicarbonate (mg/l)	81.0	85.4	69.3	59.3	59.8	37.7	37.6	47.8	45.5	40.3
Chloride (mg/l)	58.6	43.6	29.5	24.2	23.4	19.1	19.1	20.5	23.2	21.6
Magnesium (mg/l)	14.4	10.8	8.0	5.0	6.0	5.1	4.5	4.1	6.2	6.1
Potassium (mg/l)	2.0	2.1	1.9	1.3	1.1	1.1	1.0	1.3	0.9	1.3
Sodium (mg/l)	33.2	25.4	18.8	12.1	12.9	6.2	5.8	6.2	5.5	5.9

D.O. = dissolved oxygen

Table 16.2 A summary of physico-chemical characteristics of the Sigi River subcatchment.

	Upper Sigi	Kihuhwi River	Middle Sigi	Muzi River	Lower Sigi	Mabayani Dam
Temperature (^oC)	23.4	26.2	25.4	26.3	26.4	27.6
Conductivity ($\mu S/cm$)	54.0	197.3	109.4	285.2	202.1	347.0
pH	7.2	7.0	7.2	7.2	7.4	7.6
Dissolved oxygen (mg/l)	7.6	7.8	9.1	8.2	7.5	7.7
D.O. % saturation	99.6	96.4	110.9	101.6	92.4	101.5
Alkalinity-total (mg/l $CaCO_3$)	24.0	73.4	45.7	88.7	57.0	58.6
Hardness-total (mg/l $CaCO_3$)	22.0	70.4	46.4	95.7	74.5	87.1
Bicarbonate (mg/l)	40.3	95.4	59.3	82.8	77.4	81.0
Chloride (mg/l)	21.6	30.7	24.2	43.5	36.5	58.6
Magnesium (mg/l)	6.1	10.2	5.0	13.0	9.4	14.4
Potassium (mg/l)	1.3	1.9	1.3	2.3	2.0	2.0
Sodium (mg/l)	5.9	19.8	12.1	20.7	22.1	33.2

Upper Sigi = Stations 9, 11-14 Kihuhwi River = Station 10
Middle Sigi = Station 7 Muzi River = Station 6
Lower Sigi = Stations 3,5 Mabayani Dam = Station 2

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The water flowing out of the upper Sigi catchment is ionically very dilute, indicating little loss of ions from, or addition of ions by the terrestrial component of the habitat. The present study has also shown that ionic input from rainfall is very low (Table 16.3). Although for logistical reasons, nutrients were not monitored in the previous study, they are presumed to be well conserved within the forest vegetation and efficiently recycled, a situation well documented from other tropical forests. Results from the present study indicate very low levels of nutrients in the run-off from the upper Sigi above Amani.

Ionic concentration can be seen to increase progressively downstream in the Sigi (Fig. 16.6). This is particularly clearly shown by the results of conductivity and sodium measurements with values increasing six-fold between stations 14 and 2. A majority of the other parameters increase two- to three-fold. For several parameters, including sodium, chloride, bicarbonate, hardness and alkalinity, the downstream increase is not regular but tends to accelerate between stations 9 and 8. It is at this stage in the river's course that it exits from the steep, upland zone and enters the more gently sloping lowland plains. It should be noted that it is between these two stations that water from the Kihuhwi and the Muzi sub-catchment contributes to this accelerated rise as these tributaries are substantially more concentrated than the upper Sigi (Table 16.2). It is not known to what extent these elevated levels are due to anthropogenic influences or are a result of the differences in soils and land-use.

Downstream enrichment, as observed in the Sigi, can be produced by several natural causes and is a feature common in river systems. Processes involved include erosion and leaching of the river-bed and banks and the increased solubility of some ions resulting from elevated temperature; the impact of human domestic and agricultural contributions to the river may also be expected to increase significantly in the generally more heavily populated and cultivated lowland regions. It is also possible that some ions, including sodium and chloride, may be contributed to the lower Sigi from wind-blown salt-spray originating from the Indian Ocean.

Analyses of rainfall and conductivity data from the Sigi catchment has shown that conductivity (which reflects total ionic concentration) is actually highest in the rainy seasons, when by inference ions are flushed out of the catchment into the aquatic environment; and lowest in the dry season. The relationship between rainfall and the quantity and composition of material flushed out of the catchment is extremely complex.

The flushing out can only continue so long as additional material is available in the catchment for transport. Once this supply is exhausted, any subsequent rainfall will result in dilution of the inflowing water and the relationship between rainfall and ion transport changes. The quantity of material available for flushing depends upon a complex of parameters, particularly important among which is the previous flushing history. Heavy rainfall which follows closely (within a few weeks) a period of previous heavy rainfall will transport little to the receiving water as time will not have permitted the generation of more transportable material in the catchment. This material is generated by weathering, erosion, and biological processes such as leaf- and litter-fall and decomposition. It is thus generally the case that the longer the dry season preceeding heavy rain lasts, the greater will be the quantity of material available for transport.

Similarly, the intensity of the rainfall following a dry season greatly influences the extent of washout from the catchment, especially in catchments with extensive areas of bare ground on moderate to steep slopes and an associated high susceptibility to erosion. In such catchments, if the first rains are torrential, much of the loose friable dust will be immediately swept away and serious erosion results. In contrast, if the first rains fall as light showers, the surface deposits will absorb this moisture and become bound by it. Binding will be particularly effective where the clay fraction is high.

If a dry sunny period then follows, the bound material may be hardened by the sun and form an erosion-resistant protective skin, which will better withstand subsequent heavy rains. In these circumstances much less material will be swept into the receiving waters. The quantity of material

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transported from the catchment is thus not predictable from rainfall data alone, since the type of rainfall is of paramount importance, as are ground vegetation cover and slope.

2.3.2 Biological parameters

Sigi River: There is little evidence to suggest that *in situ* primary production in the river is significant. The only aquatic plants which do contribute to riverine primary production above Mabayani Dam are the floating aquatic macrophytes *Pistia stratiotes* (Nile cabbage) and *Impomoea aquatica* (the water ivy). The former is by far the most abundant and occurs along the middle and lower Sigi in large numbers. During the dry season large areas of the slowly flowing river are covered with floating mats of *Pistia*. *Impomoea* is only abundant at the junction of the Sigi and upper end of Mabayani Dam. At this point river sediment is deposited as mud banks, which the water ivy colonizes from the river bank.

Mabayani Dam: In Mabayani Dam plant primary production by phytoplankton predominates. No significant macrophytes have been observed in the dam and even the riverine species mentioned above apparently fail to survive when transported to the dam during the rains. Zooplankton is abundant in the dam and, according to local opinion, so too are fish.

The dam presently contains water of an acceptable standard for raw water supply. Evidence has, however, been collected which indicates that the system is fragile and open to perturbation, especially from additional loading of plant nutrients and/or oxidizable organic matter. It appears probable that increased BOD (biological oxygen demand) resulting from greater loading, in conjuction with periods of prolonged thermal stratification during the dry season (December – January especially) can lead to undesirable deoxygenation of the bottom waters (hypolimnion) which, if prolonged, may be expected to lead to anoxia and nutrient release from the sediment. Under such conditions algal blooms are a likely response to internal loading with drastic and immediate reduction in water quality.

Increased loading of the dam could result from nutrient losses from the catchment as a consequence of deforestation and erosion of soils which disrupt the integrity of the tight nutrient cycling in the forest biome. In addition, the transport of the leaf litter and humus from the forest floor to the river will increase nutrient input to the river as these materials decay. The decay of all felled and destroyed forest vegetation in the catchment, which is not removed by the loggers will, over time, increase both BOD and nutrient levels in the river to an unknown extent.

Raised nutrient levels in the river may increase the abundance of *Pistia*; this, however, is uncertain since it is not known what factors presently limit its productivity and abundance. If nutrients, rather than, for example, suitable quiet-water areas in the river, are limiting, then additional nutrients are most likely to increase the biomass of *Pistia*. This in turn will increase the loading on the dam during and following the next rains, as described below.

During the early part of the seasonal rains and especially in the April rains which follow the long dry season, *Pistia* is abundant in the middle and lower Sigi and is swept downstream by the rising floodwater into Mabayani Dam. A portion of these plants remain in the reservoir and some are swept over the spillway when it is overtopped. *Impomoea* is also torn loose at this time and enters the dam.

The rains also flush nutrients, organic debris and inorganic particulates from the catchment which have accumulated during the dry season. This pulse of nutrients stimulates algal growth in the dam and the algal population density has been shown to rise shortly afterwards.

The *Pistia* and *Impomoea*, which are brought into the reservoir and which are subsequently retained, do not appear to survive and, in the absence of contrary evidence, it must be assumed that they die and decay in situ. The decay of these aquatic macrophytes and the organic detrital matter imported from the catchment consumes unquantified but substantial amounts of oxygen from the water in the dam during subsequent weeks.

After the long rains, the decay of this organic matter, and also of the algal populations produced by the nutrients flushed from the catchment, continues. So long as the water column remains well mixed

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by wind action the water is aerated from the surface and deoxygenation is retarded. In the following dry season winds are less strong and thermal stratification has been observed to develop in the reservoir. Stratification effectively separates the lower water strata of the dam (where decay and oxygen consumption are going on) from the surface water (where diffusion of oxygen from the atmosphere and photosynthesis are occurring). The bottom waters thus become progressively deficient in oxygen while stratification persists and decay continues.

At the time of the Sigi River Study (1984–85) the amount of organic matter causing oxygen reduction appeared not to be suffient to reduce the oxygen content in the hypolimnion (lower strata) to zero under the then prevailing conditions and in the time available. BUT, if the organic load increases or, if in a future dry season the period of stratification lasts for a longer period of time than in the '84–'85 dry season, oxygen-free conditions could occur with potentially very serious consequences for the security of the Tanga water supply.

Increased loading with nutrients and organic matter is likely to occur as a consequence of further deforestation in the upper catchment and also, and probably much more importantly, from the impact of effluents from the several sisal decortication factories in the catchment should these become fully operational in the future. The assumed future adverse impacts of the sisal factory effluent presupposes a continuation of wet decortication and discharge of raw or poorly treated effluent into the river, as was the practice in the past. With the data presently available it cannot be stated categorically when, how, or to what extent these influences will adversely impact the dam but there seems a high probability that they will do so to an unacceptable degree.

One consequence of anoxia in the bottom waters of organically loaded reservoirs is the release of plant nutrients (especially phosphates) from the sediment where they were previously bound in an oxidized or precipitated form. Under reducing conditions these nutrients are released and, when stratification is eventually broken down by the wind, they are carried into the upper illuminated waters of the dam where they are available for algal photosynthesis. There then follows a period of rapid algal growth, stimulated by the abundant nutrients, the products of which clog water filters and impart undesirable taste and odour to the water. The subsequent death and decay of the algal population contributes more organic matter and nutrients to the bottom sediments which will again be released on the return of anoxic conditions during later periods of stratification. This internal loading can become self-sustaining and boosted by further inputs of nutrients and organic debris from the catchment in following wet seasons.

It is important to appreciate in this context that the outlet from the dam to the water treatment plant is on the reservoir floor in the area most frequently and severely affected by reduced water quality conditions. Any deoxygenated water abstracted from the bottom would seriously affect the efficiency and cost of water treatment and can make the finished product of poor quality or, under extreme conditions, the water may become economically untreatable.

From the foregoing, it is apparent that any further stress on Mabayani Dam is undesirable and constitutes a real threat to the viability of the dam as a reservoir of raw water for supply to Tanga. It is therefore necessary to compare carefully the economic benefits derived from any further logging of the Sigi catchment and the implementation of the proposed rehabilitation of the sisal industry with their attendant and potentially detrimental consequences to Tanga township water supply. In my opinion the balance is clearly in favour of protecting the Tanga water supply, since the town now has no adequate alternative sources of potable water and a considerable economic investment in the dam, treatment works and distribution system has already been made and would be put in jeopardy. It should be borne in mind, however, that of the two principal threats to the Tanga water supply, deforestation and sisal decortication, the greatest hazard remains the pollution of Mabayani Dam by the inflow of effluent resulting from wet decortication.

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2.4 The IUCN Usambara study Nov – Dec 1986

Unlike the Sigi River Catchment Study which produced survey data on water quality for the entire Sigi catchment, the IUCN study concentrated on the upper reaches of the Sigi above Amani and focused on the influence of the indigenous forest and the associated logging activities on the chemistry of the water draining the upper catchment. Several analyses of rainwater were also made, which were not carried out in the earlier study.

Because of the extreme dilution of the water to be analysed and the absence of good analytical laboratory facilities on site, many of the data produced during the IUCN study are equivocal, their accuracy doubtful and consequently difficult to interpret. Doubt in the accuracy of some analyses stems from the inconsistent relationship between the measured conductivity of the samples, which is believed to be accurate because of the intrumentation used, and the concentrations of cations assayed.

There are also several instances of anomalously high or low records, the accuracy of which cannot be evaluated in the absence of sufficient replicate analyses. No detailed assessment or evaluation of these data is therefore attempted here. Certain broad generalisations and observations can, however, be drawn from the data as a whole and from the conductivity and pH measurements in particular. The former is likely to be most accurate because the method used to measure it is usually very reliable.

Data on conductivity and pH from multiple samplings of rain water, throughfall, stem flow, river flow and runoff from erosion plots are summarized in Table 16.3 and illustrated in Fig. 16.7. Throughfall is rain water which has passed through the forest canopy making contact mainly with leaves and smaller branches and which then drips off and falls to the ground below. Stem flow is rain water intercepted by leaves but which then runs down branches and tree trunks to the ground. As stem flow is in longer and more intimate contact with the tree, it has a greater opportunity to pick up materials from the tree during its passage over the bark.

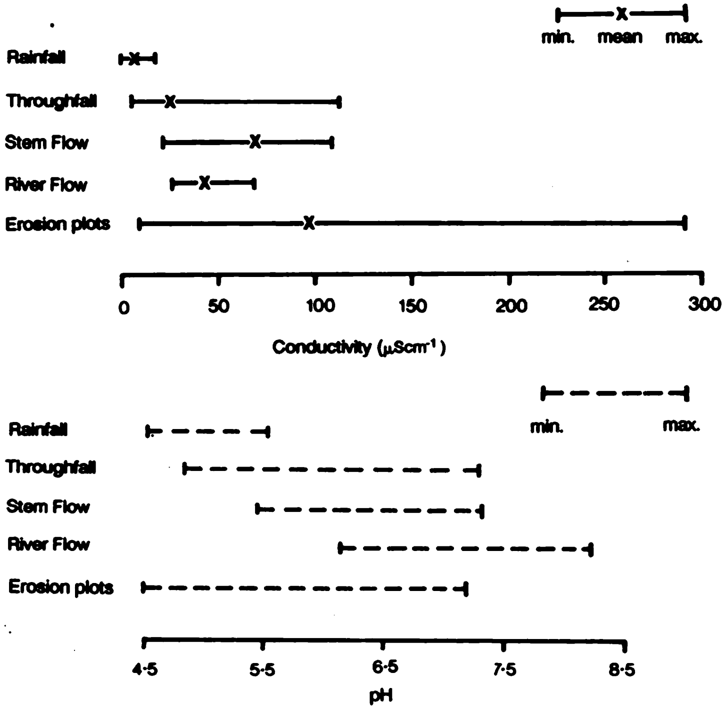

Figure 16.7 Mean conductivity and pH range in rain water, throughfall, stemflow, river flow and erosion plot run-off.

Table 16.3 Conductivity and pH of rain water throughfall, stem flow, stream flow and erosion plot run-off.

	CONDUCTIVITY (µS/cm)				pH	
	Mean +/-	SD	(n)	Range	Range	(n)
RAINFALL	6.0	4.6	7	14.8 - 2.4	5.55 - 4.56	10
THROUGHFALL						
Tree 1: *Maesopsis*	18.1	17.3	9	64.2 - 10.9	7.30 - 5.41	9
Tree 2: Sp. *indet.*	42.3	40.1	9	115.7 - 6.1	7.15 - 5.44	9
Tree 3: Sp. *indet.*	28.1	8.5	3	34.1 - 18.3	6.85 - 6.60	3
Tree 4: *Allanblackia*	24.2	10.3	9	39.9 - 11.3	6.77 - 5.04	9
STEMFLOW						
Tree 1: *Maesopsis*	70.1	4.3	2	100.8 - 39.4	7.35 - 6.33	2
Tree 2: Sp. *indet.*	57.5	-	1	-	5.53	1
Tree 4: *Allanblackia*	58.3	24.7	4	81.5 - 23.3	6.80 - 6.22	4
Trees 5,6,7: *Maesopsis*	47.4	34.7	6	111.1 - 22.8	6.94 - 6.22	6
EROSION PLOTS						
Number 1	56.6	44.1	6	115.8 - 18.9	5.9 - 4.8	6
Number 2	104.6	94.6	4	237.0 - 20.1	6.3 - 5.5	4
Number 3	126.5	112.0	4	292.0 - 47.9	6.7 - 4.6	4
Number 4	90.6	79.2	3	169.3 - 10.9	7.2 - 4.5	3
RIVERFLOW						
Site 5 (upstream)	29.7	2.1	3	32.1 - 28.1	6.5 - 6.3	3
Site 6 (downstream)	28.1	0.9	3	29.1 - 27.3	7.1 - 6.5	3
Shamba la Chai	40.0	0.0	10	40.0 - 40.0	8.2 - 6.3	10*
Kwamkoro	54.5	9.7	16	70.0 - 41.0	7.8 - 6.5	16*
Kwam-Chai	47.9	3.7	14	50.0 - 40.0	8.0 - 6.2	14*

**Source: Sigi River Catchment Study - Tanga. Final Report August 1986.*

Rain water: Seven rain water samples were analysed with a mean conductivity of 6.0 microS/cm. This value may be compared with that of distilled water which is usually below 2.0 microS/cm. The rain water is therefore not pure and has been shown to contain small amounts of the four major cations (Ca, Mg, Na, K) monitored in this study. Carbon dioxide in the atmosphere dissolves in rain and produces carbonic acid which results in the low pH readings (4.6 – 5.6) recorded. The presence of other anions (chloride and sulphate in particular) was not determined, though alkalinity (a measure of carbonate species) was very low in most samples with a mean of 0.48 mg/1. The pH of the rain water varied from 4.6 to 5.6, which is acidic but not unusual for rain water because of the presence of carbonic acid as mentioned above.

Throughfall: Water samples collected after rain had passed through the canopies of several tree species had mean conductivity values ranging from 18.1 to 29.1 microS/cm (max. 40.1, min. 8.5). Values are thus moderately variable and, on average, 3 to 5 times higher than in rain water. Ions are therefore shown to be picked up from the tree canopy; these may come from either dust particles deposited on the leaves and bark or from organic materials exuded by the leaves. The pH of throughfall water varied over two orders of magnitude (100-fold) from 5.0 to 7.3. Comparison with the rain water values shows a move towards more alkaline conditions.

Stem flow: Mean values for conductivity from several tree species ranged from 47 to 70 microS/cm (max. 111, min. 23). Levels in stem flow are thus, as expected, higher than in throughfall and rain water by 2-fold and 10-fold respectively. pH values ranged from 5.5 to 7.4. These are slightly higher (more alkaline) than in the throughfall, but the difference is probably not significant.

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River flow: Five stations listed in Table 16.3 were used to obtain an impression of conditions in small streams in the upper catchment. Values for mean conductivity per stream varied from 30 to 55 micro/cm (max. 70, min. 27). These values lie between those for throughfall and stem flow. They also lie between those for rain water and that passing through or over trees which suggests that some dilution of the more concentrated tree-intercepted water is taking place. From this observation it can be concluded that a significant but unquantified amount of water passes from the atmosphere to the ground without interception by the forest canopy. The water in the streams is more alkaline than that from the samples mentioned above and the pH ranges from 6.2 to 8.2. This increase is most likely attributable to dissolution of carbonates from the soils and bedrock.

Erosion plots: Four erosion plots in fairly dense forest (mixture natural forest and *Maesopsis)* were sampled and the run-off water was shown to have mean conductivities per plot ranging from 57 to 127 microS/cm (max. 292, min. 11). The runoff is therefore very variable both between plots and temporally at the same plot. This reflects the perturbed condition of these trial areas. More data are required to explain the cause of this variation. The increase in conductivity between the original rain water and plot outflow is approximately 16-fold on average and indicates substantial loss of ions resulting from removal of vegetation cover and disturbance of the soil layer. Minimum levels of pH in erosion plot runoff were similar to rainfall i.e. acid at 4.6, but some alkaline results were obtained in the plots (pH max. 7.2, rain max. 5.6) revealing further wide variation of uncertain origin.

2.5 Summary

Ionically, dilute rain water passing through the forest canopy becomes chemically enriched by contact with leaves and branches which have dry deposition dust, and organic exudates from the trees on their surface. The longer the period of contact, and the larger the area of tree surface contacted, the greater the concentration effect. Stem flow thus exceeds throughfall in ionic concentration by a factor of two. Stream water draining the forest study area has a conductivity, which is above that of the rain, similar to, but slightly higher than throughfall, but much less than stem flow. This implies a greater contribution to stream inputs by waters of low conductivity, that is from throughfall and rain falling directly to the forest floor without being intercepted by the forest trees. The influence of the forest understory in this respect was not investigated in this, or the previous study. Areas of disturbed forest floor (erosion plots, and by inference logging sites and areas of seasonal cultivation) contribute the greatest quantities of ions and sediment to the streams and the impact of such disturbances on the water quality of the stream is proportional to the area disturbed, the slope of the land and other contributory factors.

The enrichment of rain water passing vertically through a natural forest must be considered as normal and some portion at least of the additional ions in solution will be taken up and utilized by the root systems of the forest vegetation and the trees themselves. This process may in fact act as a nutrient collection mechanism whereby the canopy filters dry particulates from the atmosphere, which are then transported to the forest floor and the soil which makes the nutrients available to the roots.

Stream enrichment by soil erosion resulting from land-use disturbances is, in contrast, a wholly negative impact leading to significant loss of nutrients (fertility) and valuable soil from the catchment. Some pollution of the receiving water is also to be anticipated.

3. The future of the Sigi catchment

Various scenarios can be constructed to assess the implications of future changes and developments in the Sigi catchment. Three of the most probable are considered here and these focus principally on the future of the sisal industry in the Sigi basin.

3.1 Scenario 1: to rehabilitate the sisal estates

The single most important problem facing the Sigi River catchment from a water quality point of view is the risk from sisal factory effluent. This source of pollution is, in my opinion, substantially more

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serious than that posed by logging or deforestation associated with land-use changes in the upper catchment in terms of its probable impact on the Tanga water supply. This is not to suggest, however, that logging and deforestation and the consequent loss of indigenous species and habitat are unimportant or that they can be allowed to proceed unchecked. The conservation of these vital natural resources is of paramount importance.

Should a resurgence in sisal production occur, then unless the strictest of measures are taken to prevent any increase over the present pollutant load (which may already be too great), the reservoir at Mabayani will probably be rendered unusable as a source of water for Tanga and water shortage in the town will become acute.

Three alternative administrative measures appear possible:

- only allow dry decortication in the Sigi catchment area, or
- allow no sisal decortication within the Sigi catchment area, or
- cancel all existing water abstraction permits to sisal factories and re-issue with additional clauses to the effect that no effluent may be returned to the watercourses at any time or under any circumstances, and then vigorously enforce this ruling. It may be noted that such measures imposed in Kenya on coffee factories in Central Province proved reasonably effective in the late 1970's.

3.2 Scenario 2: to allow the run-down of the sisal estates to continue

Presently, approximately 160 km^2 of the Sigi catchment are under sisal cultivation with the majority of the area either entirely out of production or only sporadically harvested. Overall, productivity is very low as a consequence of the poor economic performance of sisal in world markets and because of management difficulties in Tanzania. Under these circumstances, and in view of the low probability of an increase in the profitability of sisal in the foreseeable future, the abandonment of sisal and a turn to other crops or land-uses is a viable alternative option which should be given serious consideration.

If, as is the case today, the sisal plantations are not properly tended, then by default secondary regeneration of scrub and woodland will continue. Economically this would be the least acceptable land-use but would have the minimum impact on water quality in the Sigi, as vegetation cover would increase and soil erosion correspondingly decline. The problem of effluent from sisal factories would naturally cease to exist.

3.3 Scenario 3: conversion from sisal estates to forest plantations

A more appropriate solution would be a change in land-use from sisal to alternative crops, or to other non-crop land-uses such as ranching if this were deemed worthwhile. One alternative land-use which would simultaneously solve the local timber shortage and the forest logging problems in the upper catchment would be to extend the existing teak plantations further into the sisal areas. Other species besides teak could also be introduced after careful selection and trials, to diversify the timber resource base.

Whatever alternative land-use is decided upon there will inevitably be a period of transition from one crop to another. During this period the soil erosion hazard will increase since vegetation cover will be temporarily absent. Several anti-soil erosion practices are available to prevent or at least reduce soil loss during transition. These include:

- leaving the sisal rows intact along watercourses to act as a buffer zone between the rivers and the land being prepared for replanting.
- to use only contour ploughing and planting and avoid clear stripping of the sisal, especially in those areas with greater erosion hazard as identified in Fig. 16.4.
- in the case of afforestation, interplanting the seedlings between the sisal rows could benefit the young trees and enhance growth by providing shade and shelter in the early stages. Once the trees are established the sisal can be removed.

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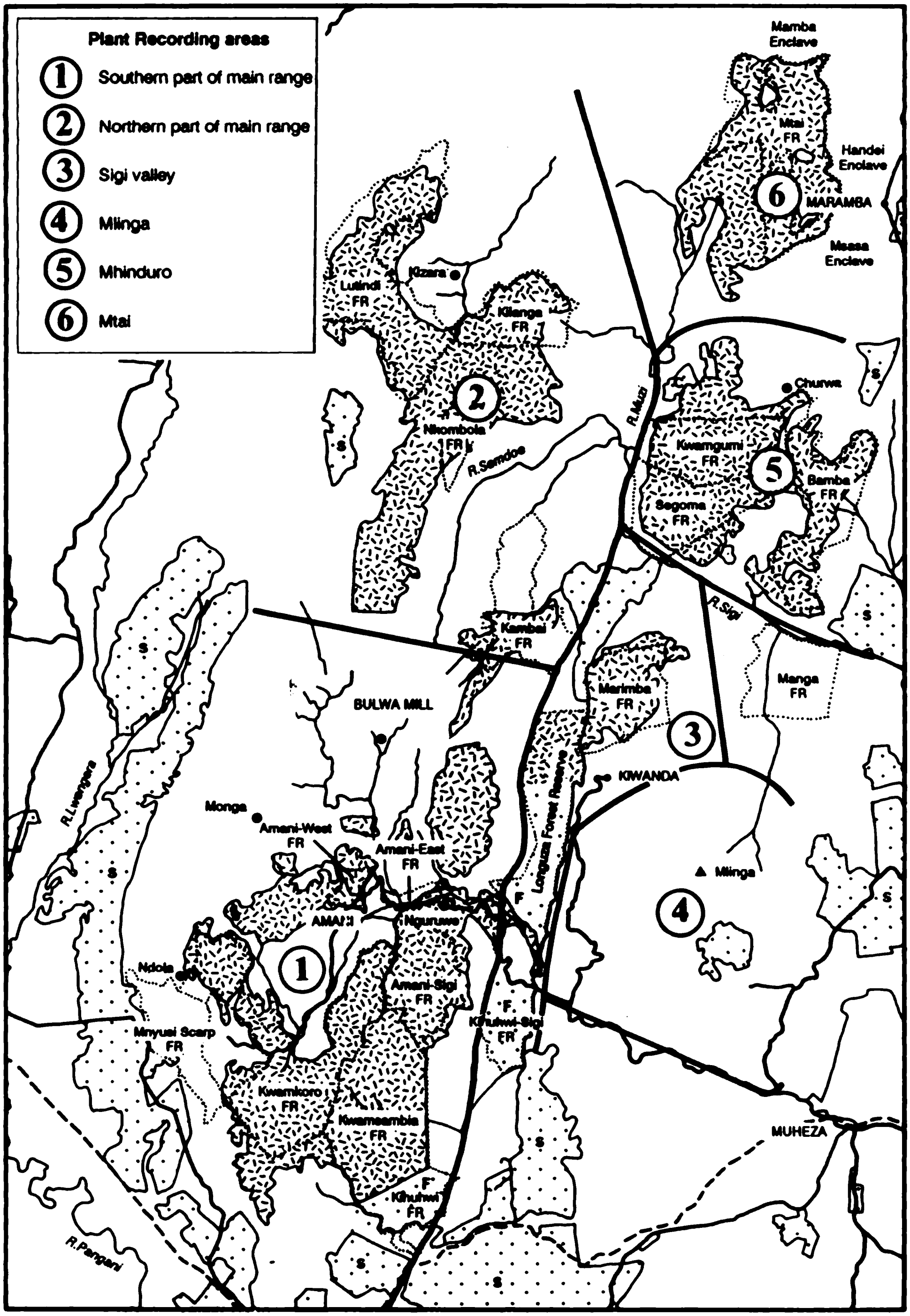

Figure 17.1 Map of East Usambaras showing subdivisions used for plant recording.

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17. A Preliminary List of Plant Species Recorded from the East Usambara Forests

by C.K. Ruffo, C. Mmari, S.P. Kibuwa, J. Lovett,
S. Iversen & A.C. Hamilton

This chapter contains a list of some of the plants recorded from the East Usambaras, with notes on their distributions. Three separate lists are presented. The first is of indigenous forest trees reaching a height of over 10 metres; this list is probably fairly complete. The second is of introduced trees naturalized in the forest. The third list, which is very incomplete, is of other forest plants.

1. Introduction to the provisional list of indigenous forest trees

This list is compiled from various sources and includes all species known to occur, even if not seen during the present survey. Information is given in the following order:

a) Name and commonly used synonyms

Names usually follow the Flora of Tropical East Africa, where available.

b) Records of presence on the East Usambaras from published sources

FTEA	Flora of Tropical East Africa (1952 *et seq.)*. T3 is the flora area covering extreme north-east Tanzania; it includes the East Usambaras (EU). Other flora areas used in the flora are given as K (Kenya) 7; T (Tanzania) 6; etc.
R & H	Rodgers & Homewood (1982). For many species the list in this paper does not distinguish between those occurring on the Usambaras as a whole (US) and those restricted to the East Usambaras (EU) or West Usambaras (WU) only.
B & G	Brenan & Greenway (1949).
P	Polhill (1968).
C & W	Chapman & White (1970).

c) Our records, given according to location (Fig. 17.1)

1. Southern part of main range:
A = Amani-Sigi FR, including Nguruwe
B = Bulwa
K = Kwamkoro FR
M = Monga/Ndora
N = Amani area, including Amani East and Amani West FRs
S = Kwamsambia/Kihuhwi FRs

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2. Northern part of main range:
K = Kilanga FR
L = Lutindi FR, including Kitivo
Z = Kizara/Kizerui

3. Sigi (Zigi) valley area:
L = Longuza FR (also lower slopes to the west)
M = Marimba FR
Z = Sigi (Zigi) river (near Fanusi)/Mangubu

4. Mlinga

5. Mhinduro:
A = Kwamgumi/Segoma (unspecified)
C = Churwa area
G = Kwamgumi FR
S = Segoma FR

6. Mtai

s.l. means locality uncertain

Records without further comment are field identifications (mainly by Ruffo).

Records with an asterisk are supported by a specimen which has been checked in an herbarium, usually Lushoto (LH) or East African Herbarium (EAH), occasionally Kew (KEW).

Collection numbers of specimens deposited in herbaria are given. Collectors: H = Hamilton, K = Kibuwa, L = Linder, M = Mmari, R = Ruffo.

d) Summary distribution on the East Usambaras (based on the views of Ruffo and Hamilton)

Lowland forest is found below about 850 m and includes forest on the escarpments of the main range. Submontane forest is found above about 850 m and includes the plateau forests of the main range.

e) A note on the distribution of the plant on a wider geographical scale

Sources of information additional to those noted under section b above:

D & G	Dale & Greenway (1961)
E	Eggeling (1940)
H	Hamilton (1981)
H & D	Hutchinson & Dalziel (1927–28)
KTSL	Beentje (in prep.)
L	Lovett (pers. comm. or in prep.)
TAI	Faden *et al.* (in press)
W	White (1962)

f) Endemic status, referring to the overall world distribution of the species.

For species not covered in FTEA, distributions are often somewhat uncertain.

1. Only on East Usambaras.

2. East Usambaras and one or a few similarly restricted localities in eastern Tanzania or occasionally in eastern Kenya, Mozambique or Malawi.

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3. More widely distributed in the East African coastal forests. Not in the Guineo-Congolian forests of Central and West Africa (Zaire etc.).

4. Widely distributed in African tropical forests, usually also in Central or West Africa.

Geographical abbreviations used:

A	Africa	NE	North-east
E	East	S	South
EA	East Africa (Kenya, Tanzania, Uganda)	SA	South Africa
		ST	South Tanzania
EK	East Kenya	T	Tanzania
ET	East Tanzania	US	Usambaras (in general)
EU	East Usambaras	W	West
FR	Forest Reserve	WA	West Africa
K	Kenya	WU	West Usambaras
N	North	Z	Zambia

2. Provisional list of indigenous forest trees reaching a height of over 10 metres

AGAVACEAE

Dracaena steudneri Engl. R & H-US. Summary distr. EU - small widely distributed tree of gaps in submontane forest, persisting on sites of old gaps. Widely distr. A., e.g. in U (H). Endemic status - 4.

ALANGIACEAE

Alangium chinense (Lour.) Harms FTEA - T3, EU (Mlesa). R & H - US. Our records - 1K, 2L, 6. Summary distr. EU - medium-sized pioneer tree of submontane forest. Very widely distributed tropical A and Asia (FTEA). Endemic status - 4.

ANACARDIACEAE

Lannea welwitschii (Hiern) Engl. (syn. *L. amaniensis* Engl. & K.Krause (FTEA)) FTEA - T3, EU (Misima, Amani). R & H - endemic EU (refers to L. amaniensis). P - near endemic US (refers to *L. amaniensis*). Our records - 1S, 2KL, 3LM, 5AG, 6. Summary distr. EU - large, widely distributed lowland tree. Widely distributed A (FTEA). Endemic status - 4.

Sorindeia madagascariensis DC. (syn. *S. usambarensis* Engl. (FTEA)) FTEA - T3. R & H - endemic WU. P - endemic US. Our records - 1BKNS, 2KL, 3LM, 4, 5AG, 6*(R & M 2037 det. LH). Summary distr. EU - small widely distributed tree, common in submontane forest, rarer in lowland forest. Widely distributed EK, ET, ST and to south (FTEA). Endemic status - 3.

ANNONACEAE

Anonidium usambarense R.E. Fr. FTEA - T3, EU (recorded from Amani in 1910 and not seen since). R & H - endemic EU. P - endemic US. Not seen during present survey. Endemic EU (FTEA). Endemic status - 1.

Enantia kummeriae Engl. & Diels FTEA - T3, EU (Amani, Derema, Kwamkoro). R & H - endemic EU. P - endemic US. Our records - 1NS*(R & M 2222 det. LH), 2L, 5A, 6. Summary distr. EU - medium-sized tree of submontane forest. Endemic EU (FTEA); on Uzungwas (L). Endemic status - 2.

Greenwayodendron suaveolens (Engl. & Diels) Verdc. subsp. *usambaricum Verdc.* FTEA - T3, EU (Amani, Kwamkoro & between Kwamkoro & Sangerawe). R & H - endemic EU. Our records - 1BKN*(R & M 2195 det. LH)S, 2L. Summary distr. EU - large tree of submontane forest, only known from the main EU range. Subsp. confined EU; other subsp. widespread W & central A (FTEA). Endemic status - 1.

Isolona heinsenii Engl. & Diels FTEA - T3, EU (Amani area). R & H - endemic EU & Magombera. P - near endemic US. Our records - 1K*(R & M 2269 det. LH)S, 2L. Summary distr. EU - small tree of submontane forest, only known from the main EU range. Only known EU & Magombera FR (FTEA). Endemic status - 2.

Lettowianthus stellatus Diels (specific identity slightly uncertain, but the EU tree is probably this species (FTEA)) FTEA - T3, EU (above Magunga Estate). Summary distr. EU - small tree of submontane forest, probably rare. Known from lowland forest & Brachystegia woodland in EK & ET (refers to L. stellatus & L. sp.) (FTEA). Endemic status - 3.

Polyceratocarpus scheffleri Engl. & Diels FTEA -T3, EU (Derema, Ngwelo & between Kwamkoro & Sangerawe; not seen since 1916). R & H - endemic EU. P - endemic US. Our records - 1K (leaf seen, Ruffo). Summary distr. EU - rare tree of submontane forest. Confined to EU (FTEA); on Uzungwas (L). Endemic status - 2.

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Uvariodendron oligocarpum Verdc. Our records - 1K*(R & M 1730 det. KEW)S. Summary distr. EU - small tree of submontane forest, restricted to S end of main range. Previously recorded WU (L). Endemic status -2.

Uvariodendron pycnophyllum (Diels) R.E.Fr. FTEA - T3, EU (Sigi Valley nr. Amani). R & H - endemic EU & WU. P - endemic US. Our records - 1S*(R & M 1727 det. EAH), 3M*(R & M 2138 det. EAH). Summary distr. EU - small tree of submontane forest. Confined to T3 (FTEA). Endemic status - 2.

Uvariodendron usambarense R.E.Fr. FTEA - T3, EU (Derema). R & H - endemic EU & Ngurus. P - near-endemic US. Our records - 1S*(R & M 2263 det. LH), 3L, 6. Summary distr. EU - small tree of submontane forest. Confined to T3 & T6 (FTEA). Endemic status - 2.

Xylopia aethiopica (Dunal) A. Rich. FTEA - T3, EU (Mlinga). Our records - 1KS*(R & M 1855 det. EAH), 3L*(R & M 1910 det. EAH). Summary distr. EU - small tree of submontane forest, restricted to S end of main range. Widely distributed A (FTEA). Endemic status - 4.

Xylopia parviflora (A. Rich.) Benth. FTEA -T3, EU (Kihuhwi River). P - near- endemic US. Our records - 1S*, 3L*, 5A. Summary distr. EU - small lowland forest tree. Widely distributed A (FTEA). Endemic status - 4.

APOCYNACEAE

Funtumia africana (Benth.) Stapf R & H - US. Our records - 1KS, 2KL, 4, 5AG, 6. Summary distr. EU - medium-sized tree, abundant in lowland forest, rarer in submontane forest. Widely distributed A, e.g. in U (H). Endemic status - 4.

Rauvolfia caffra Sond. Our records - 1S, 3LM, 4. Summary distr. EU - medium-sized lowland forest tree, occasional in submontane forest. Widely distributed A, e.g. in K (D & G). Endemic status - 4.

Tabernaemontana pachysiphon Stapf R & H - US. Our records - 1BKNS, 2L, 6 (but need checking). Summary distr. EU - small tree, probably the most abundant sp. of the genus in submontane forest. Probably often confused with T. ventricosa in the field. Widely distributed A, e.g. in U (H). Endemic status - 4.

Tabernaemontana stapfiana Britten Seen by Lovett in Lutindi FR. Widely distributed A. Endemic status -4.

Tabernaemontana ventricosa A. DC. R & H - US. Our records - 1S, 3L*, 4, 5A, 6 (but need checking). Summary distr. EU - small tree, probably the most abundant sp. of the genus in lowland forest. Probably often confused with T. pachisiphon in the field. Widely distributed A, e.g. in U (H). Endemic status - 4.

Voacanga thouarsii Roem. & Schult. R & H - US. Our records - 1N. Summary distr. EU - small swamp forest tree, seen on the plateau near Kwamkoro and Amani. Widely distributed A, e.g. in U (H). Endemic status - 4.

AQUIFOLIACEAE

Ilex mitis (L.) Radlk. FTEA - T3. R & H - US. Our records - 1KN. Summary distr. EU - small tree of submontane forest, confined to S end of main range. Widely distributed A (FTEA). Endemic status - 4.

ARALIACEAE

Cussonia spicata Thunb. FTEA - T3, WU. R & H - US. Our records - 2L, 4. Summary distr. EU - small locally distributed tree of submontane forest, in gaps. Widely distributed A (FTEA). Endemic status - 4.

Cussonia zimmermannii Harms FTEA - T3, WU. Our records - 5A, 6. Summary distr. EU - small lowland forest tree of gaps, apparently only on Mhinduro and Mtai. Recorded EK, ET, NE Mozambique (FTEA). Endemic status - 3.

Polyscias fulva (Hiern) Harms FTEA - T3, EU (Ngwelo-Derema). R & H - US. Our records - 1BKS, 2L. Summary distr. EU - medium-sized submontane forest tree of gaps, only on the main range. Widely distributed A (FTEA). Endemic status - 4.

Schefflera goetzenii Harms FTEA - T3, WU. R & H - US. Our records - 4. Summary distr. EU - a strangler/small tree of submontane forest, on Mlinga and probably also S end of main range. Widely distributed A (FTEA). Endemic status - 4.

BIGNONIACEAE

Fernandoa magnifica Seem. Our records - 1S*(R & M 1795 det. LH), 3M, 4, 5AG. Summary distr. EU - small widely distributed lowland forest tree. Found Coastal Province K (D & G) & coastal belt T (B & G). Endemic status - 3.

Markhamia lutea (Benth.) K.Schum. (syn. *M. hildebrandtii* (Baker) Sprague, R & H - US. Our records - 1S*(R & M 1842 det. LH), 2KL, 3LM, 4, 5AG, 6. Summary distr. EU - small widely distributed lowland forest tree of gaps, rarer in submontane forest. Widely distributed A, e.g. in K (D & G). Endemic status - 4.

BOMBACACEAE

Rhodognaphalon schumannianum A. Robyns R & H - US. Our records - 1S, 2KL, 3L, 5AG, 6. Summary distr. EU - large widely distributed lowland forest tree. Found coastal forests K & T (B & G, D & G). Endemic status - 3.

BORAGINACEAE

Cordia africana Lam. (syn. *C. abyssinica* R. Br.) R & H - US. Our records - 1S, 2L. Summary distr. EU - medium sized tree of open places in forest in upper parts of lowland forests, confined to main range. Widespread in A, e.g. in U (H). Endemic status - 4.

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BURSERACEAE

Commiphora eminii Engl. ssp. *zimmermanni* (Engl.) Gillett R & H - US. Our records - 2L, 6. Summary distr. EU - small lowland forest tree. Coastal forests K (D & G); ET (B & G). Endemic status - 3.

CAESALPINIACEAE

Afzelia quanzensis Welw. FTEA - T3. R & H - US. Our records - 3L. Summary distr. EU - big lowland forest tree. Widely distributed A (FTEA). Endemic status - 4.

Cassia angolensis Hiern FTEA - T3, EU (Amani). R & H - US. Not seen during present survey. Widely distributed A (FTEA). Endemic status - 4.

Cynometra brachyrrachis Harms FTEA - T3, EU (Amani, Bomole Rd., R & H - endemic EU. P - endemic EU. (*Cynometra* spp. are common in both lowland and submontane forest on EU, but most spp. cannot be identified from sterile material: fertile trees were not encountered during the present survey). Endemic EU (FTEA). Endemic status - 1.

Cynometra engleri Harms FTEA - T3, EU (Longuza). R & H - endemic EU. P - endemic EU. Our records - 1BK*(R & M 1932), 2KL, 3L*(R & M 1932 det. EAH), 5G*(R & M 2257 det. LH) (can be easily ident. in field). Summary distr. EU - large widely distributed lowland forest tree. Endemic EU (FTEA). Endemic status - 1.

Cynometra longipedicellata Harms FTEA - T3, EU (Amani). R & H - endemic EU. P - endemic EU. (See note under *C. brachyrrachis*). Endemic EU (FTEA). Endemic status - 1.

Cynometra webberi Bak. f. FTEA - T3. Our records - 3M*(R & M 2139 det. EAH). (See note under *C. brachyrrachis*). Found coastal K (K7) & T (T3, 6) (FTEA). Endemic status - 3.

Cynometra sp. A (of FTEA) FTEA - T3, EU (Amani - Maramba). R & H - endemic EU. (See note under *C. brachyrrachis*). Possibly conspecific with *C. alexandri* C.H. Wright, a widely distributed tree in A (FTEA). Endemic status - assumed 4.

Cynometra sp. B (of FTEA) FTEA - T3, EU (Amani). R & H - endemic EU. (See note under *C. brachyrrachis*). Endemic EU (FTEA). Endemic status - 1.

Dialium holtzii Harms FTEA - T3, EU (Longuza). R & H - US. Our records - 1S*(R & M 1860 det. LH), 3L*(R & M 1923 det. LH), 5AG, 6. Summary distr. EU - medium-sized widely distributed lowland forest tree. Coastal T & Mozambique (FTEA); also K7 (KTSL). Endemic status - 3.

Englerodendron usambarense Harms FTEA - T3, EU (Tongwe-Mlinga, Amani, Kwamkoro). R & H - endemic EU. P - endemic EU. Our records - 1K*(R & M 2179 det. LH)NS. Summary distr. EU - medium-sized tree of submontane forest, restricted to S of main range. Endemic EU (FTEA); also WU (L). Endemic status - 2.

Erythrophleum suaveolens (Guill. & Perr.) Brenan FTEA - T3, EU (Sigi). R & H - US. Our records - 1S*(R & M 1794 det. LH), 3L, 6*. Summary distr. EU - large lowland forest tree. Widely distributed A (FTEA). Endemic status - 4.

Isoberlinia scheffleri (Harms) Greenway FTEA - T3, EU (Sigi, Amani). R & H - endemic EU, WU, Magombera, Ngurus. P - endemic US. Our records 1BKN*(R & M 2320 det. LH)S, 2L, 3L, 4, 6. Summary distr. EU - large tree common in submontane forest, occasional in lowland forest. Found WU, EU & probably T6 (FTEA). Endemic status - 2.

Julbernardia magnistipulata (Harms) Troupin FTEA - T3, EU (Sigi). R & H - US. Our records - 1K*(R & M 1832 det. LH)NS*, 3L*(R & M 2321 det. LH). Summary distr. EU - large lowland forest tree. Coastal K (K7) and T (T3) only (FTEA). Endemic status - 2.

Oxystigma msoo Harms FTEA - T3, ?EU (Amani). R & H - US. Our records - 2L* (R & M 2253 det. LH). Summary distr. EU - a large tree of submontane forest. We have confirmed its presence on EU (Lutindi FR). Found in ET only (T2, T3) (FTEA and our record); also T7 (KTSL). Endemic status - 2.

Scorodophloeus fisheri (Taub.) J. Leon. FTEA - T3. R & H - US. Our records - 3L*(R & M 2149 det. LH)M, 5A, 6. Summary distr. EU - small lowland forest tree. EK & ET (FTEA). Endemic status - 3.

Zenkerella egregia J. Leon. FTEA - T3, EU (Longuza, Kwamtili). R & H - endemic EU, Ulugurus. Our records - 1S*(R & M 1955A det. LH), 5G*(R & M 1955 det. LH). Summary distr. EU - small lowland forest tree, apparently only at Longuza/Kihuhwi. Endemic to T3, T6 (FTEA). Endemic status - 2.

Zenkerella grotei (Harms) J. Leon. FTEA - T3, EU (Amani, Kwamkoro). R & H - endemic EU, WU. P - endemic US. Our records - 1K*(R & M 1996 det. LH)S, 2K*(R & M 2323 det. LH), 3L, 5A. Summary distr. EU - small submontane forest tree. Endemic to EU & WU (FTEA). Endemic status - 2.

CARICACEAE

Cylicomorpha parviflora Urban FTEA - T3, EU. R & H - US. Our records 1BK*(R & M 2226 det. LH)S, 2KL, 3L, 6. Summary distr. EU - medium-sized gap sp., mainly in submontane forest, occasionally in lowland forest. Found in EK (K4), ET (T3, 6, 7) and S to Malawi (FTEA). Endemic status - 3.

CELASTRACEAE

Maytenus acuminata (L.f.) Loes. Our records - 1KN. Summary distr. EU - small submontane forest tree restricted to S end of main range. Widely distributed in A, e.g. in U (H). Endemic status - 4.

Maytenus undata (Thunb.) Blakelock Our records - 2L*K*Z*(R & M 1801, 2283, 1751 det. EAH). Summary distr. EU - small submontane forest tree restricted to N end of main range. Widely distributed in A, e.g. in U (H). Endemic status - 4.

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CHRYSOBALANACEAE

Magnistipula butayei De Wild. subsp. *greenwayi* (Brenan) F.White FTEA - EU (Amani). Uncommon in submontane forest. Also in Zaire.(FTEA). Endemic status - 4.

Maranthes goetzeniana (Engl.) Prance (syn. *Parinari goetzeniana* Engl.) FTEA - T3, EU. R & H - US. P - endemic EU. Our records - 1BNS, 2L. Summary distr. EU - common large submontane forest tree, only on main range. Confined EU (FTEA); also known Zimbabwe, Mozambique (Flora Zambesiaca); on Uzungwas (L). Endemic status - 2.

Parinari excelsa Sabine FTEA - T3. R & H - US. Our records - 1BKS, 2L, 4, 6. Summary distr. EU - common large submontane forest tree. Widespread A (FTEA). Endemic status - 4.

COMBRETACEAE

Combretum schumannii Engl. FTEA - T3, EU (Kwamkuyu Falls). Our records - 1S*(R & M 1888 det. LH), 2KL, 3LM, 5A. Summary distr. EU - large widely distributed lowland forest tree. Found EK, ET & to S (FTEA). Endemic status - 3.

Terminalia sambesiaca Engl. & Diels FTEA - T3, EU (Sigi valley nr. Amani). R & H - US. Our records - 1S, 2L, 3LM, 4, 5AG, 6. Summary distr. EU - large widely distributed lowland forests tree. Widely distributed EK, ET, ST & to S (FTEA). Endemic status - 3.

CYATHEACEAE

Cyathea manniana Hook. R & H - US. Our records - 1KS, 2L. Summary distr. EU - tree fern of open places, mainly near streams, in submontane forest. Widespread in A, e.g. in U (E). Endemic status - 4.

DICHAPETALACEAE

Tapura fisheri Engl. Our record - 5G*(R & H 2050 det. EAH: first record for T3). Summary distr. EU - small tree, our record from lowland forest (Kwamgumi FR). Widespread in A, e.g. in U (E). Endemic status - 4.

EBENACEAE

Diospyros abyssinica (Hiern) F. White (syn. *D. amaniensis* Guerke) R & H - US. Our records - 1BK*(R & M 2279 det. LH). Summary distr. EU - medium-sized tree of submontane forest, only known from S end of main range. Widespread in A, e.g. in Z (W). Endemic status - 4.

Diospyros mespiliformis Hochst. ex A. DC. R & H - US. Our records - 1N, 5A. Summary distr. EU - large lowland forest tree. Widespread in A, e.g. in Z (W). Endemic status - 4.

Diospyros natalensis (Harv). Brenan R & H - US. Our records - 5A, 6. Summary distr. EU - small lowland forest tree only known from Mhinduro & Mtai. Widespread in A, e.g. in Z (W). Endemic status - 4.

Diospyros squarrosa Klotzsch. Our records - 1S, 2L, 3LM, 4, 5AG, 6. Summary distr. EU - small widely distributed lowland forest tree. In EK (D & G); in T, confined to E acc. herbarium records at Lushoto. Endemic status - 3.

ERICACEAE

Agauria salicifolia (Lam.) Hook. f. ex Oliv. R & H - US. Our records - 6. Small tree only recorded from the top of Mt Mtai. Widely distributed A, e.g. in U (H). Endemic status - 4.

EUPHORBIACEAE

Alchornea hirtella Benth. f. Our records - 1BK*(H 86/81 det. EAH)S, 2L*(R & M 1991 det. LH), 3L, 4. Summary distr. EU - small tree or shrub in submontane forest, mainly in gaps. Widespread in A, e.g. in U (H). Endemic status - 4.

Antidesma membranaceum Muell. Arg. Our records - 1KS, 2KL, 3L*(R & M 2147 det. LH), 5A, 6*(H 86/99 & H 86/124 det. KEW). Summary distr. EU - small tree mainly in lowland forest, occasionally in submontane forest. Widespread in A, e.g. in K (D & G). Endemic status - 4.

Bridelia micrantha (Hochst.) Baill. R & H - US. Our records - 1BKS, 2L*(R & H 2287 det. LH), 3L, 4. Summary distr. EU - a small tree mainly in lowland forest, occasionally in submontane forest; mainly on forest edges. Widespread in A, e.g. in U (H). Endemic status - 4.

Cleistanthus polystachyus Hook. ex Planchon R & H - US. B & G - EU. Our records - 6*(H 86/119 det. KEW). Summary distr. EU - rare small tree. Widespread in A, e.g. in WA (H & D). Endemic status - 4.

Croton macrostachyus Hochst. ex Del. Our records - 1S, 2KL, 3L, 5A, 6. Summary distr. EU - medium-sized tree of gaps mainly in lowland forest, occasionally in submontane forest. Widespread in A, e.g. in U (H). Endemic status - 4.

Croton sylvaticus Krauss. R & H - US. B & G - EU. Our records - 1S*(R & M 2289 det. LH), 3L*(R & M 1926 det. LH), 5G, 6*(H 86/128 det. KEW). Summary distr. EU - small lowland forest tree. Widespread in A, e.g. in K (D & G). Endemic status - 4.

Drypetes gerrardii Hutch. R & H - US. Our records - 1BKS, 2L. Summary distr. EU - medium-sized submontane forest tree only known from main range where it can be common. Widespread in A, e.g. in U (H). Endemic status - 4.

Drypetes natalensis (Harv.) Hutch. Our records - 3L*(R & M 1861 det. LH), 5C*(R & M 2088 det. LH). Summary distr. EU - small lowland forest tree. Coastal forests & scrub in K (D & G); lowland forest in ET (Ruffo). Endemic status - 3.

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Drypetes usambarica (Pax) Hutch. R & H - endemic EU, WU, Kinga Mts. Our records 1BK*(R & M 2110 det. LH)S, 2KL, 3M, 4*(R & M 2097 det. LH), 6*(R & M 2039 det. LH). Summary distr. EU - medium-sized submontane forest tree. Found in US & Kinga Mts (B & G); also Uzungwas (L); var. mrimae in K7 (KTSL). Endemic status - 2.

Macaranga capensis (Baill.) Sim (syn. *M. kilimandscharica* Pax) R & H - US. Our records - 1KNS, 2KL, 3L, 4, 5G, 6. Summary distr. EU - common medium-sized tree of gaps in both lowland and submontane forest. Widespread in A, e.g. in Z (W). Endemic status - 4.

Neoboutonia macrocalyx Pax R & H - US. Our records - 2L, 3L. Summary distr. EU - small submontane forest tree locally present in Lutindi FR and in the upper part of Longuza FR. Widespread in A, eg in U (H). Endemic status - 4.

Ricinodendron heudelotii (Baill.) Heckel R & H - US. Our records - 1S, 2K*(R & M 2303 det. LH)L, 3LM, 5AG, 6. Summary distr. EU - large widely distributed lowland forest tree. Widespread in A, e.g. in U (H). Endemic status - 4.

Sapium ellipticum (Krauss) Pax R & H - US. Our records 1K*(R & M 2290 det. LH)S, 2L, 3LM, 5A, 6*(H 86/123 det. KEW; R & M 1976 det. LH). Summary distr. EU - common medium-sized tree in both lowland and submontane forest. Widespread in A, eg in K (D & G). Endemic status - 4.

FLACOURTIACEAE

Caloncoba welwitschii (Oliv.) Gilg FTEA - T3, EU (Lutindi peak). R & H - US. Our records - 1BKS. Summary distr. EU - small tree of submontane forest in S end of main range. Widely distributed A (FTEA). Endemic status - 4.

Dasylepis integra Warb. FTEA - US, T3. R & H - endemic WU, Taita Hills (K), Mbulu, Pare. P - near-endemic. Our records - 1A*(R & M 2201 det. LH)KS, 6*. Summary distr. EU - small submontane forest tree common in S of main range. Confined to EK & ET (FTEA). Endemic status - 2.

Homalium longistylum Mast. FTEA - T3, EU (Derema). R & H -US. P- endemic US. Tree of submontane forest. Widely distributed A (FTEA). Endemic status -4.

Rawsonia lucida Harv. & Sond. FTEA - T3. R & H - US. Our records - 1BKNS*(R & M 2215 det. LH), 2KL, 3LM, 6. Summary distr. EU - small submontane forest tree. Widely distributed A (FTEA). Endemic status - 4.

GRAMINEAE

Oreobambos buchwaldii K. Schum. FTEA - T3, EU (Derema). R & H - US. Our records 1A, 2L, 6. Summary distr. EU - locally distributed bamboo in submontane forest. Widely distributed A (FTEA). Endemic status - 4.

GUTTIFERAE

Allanblackia stuhlmannii (Engl.) Engl. FTEA - T3, EU (Amani). R & H - endemic EU, WU, Ulugurus. Our records - 1BK*(H 86/79 det. EAH)NS, 2KL, 4, 6. Summary distr. EU - common large submontane forest tree. Only known T3, 6, 7 (FTEA); on Uzungwas (L). Endemic status - 2.

Garcinia buchananii Bak. Our records - 1K*(R & M 2114 det. LH)S. Summary distr. EU - small submontane forest tree only known from S of main range. Widely distributed A (FTEA). Endemic status - 4.

Garcinia volkensii Engl. (syn. *G. usambarensis* Engl.) FTEA - T3. R & H - US. Our records - 1B, 2L, 6. Summary distr. EU - small submontane forest tree. Widely distributed A (FTEA). Endemic status - 4.

Harungana madascariensis Lam. ex Poir. FTEA - T3. R & H - US. Our records - 1BKS, 2LK, 3L, 4. Summary distr. EU - medium-sized gap sp. in submontane forest. Widely distributed A (FTEA). Endemic status - 4.

Symphonia globulifera L.f. FTEA - T3, EU (Mlinga peak). Our records - 2Z. Summary distr. EU - large submontane forest tree of very local distribution, between Kilanga & Lutindi FRs and on Mlinga. Widely distributed A (FTEA). Endemic status - 4.

HERNANDIACEAE

Gyrocarpus americanus Jacq. FTEA - T3, EU (Kisiwani). R & H - US. Our records 2A, 3L, 5A. Summary distr. EU - big lowland forest tree of local distribution, between Fanusi & Kisiwani & on Mhinduro. Widely distributed EA & SA; also Asia, America (FTEA). Endemic status - 4.

ICACINACEAE

Alsodeiopsis schumannii (Engl.) Engl. FTEA - T3, EU (Amani). R & H - endemic EU, WU, Ulugurus. Our records - 1BKS, 2K*(H 86/30, H 86/33 det. EAH)L. Summary distr. EU - common small tree of submontane forest, only on the main range. Confined to ET & ST (FTEA); on Uzungwas (L). Endemic status - 2.

Apodytes dimidiata E. Meyer ex Arn. FTEA - T3. R & H - US. Our records - 1K*(H 86/212 det. EAH), 2L. Summary distr. EU - medium-sized tree of ridges in submontane forest on the main range. Widely distributed A (FTEA). Endemic status - 4.

LAURACEAE

Beilschmiedia kweo (Mildbr.) Robyns & Wilczek R & H - endemic EU, WU. P - endemic EU. Our records - 1BK*(R & M 2229 det. LH)NS, 2L. Summary distr. EU - large submontane forest tree only on the main range. Also on Uzungwas (L). Endemic status - 2.

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Cryptocarya liberiana Engl. P - near-endemic US. B & G - EU, WU, Ulugurus. Not seen during present survey. Found EU, WU, Ulugurus; also Taita in K7 (TAI). Endemic status - 2.

Ocotea usambarensis Engl. R & H - US. Our records - 1BKS*(R & M 2285 det. LH), 2L. Summary distr. EU - large submontane forest tree only on the main range where it is commonest in the S. Widely distributed A, e.g. in U (H). Endemic status - 4.

LECYTHIDACEAE

Barringtonia racemosa (L). Spreng. FTEA - T3, EU (Sigi valley & Magunga Estate). R & H - US. Our records - 1S, 3L*(R & M 2108 det. LH)M, 4, 6. Summary distr. EU - small lowland forest tree found near streams. Widely distributed EA, also Asia, Australasia, Pacific (FTEA). Endemic status - 4.

LOGANIACEAE

Anthocleista grandiflora Gilg (syn. *A. zambesiaca* Baker of FTEA) FTEA - T3, EU (Amani, Kwamkoro). R & H - US. Our records 1BKS, 2KL, 4, 6*(R & M 2038 det. EAH). Summary distr. EU - common large submontane forest tree. Widely distributed A (FTEA). Endemic status - 4.

Strychnos usambarensis Gilg FTEA - T3, EU (Mangubu to Misoswe & E of Mashewa). R & H - US. Not seen during present survey. Widely distributed A (FTEA). Endemic status - 4.

MELASTOMATACEAE

Memecylon brenanii A. & R. Fernandes FTEA - T3, EU (Kwamkoro). R & H - endemic EU. P - endemic US. Distribution on EU not very certain. Endemic EU (FTEA). Endemic status - 1.

Memecylon greenwayi Brenan FTEA - T3, EU (only Mlinga). R & H - endemic EU. P - endemic US. Our records - 4*(R * M 2273 det. LH). Summary distr. on EU - small tree confined to Podocarpus forest on Mlinga Peak. Endemic EU (Mlinga). Endemic status - 1.

MELIACEAE

Entandrophragma excelsum (Dawe & Sprague) Sprague P & H - US. Our records - 1KNS, 2L, 6. Summary distr. on EU - large rather uncommon submontane forest tree. Widely distributed A, e.g. in U (H). Endemic status - 4.

Khaya nyasica Bak. f. R & H - US. Our records - 1KS, 2KL, 3L, 5A, 6. Summary distr. EU - widely distributed large lowland forest tree, occasionally in submontane forest. Widely distributed A, e.g. in Z (W). Endemic status - 4.

Lepidotrichilia volkensii (Guerke) Leroy R & H - US. B & G - EU. Distribution on EU uncertain. Widely distributed A, e.g. in U (H). Endemic status - 4.

Trichilia dregeana Sond. R & H - US. Our records - 1KNS, 2L, 5G. Summary distr. EU - large tree of upper lowland and submontane forest, sometimes common. Widely distributed A, e.g. in U (H). Endemic status - 4.

Trichilia roka(Forssk.) Chiov. (syn. *T. emetica* Vahl) R & H - US. Our records - 1BS, 2L, 3L, 4, 6. Summary distr. EU - medium-sized lowland forest tree. Widely distributed A, e.g. in Z (W). Endemic status - 4. (This species should be checked as there may be confusion with other Trichilias.)

MELIANTHACEAE

Bersama abyssinica Fresen. FTEA - T3, EU (Amani, Mt Bomole, Ngambo, Bulwa). R & H - US. Our records - 1KS, 2L*(H 86/202 det. EAH), 3M, 6*(R & M 2286 det. LH). Summary distr. EU - small submontane forest tree of gaps. Widely distributed A (FTEA). Endemic status - 4.

MIMOSACEAE

Albizia adianthifolia (Schumach.) W.F. Wight FTEA - T3, EU (Amani). R & H - US. Not seen during present survey. Widespread in A (FTEA). Endemic status - 4.

Albizia glaberrima (Schumach. & Thonn). Benth. (syn. *A. glabrescens* Oliv.) FTEA - T3, EU (Sigi-Kwamkuyu). R & H - EU. Our records - 1S, 2L, 3L, 4, 6. Summary distr. EU - common large lowland forest tree. Widely distributed A (FTEA). Endemic status - 4.

Albizia gummifera (J.F. Gmel.) C.A. Sm. FTEA - T3. R & H - US. Our records - 1BKNS, 2KL, 3LM, 4, 5A, 6. Summary distr. EU - common large submontane forest tree, occasionally in upper parts of lowland forest. Widely distributed A (FTEA). Endemic status - 4.

Albizia zimmermannii Harms FTEA - T3, EU (Amani, Kwamshindi). R & H - US. Our records - 5A, 6. Summary distr. on EU - large lowland forest tree only seen on Mhinduro & Mtai. Widely distributed eastern EA & to S (FTEA). Endemic status - 3.

Newtonia buchananii (Baker) Gilb. & Bout. FTEA - T3, EU (Amani). R & H - US. Our records - 1BKNS, 2KL, 3L, 4, 6. Summary distr. EU - large common widely distributed submontane forest tree. Widely distributed A (FTEA). Endemic status - 4.

Newtonia hildebrandtii (Vatke) Torre FTEA - T3. R & H - US. Our records - 1S, 2L. Summary distr. EU - large lowland forest tree. Widely distributed eastern EA & to S (FTEA). Endemic status - 3.

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Newtonia paucijuga (Harms) Brenan FTEA - T3, EU (Longuza). R & H - US. Our records - 2L, 3M, 4, 5AG*(R & M 2254 det. LH), 6. Summary distr. EU - large lowland forest tree. Only known EK & ET (FTEA). Endemic status - 3.

Parkia filicoidea Welw. ex Oliv. FTEA - T3, EU (Sigi-Kwamkuyu rivers). R & H - US. Our records - 1KS, 2L, 3LM, 6. Summary distr. EU - large lowland forest tree, occasionally in submontane forest. Widely distributed A (FTEA). Endemic status - 4.

MONIMIACEAE

Xymalos monospora (Harv.) Baill. FTEA - T3. R & H - US. Our records - 1BNK, 2L. Summary distr. EU - small submontane forest tree of gaps, only known from main range. Widely distributed A (FTEA). Endemic status - 4.

MORACEAE

Antiaris toxicaria Lesch. R & H - US. Our records - 1BKS, 2LK, 3L*(R * M 2268 det. LH)M, 4, 5AG, 6. Summary distr. EU - large common widely distributed lowland forest tree, occasionally in submontane forest. Widely distributed A, e.g. in U (H). Endemic status - 4.

Dorstenia kameruniana Engl. (syn. *Craterogyne kameruniana* (Engl.) Lanjouw) Our records - 1S*(R & M 1845 det. LH), 2KL, 3L*(R & M 1871 det. LH)M, 4, 6. Summary distr. EU - small lowland forest tree. Found EK (D & G), ET (B & W). Endemic status - 3.

Ficus cyathistipula Warb. (syn. *F. rhynchocarpa* Mildbr. & Burret) R & H - US. Our records - 2L*(R & M 1981 det. LH). Summary distr. EU - small lowland forest tree. Widespread in A, e.g. in K (D & G). Endemic status - 4.

Ficus exasperata Vahl Our records - 1BKS, 2L, 4, 5AG, 6*(H 86/133 det. EAH). Summary distr. EU - common medium-sized lowland and submontane forest tree. Widespread A, e.g. in Z (W). Endemic status - 4.

Ficus lutea Vahl (syn. *F. subcalcarata* Warb. & Schweinf.) R & H - US. B & G - EU. Our records - 1B, 2L, 3L. Summary distr. EU - small lowland forest tree. Widespread in A, e.g. K (D & G). Endemic status - 4.

Ficus natalensis Hochst. Our records - 2L, 3L, 4. Summary distr. EU - small tree/strangler in lowland forest. Widespread in A, e.g. Z (W). Endemic status - 4.

Ficus scassellattii Pampanini (syn. *F. kirkii* Hutch.) R & H - US. B & G - EU. Our records - 2L, 3L, 4. Summary distr. EU - small submontane forest tree/strangler. Found EU, WU (B & G) & Tavetta (D & G); widespread in A (FTEA typescript). Endemic status - 4.

Ficus sur Forssk. (syn. *F. capensis* Thunb.) R & H - US. Our records - 1BKS, 2KL*(H 86/204 det. EAH), 4, 5AG. Summary distr. EU - large lowland and submontane forest tree. Probably the commonest large Ficus. Widespread in A, e.g. in Z (W). Endemic status - 4.

Ficus sycomorus L. R & H - US. Our records - 1S*(H 86/86 det. KEW), 5AG*(H 87/12 det. LH), 6*(H 86/125 det. KEW). Summary distr. EU - large lowland forest tree. Widespread in A, e.g. in Z (W). Endemic status - 4.

Ficus thonningii Blume Known from lowland and submontane forest on EU (L). Endemic status - 4.

Ficus usambarensis Warb. R & H - endemic EU, WU. P - endemic US. B & G - EU, WU. Not seen during present survey. Also in T4 (Iversen). Endemic status - 2.

Ficus vallis-choudae Del. R & H - US. Our records - 1S*(H 86/95 det. KEW), 4. Summary distr. EU - large lowland forest tree. Widely distributed A, e.g. in Z (W). Endemic status - 4.

Mesogyne insignis Engl. R & H - US. B & G - EU, WU, Ngurus, Ulugurus. Our records - 1BK*(R & M 2189 det. LH)N, 2KL, 3L*M, 5G, 6. Summary distr. EU - common small tree of submontane forest. Found as in B & G (above). Endemic status 2.

Milicia excelsa (Welw.) Berg (syn. *Chlorophora excelsa* (Welw.) Benth.) R & H - US. Our records - 1S, 2KL, 3LM, 4, 5AG, 6. Summary distr. EU - large common widely distributed lowland forest tree, occasionally in submontane forest. Widely distributed A, e.g. in U (H). Endemic status - 4.

Morus mesozygia Stapf R & H - US. Our records - 1S, 3L*(R & M 1869 det. LH)M, 5A. Summary distr. EU - large lowland forest tree. Widespread in A, e.g. in U (H). Endemic status - 4.

Myrianthus holstii Engl. (sometimes placed in family Cecropiaceae) R & H - US. Our records - 1BK*(R & M 2231 det. LH)NS, 2KL, 4, 6. Summary distr. EU - common medium-sized widely distributed submontane forest tree. Widespread in A, e.g. in U (H). Endemic status - 4.

Treculia africana Decne. R & H - US. B & G - EU. Not seen during present survey. Widespread in A, e.g. in U (H). Endemic status - 4.

Trilepsium madagascariense DC. (syn. *Bosqueia phoberos* Baill.) R & H - US. Our records - 1KS, 2KL, 3L*(R & M 1922 det. LH), 5AG, 6. Summary distr. EU - common medium-sized lowland forest tree, occasionally in submontane forest. Widely distributed A, e.g. in U (H). Endemic status - 4.

MYRISTICACEAE

Cephalosphaera usambarensis (Warb.) Warb. R & H - endemic EU, WU, P - near- endemic US. B & G - EU, WU. Our records - 1BNS, 2K*(R & M 2232 det. LH)L, 3L, 6. Also Ngurus & Ulugurus (Ruffo) and Uzungwas (L). Summary distr. EU - large submontane forest tree. Distribution as above. Endemic status - 2.

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MYRSINACEAE

Maesa lanceolata Forssk. Our records - 1B, 2KL, 4. Summary distr. EU - small submontane forest tree in gaps. Widespread in A, e.g. in U (H). Endemic status - 4.

Rapanea melanophloeos (L.) Mez R & H - US. Our records - 2L. Summary distr. EU - small tree only on Lutindi Peak. Widespread in A, e.g. in U (H). Endemic status - 4.

MYRTACEAE

Syzygium cordatum Hochst. ex Krauss R & H - US. Our records - 3LM. Summary distr. EU - small riverine tree in lowland forest. Widespread A, e.g. in U (H). Endemic status - 4.

Syzygium guineense (Willd.) DC. subsp. *afromontanum* F. White R & H - US. Our records - 1KS, 2L, 6*(R & M 2026 det. LH). Summary distr. EU - large common submontane forest tree. Widespread A, e.g. in Z (W). Endemic status - 4.

OCHNACEAE

Ochna holstii Engl. R & H - US. Our records - 1KN. Summary distr. EU - small submontane forest tree only known from S of main range. Widespread A, e.g. in K (D & G). Endemic status - 4.

Ouratea reticulata (Beauv.) Engl. (syn. *O. warneckei* Gilg & Engl.) R & H - near endemic. B & G - EU. Our records - 1AK*(R & M 2014 det. LH). Summary distr. EU - small tree only known from S of main range. Also on Uzungwas (L). Endemic status - 2.

OLACACEAE

Strombosia scheffleri Engl. FTEA - T3, EU (Kwamkoro-Sangerawe). R & H - US. Our records - 1BK*(R & M 2317 det. LH)S, 2K*(R & M 1773 det. LH)L, 3M, 4, 5G, 6. Summary distr. EU - large widely distributed common submontane forest tree. Widespread in A (FTEA). Endemic status - 4.

OLEACEAE

Chionanthus mildbraedii (Gilg & Schellenb.) Stearn Our records - 1KS*. Summary distr. EU - small tree in submontane riverine forest only known from S of main range. Widespread in A (FTEA). Endemic status - 4.

Olea capensis L. (syn *O. welwitschii* (Knobl.) Gilg & Schellenb.) FTEA - T3. R & H - US. Our records - 1K. Summary distr. EU - rare large submontane forest tree only known from S of main range. Widespread in A (FTEA). Endemic status - 4.

PALMAE

Phoenix reclinata Jacq. FTEA - T3. R & H- US. Our records - 2LZ, 6. Summary distr. EU - only known summits in Lutindi & Mtai FRs. Widely distributed A (FTEA). Endemic status - 4.

PANDANACEAE

Pandanus stuhlmannii Warb. R & H - US. B & G - EU. Our records - 1AK, 4, 6. Summary distr. EU - screw-palm of rocky places, local, possibly confined to rocky summits. Found EU & near T coast (B & G). Endemic status - 3.

PAPILIONACEAE

Angylocalyx braunii Harms FTEA - T3, EU (Singale (prob. Sengere nr. Sigi), Potwe. R & H - endemic EU, Ulugurus, Ngurus, Kenya coastal forests. Our records - 1S*(R & M 1857 det. LH), 5AG*(R & M 2047 det. LH), 6. Summary distr. EU - small lowland forest tree. Only known EK (K7), ET (T3,6) (FTEA). Endemic status - 3.

Craibia brevicaudata (Vatke) Dunn ssp. *schliebenii* (Harms) Gillett (syn. *C. gazensis* (Bak. f.) Bak. f.) FTEA - T3. R & H - US. Our records - 1S, 3L. Summary distr. EU - small lowland forest tree. Widely distributed A (FTEA). Endemic status - 4.

Craibia zimmermannii (Harms) Harms ex Dunn FTEA - T3, EU (Bomole-Amani, Amani). R & H - US. Not seen during present survey. Found ET & to S (FTEA); also Taita in K7 (TAI). Endemic status - 3.

Dalbergia boehmii Taub. FTEA - T3. Our records 3L, 5S. Summary distr. EU - medium-sized lowland forest tree. Found also WU (FTEA). Endemic status - 4.

Millettia oblata Dunn subsp. *oblata* FTEA - T3, EU (Sangarawe, Monga). Not seen during present survey. Found EU, WU (FTEA). Endemic status - 2.

Millettia sacleuxii Dunn FTEA - T3, EU (Sigi-Longuza). R & H - endemic EU, Ulugurus, Ngurus. Our records 1S*(R & M 1844 det. LH), 3M. Summary distr. EU - small lowland forest tree. Found in ET only (T3,6) (FTEA). Endemic status - 2.

Pterocarpus mildbraedii Harms subsp. *usambarensis* (Verdc.) Polhill FTEA - T3, EU (Sigi R. at Mangubu, Kwekangara, Masema). R & H - endemic EU. P - endemic US. Our records - 1S*(R & M 1864 det. LH), 3L*, 5AG. Summary distr. EU - large lowland forest tree. Endemic EU (FTEA); on Uzungwas (L). Endemic status - 2.

Pterocarpus tinctorius Welw. race "*stolzii*" FTEA - T3, EU (Amani). R & H - US. Our records - 1A*(R & M 1748 det. EAH)K*(H 86/216 det. EAH)S, 2L, 3LM, 4. Summary distr. EU - large submontane forest tree, occasionally in lowland forest. Known only from ST & ET (FTEA). Endemic status - 3.

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Schefflerodendron usambarense Harms FTEA - T3, EU (Kwamkoro, Amani, Sangarwe). P - endemic. Our records - 1K*(R & M 1752 det. LH)NS, 3L, 5AG, 6*(R & M 2034 det. LH). Summary distr. EU - medium-sized submontane forest tree. Found EU, Zaire (FTEA). Endemic status - 4.

PITTOSPORACEAE

Pittosporum viridiflorum Sims FTEA - T3, EU (Maramba, Longuza, Uberi-Monga). Not seen during present survey. Widely distributed A (FTEA). Endemic status - 4.

PODOCARPACEAE

Podocarpus latifolius (Thunb.) R.Br. ex Mirb. FTEA - T3. B & G - EU (Mlinga peak only). R & H - US. Our records - 4*(R & M 1965 det. LH). Summary distr. EU - medium-sized submontane forest tree only on Mlinga Peak. Widely distributed A (FTEA). Endemic status - 4.

RHAMNACEAE

Ziziphus mucronata Willd. FTEA - T3. Our records - 6*(H 86/106 det. KEW). Summary distr. EU - lowland forest tree. Widespread A (FTEA). Endemic status -4.

Ziziphus pubescens Oliver FTEA - T3. Our records - 6*(H 86/152 det. KEW). Summary distr. EU - lowland forest tree. Widespread A (FTEA). Endemic status -4.

RHIZOPHORACEAE

Anisophyllea obtusifolia Engl. & Brehm FTEA - T3, EU (Amani, Sangarawe). R & H - endemic EU. P - endemic US. Our records 1KNS, 2L, 3L, 4, 5A, 6. Summary distr. EU - common large submontane forest tree. Endemic EU (FTEA); on Uzungwas (L). Endemic status - 2.

Cassipourea gummiflua Tul. Herbarium specimens seen from EU, also leaves in the forest (L). Distr. on EU uncertain. Widespread A (FTEA). Endemic status - 4.

ROSACEAE

Prunus africana (Hook. f.) Kalkm. (syn. *Pygeum africanum* Hook. f.) FTEA - T3. R & H - US. Our records - 2L*(R & M 1806 det. LH). Summary distr. EU - only one tree seen, in Lutindi FR. Widespread in A (FTEA). Endemic status - 4.

RUBIACEAE

Aulacocalyx diervilleoides K. Schum. (syn. *Heinsenia diervilleoides* K. Schum.) Our records - 1K*(R & M 2250 det. LH), 2LZ*(R & H 2252 det. LH). Summary distr. EU - small submontane forest tree. Widespread A, e.g. in U (H). Endemic status - 4.

Breonadia salicina (Vahl.) Hepper & Wood Seen by Lovett at Amani on edge of scarp. Also in Malawi (C & W). Endemic status - 4.

Hallea rubrostipulata (K.Schum.) Leroy (syn. *Mitragyna rubrostipulata* (K. Schum.) Havil.) R & H - US. B & G - US. Our records - 1A. Summary distr. EU - medium-sized swamp tree only seen in submontane forest near Amani. Widespread in A, e.g. in U (H). Endemic status - 4.

Ixora scheffleri K. Schum. & K. Krause R & H - endemic EU. P - endemic US, but sp. imperfectly known. B & G - EU (nr. Derema). Not seen during present survey. Also on Uzungwas (L); there is a ssp. endemic to Mt Kenya (Beentje). Endemic status - 2.

Morinda asteroscepa K. Schum. FTEA - T3, EU (Amani, Mt. Bomole). R & H - US. P - near-endemic US. Our records - 1ABK*(R & M 2186 det. LH)MS*(H 86/94 det. KEW), 2L, 3L, 4. Summary distr. EU - large submontane forest tree growing in gaps. Found ET (T3,6), Malawi (FTEA). Endemic status - 3.

Oxyanthus pyriformis (Hochst.) Skeels ssp. *tanganyikensis* Bridson (syn. *O. goetzei* K. Schum.) Our records - 1KS, 2L, 3L*(R & M 1896 det. LH), 5A, 6. Summary distr. EU - small submontane forest tree. Found EK (D & G), ST (B & G). Endemic status - 3.

Oxyanthus speciosus DC. R & H - US. Our records - 1*(R & M 2106, 2188 det. LH)AKS, 3L, 4. Summary distr. EU - small submontane forest tree in gaps. Widespread in A, e.g. in K (D & G). Endemic status - 4.

Pauridiantha paucinervis (Hiern) Bremek. ssp. *holstii* (K. Schum). Verdc. Our records - 1M*(R & M 2330 det. LH)S, 2L, 3L. Summary distr. EU - small submontane forest tree. Widespread in A, e.g. in K (D & G). Endemic status - 4.

Polysphaeria macrantha Brenan R & H - endemic EU. P - endemic US. B & G - EU & possibly Simbili forest (Tabora Dist). Not seen during present survey. Endemic EU. Endemic status - 1.

Porterandia penduliflora (K. Schum.) Keay (syn. *Amaralia penduliflora* (K. Schum.) Wernham) R & H - endemic EU. P - near-endemic EU. B & G - EU. Our records - 1N*(R & M 1748 det. LH). Also T3, T6 & T8 (Iversen); probably also on Uzungwas (L). Endemic EU. Endemic status - 2.

Psychotria capensis (Eckl.) Vatke ssp. *riparia* (K. Schum. & K. Krause) Verdc. (syn. *Grumilea riparia* K. Schum. & K. Krause) Our records - 2L. Summary distr. EU - small tree. Specimens from Arusha & near T coast in Lushoto Herbarium; recorded Thika & Lamu District in K (D & G). Endemic status - 4.

Psydrax parviflora (Afzel.) Bridson ssp. *rubrocostata* (Robyns) Bridson R & H - US. B & G - EU (Derema). Not seen during present survey. Widespread A, e.g. U (H). Endemic status - 4.

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Rothmannia manganjae (Hiern) Keay Our records - 1BS, 2KL, 3L, 6*(H86/102 det. KEW). Summary distr. EU - small tree in lowland and submontane forest. Widespread A, e.g. in K (D & G). Endemic status - 4.

Rothmannia urcelliformis (Hiern) Bullock ex Robyns Our records - 5G* (first record EU). Summary distr. - small lowland forest tree. Widespread A, e.g. in U (H). Endemic status - 4.

RUTACEAE

Teclea nobilis Del. FTEA - T3. R & H - US. Our records 1KS, 5G. Summary distr. EU. - small submontane forest trees. Widely distributed A (FTEA). Endemic status - 4.

Teclea simplicifolia (Engl.) Verdoorn FTEA - T3. R & H - US. Our records - 2L*(R & M 2304 det. LH), 6*(H 86/20 det. KEW). Summary distr. EU - small submontane forest tree. Found in K, T & Ethiopia (FTEA). Endemic status - 4.

Teclea trichocarpa (Engl.) Engl. FTEA - T3, EU (Longuza, Derema). R & H - US. Not seen during present survey. Widely distributed A (FTEA). Endemic status - 4.

Zanthoxylum deremense (Engl.) Kokwaro FTEA - T3, EU (Derema, Amani). R & H - US. P - endemic US, but sp. imperfectly known. Not seen during present survey. Found ET & Malawi (FTEA). Endemic status - 2.

Zanthoxylum gillettii (de Wild.) Waterm. FTEA - T3, EU (Amani, Bomole, Derema). R & H - US. P - near-endemic. Our records - 1KS*(R & M 2250 det. LH), 2L, 3L, 6. Summary distr. EU - large submontane forest tree. Widely distributed A (FTEA). Endemic status - 4.

Zanthoxylum usambarense (Engl.) Kokwaro FTEA - T3. R & H - US. Our records - 1K, 2L, 5C*(R & M 2093 det. LH). Summary distr. EU - medium-sized submontane forest tree. Widely distributed A (FTEA). Endemic status - 4.

SAPINDACEAE

Allophylus melliodorus Radlk. B & G - EU (Nguelo, Monga). P - endemic US. Our records - 2L*(H 86/205 det. EAH), 6*(H 86/126 det. EAH & H 86/135 det. KEW). Summary distr. EU - small tree only known from Lutindi & Mtai. Also on Uzungwas (L). Endemic status - 2.

Allophylus stachyanthus Gilg B & G - "apparently occurs EU". Our records 1K*, 2L, 3L, 5C*(R & H 2095 det. LH), 6. Summary distr. EU - small lowland forest tree. Also on Kilimanjaro (B & G). Endemic status - 2.

Blighia unijugata Baker R & H - US. Our records - 1K*(R & H 2233 det. LH)S, 2KL, 3L, 5AG, 6*(H 86/136 det. KEW). Summary distr. EU - common medium-sized tree of lowland & submontane forest. Widespread in A, e.g. U (H). Endemic status - 4.

Chytranthus obliquinervis Radlk. R & H - endemic US. B & G - EU (Derema). Our records - 1A*S*(R & H 1808 det. LH), 2L, 3M, 4, 5AG, 6. Summary distr. EU - small lowland forest trees of gaps. Also found on the Ulugurus (specimen Lushoto Herbarium). Endemic status - 2.

Lecaniodiscus fraxinifolius Baker (syn. *L. vaughaniae* Dunkley) Our records - 1S, 2L*(H 86/201 det. EAH), 3L, 4, 5AG, 6*(H 86/104 det. KEW). Summary distr. EU - medium-sized lowland forest tree. Widespread in A, e.g. in K (D & G). Endemic status - 4.

Placodiscus amaniensis Radlk. R & H - endemic EU. P - endemic US. B & G - EU (Amani). Not seen during present survey. Could also be on Uzungwas (specimen reported to be present at KEW) (L). Endemic status - 2.

Zanha golungensis Hiern R & H - US. Our records - 1S*(R & M 2075 det. LH), 2KL, 3L, 5A, 6*(H 86/137 & H/146 det. KEW). Summary distr. EU - common medium-sized tree in lowland forest, less common in submontane forest. Widespread A, e.g. in U (H). Endemic status - 4.

SAPOTACEAE

Afrosersalisia cerasifera (Welw.) Aubrev. FTEA - T3, EU. R & H - US. Our records - 1BK*(R & M 2015 det. EAH)N, 2KL, 3L, 4, 5A, 6. Summary distr. EU - common large tree of submontane forest and upper parts of lowland forest. Widespread A (FTEA). Endemic status - 4.

Aningeria adolfi-friedericii (Engl.) Robyns & Gilbert FTEA - T3, EU (Kwamkoro). R & H - US. Our records - 1BKS, 2KL, 3L, 6. Summary distr. EU - large submontane forest tree. Widespread A (FTEA). Endemic status - 4.

Aningeria pseudoracemosa J.H. Hemsl. FTEA - T3, EU (Kihuhwi). R & H - endemic EU, Ulugurus. Not definitely seen during present survey. Found T3 (EU) & T6 (Kimboza FR) only (FTEA). Endemic status - 2.

Bequaertiodendron natalense (Sond.) Heine & J.H. Hemsl. FTEA - T3. R & H - US. Our records - 1S*(R & M 1880 det. LH), 2L, 3L, 5AG, 6. Summary distr. EU - common widely distributed lowland forest tree, rare in submontane forest. Widely distributed A (FTEA). Endemic status - 4.

Chrysophyllum gorungosanum Engl. FTEA - T3. R & H - US. Our records - 1BK*(H 86/23 det. EAH), 2L, 6. (This sp. has probably sometimes been confused with *C. perpulchrum* in the field). Summary distr. EU - large submontane forest tree. Widely distributed A (FTEA). Endemic status - 4.

Chrysophyllum perpulchrum Mildbr. ex Hutch. & Dalz. FTEA - T3, EU (Amani - Kwamkoro Rd. & Kwamkoro). R & H - US. Our records - 1KS, 6. (See note under *C. gorungosanum*). Summary distr. EU - large submontane forest tree, probably commoner than *C. gorungosanum*. Widely distributed A (FTEA). Endemic status - 4.

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Malacantha alnifolia (Baker) Pierre FTEA - T3, EU (Sigi valley). R & H - US. Our records - 1S, 2L, 3L, 5AG. Summary distr. EU - common medium-sized lowland forest tree, occasionally in submontane forest. Widely distibuted EA & Sudan (FTEA). Endemic status - 4.

Manilkara obovata (Sabine & G. Don) J.H. Hemsl. Our records - 1K*(H86/18 det. EAH) (new record for T3 & EU). Summary distr. EU - big tree in submontane forest only known from S end of main range. Widely distributed A (FTEA). Endemic status - 4.

Manilkara sulcata (Engl.) Dubard FTEA - T3. R & H - US. Our records - 2L, 3L. Summary distr. EU - small lowland forest tree. Found EK & ET only (FTEA). Endemic status - 3.

Manilkara sp. 1 (of FTEA) FTEA - T3, EU (Ngua-Kwamkoro). Only known from collection in 1936; probably endemic but more material needed (FTEA). Not seen during present survey. Endemic status - uncertain.

Mimusops aedificatoria Mildbr. FTEA - T3, EU (Amani (Kiumba) & nr. Mashewa). R & H - US. Not seen during present survey. Found EK, ET, ST & Malawi (FTEA). Endemic status - 3.

Mimusops kummel A.DC. FTEA - T3. Our records - 5G. Summary distr. EU - medium-sized lowland forest tree. Widely distributed A (FTEA). Endemic status - 4.

Pachystela msolo (Engl.) Engl. FTEA - T3, EU (Amani area). R & H - US. Our records - 1S, 2KL, 3LM, 4, 5AG, 6. Summary distr. EU - common widely distributed lowland forest tree, occasional in submontane forest. Widely distributed A (FTEA). Endemic status - 4.

Vincentella passargei (Engl.) Aubrev. Our records - 6*(H 86/150 det. KEW). In lowland forest, only seen on Mtai. Widespread A (FTEA). Endemic status - 4.

Vitellariopsis cuneata (Engl.) Aubrev. FTEA - T3 (WU). Our records - 6*(H 86/109 det. KEW). In lowland forest, only seen on Mtai. Found WU (FTEA) & Uzungwas (L). Endemic status -2.

SIMAROUBACEAE

Odyendea zimmermannii Engl. R & H - US. P - near-endemic US. B & G - EU. Our records - 1KNS, 2KL, 3LM, 4, 6. Summary distr. EU - common submontane forest tree. Also Ngurus (specimen Lushoto Herbarium); Uzungwas (L) & EK (L); T7 (KTSL). Endemic status - 2.

STERCULIACEAE

Cola greenwayi Brenan R & H - US. P - endemic US. Our records - 1K*(R & M 2247 det. EAH), 2L. Summary distr. EU - small forest tree. Also on WU (Ruffo); T7 (TAI); widespread (Iversen). Endemic status - 2.

Cola microcarpa Brenan Our records -6. Only known Mtai. Also known Ulugurus (herbarium specimens EAH & Lushoto). Endemic status - 2.

Cola scheffleri K. Schum. R & H - endemic EU. Polhill - near-endemic EU. B & G - EU (Derema). Our records - 1S*, 2L, 5AG, 6*(H86/118 det. KEW). Summary distr. EU - widely distributed medium-sized lowland forest tree. Endemic EU. Endemic status - 1.

Cola usambarensis Engl. R & H - US. P - endemic US. B & G - EU (near Amani). Our records - 1K*N*(R & M 2025)S*(R & M 2246). Summary distr. EU - small submontane forest tree only known from S end of main range. Endemic EU. Endemic status - 1.

Leptonychia usambarensis K. Schum. R & H - endemic EU, WU, Kilimanjaro, Kenya coastal forests. P - near-endemic US. Our records - 1BKM*(R & M 1754 det. LHS), 2KLZ*(R & M 1789 det. LH), 3L, 4, 5AG*(R & M 1971 det. LH), 6. Summary distr. EU - common small lowland forest tree, occasionally in submontane forest. Distributed NE T & coastal K, T7 (Taita) (TAI). Endemic status - 3.

Sterculia appendiculata K. Schum. R & H - US. Our records - 1S*(R & M 1821 det. LH), 2LZ*, 4, 5A, 6. Summary distr. EU - large lowland forest tree. Coastal K (D & G) & coastal T (B & G). Endemic status - 3.

THEACEAE

Ficalhoa laurifolia Hiern FTEA - T3. R & H - US. Our records - 1K, 2. Summary distr. EU - large submontane forest tree of ridges, only on main range. Widely distributed A (FTEA). Endemic status -4.

TILIACEAE

Grewia goetzeana K. Schum. Our records - 1S, 2L, 3L, 5A, 6*(H 86/103 det. KEW & H 86/114 det. KEW). Summary distr. EU - small lowland forest tree. Coastal T (B & G). Endemic status - 3.

ULMACEAE

Celtis africana Burm. f. FTEA - T3. R & H - US. Our records - 1S, 2L, 3L, 5A*(R & M 2052 det. LH), 6. Summary distr. EU - small lowland forest tree. Widely distributed A (FTEA). Endemic status - 4.

Celtis gomphophylla Bak. (syn. *C. durandii* Engl.) FTEA - T3. Our records - 1M*(R & M 1763 det. LH)S, 2KL, 3L, 4, 5A, 6. Summary distr. EU - medium-sized lowland forest tree. Widely distributed A (FTEA). Endemic status - 4.

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Celtis mildbraedii Engl. FTEA - T3, EU (Amani). R & H - US. Our records - 1KS, 2KL, 3LM, 4, 5AG, 6*(H 86/107, 86/111, 86/139 det. KEW). Summary distr. EU - common large lowland forest tree, occasional in submontane forest. Widely distributed A (FTEA). Endemic status - 4.

Celtis wightii Planch. FTEA - T3, EU (Magunga Estate). R & H - US. Our records 1K*(R & M 2301 det. LH), 3L*(R & M 2120 det. LH), 5AG, 6*(H 86/100 det. KEW). Summary distr. EU - small submontane forest tree. Widely distributed A (FTEA). Endemic status - 4.

Celtis zenkeri Engl. FTEA - T3, EU (Magunga Estate). R & H - US. Our records - 1BS*, 2L, 3L. Summary distr. EU - large lowland forest tree, occasional in submontane forest. Widely distributed A (FTEA). Endemic status - 4.

Trema orientalis (L.) Bl. FTEA - T3. R & H - US. Our records - 1BS, 2L, 4, 5A. Summary distr. EU - small lowland and submontane forest tree of gaps. Widely distributed A; also in Asia (FTEA). Endemic status - 4.

VERBENACEAE

Premna chrysoclada (Bojer) Guerke Our records - 1S*(R & M 1880 det. LH), 2L, 3LM, 5A, 6. Summary distr. EU - small lowland forest tree. ET (B & G) & EK (D & G). Endemic status - 3.

Vitex amaniensis Pieper B & G - EU (Amani). P - near-endemic US. Our records - 1KN*(det. KEW)S*(R & H 2172 det. LH), 5A. Summary distr. EU - small submontane forest tree, rare in lowland forest. Also on Ulugurus (specimen in Lushoto Herbarium). Endemic status - 2.

3. Provisional list of introduced trees naturalized in the forests

(For abbreviations to localities, see Section 1.)

BIGNONIACEAE

Spathodea campanulata P.Beauv. Occasionally invading gaps in submontane forest; also commonly invading abandoned tea-estates.

EUPHORBIACEAE

Hevea brasiliensis (A. Juss.) Muell Arg. Our records - 3L. Invading lowland forest, uncommon.

Hura crepitans L. Invading forest gaps near Fanusi.

GUTTIFERAE

Garcinia sp. "*tinctoria*" Our records - 1S*(R & M 1760 det. LH).

MELIACEAE

Cedrela odorata L. Our records - 1K, 3L. Invading gaps in lowland and submontane forest, not widespread.

Melia azedarach L. Our records - 1S, 3L. Invading lowland gaps, very common in Kwamsambia FR.

MIMOSACEAE

Albizia chinensis (Osbeck) Merr. Our records - 1KS, 2L, 4, 5G, 6. Invading gaps, mostly in submontane forest, not particularly common.

MORACEAE

Ficus altissima Blume Our records - 3L*(R & M 2151 det. EAH), 5A. Invading lowland forest, not common.

PALMAE

Elaeis guineensis Jacq. Our records - 3LM. Invading lowland forest. According to Beentje (pers. comm.) this is almost certainly indigenous.

PAPILIONACEAE

Millettia dura Dunn Our records - 1KS, 2L*(R & M 2309 det. LH), 3L, 4, 5A. Invading gaps in submontane forest, common.

RHAMNACEAE

Hovenia dulcis Thunb. Our records - 1A*(R & M 2072 det. LH). Invading forest near Amani.

Maesopsis eminii Engl. Our records - 1BKNS, 3L, 5A. Very commonly invading gaps in submontane forest, less common in lowland forest.

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4. List of other forest plants

This is a list of other plants (not trees) recorded (mainly by Ruffo, Mmari and Linder) during the course of field work on the East Usambaras during 1986–87. Unlike the list of trees given earlier, THIS LIST IS CERTAINLY VERY INCOMPLETE and is given here merely by way of a record. Abbreviations are as used earlier. An additional source used for plant nomenclature is Agnew (1974).

ACANTHACEAE

Acanthus pubescens (Oliv.) Engl. 2L
Asystasia gangetica (L.) T. Anders. 1N*(Linder 3732 det. EAH)
Brachystephanus africanus S. Moore 1K*(R & M 2116 det. LH)
Brachystephanus holstii Lindau 3L*(R & M 1800)
Brillantaisia madagascariensis Lindau 2*(Linder 3756 det. EAH)
Crossandra nilotica Oliv. 6
Crossandra pungenus Lindau 2M*(R & M 1934 det. LH)
Crossandra tridentata Lindau 1M*(R & M 1765 det. LH)
Hypoestes verticillaris (L. f.) Br. 1K*(R & M 2058 det. LH)
Isoglossa dichotoma (Hassk.) B. Hansen (syn. *I. lactea* Lindau) 1K*(H 86/46 det. EAH)N*(Linder 3728 det. EAH), 6M
Justicia anisophylla (Mildbr.) Brumm 1M*(R & M 2240 det. LH)
Justicia engleriana Lindau (syn. *Adhatoda engleriana* C.B.Cl.) 6*(Linder 3780 det. EAH)
Justicia grandiflora Mildbr. 1K*(R & M 1836 det. LH)
Justicia inaequalis Brummit. 1M*(R & M 1826 det. LH)
Justicia interrupta (Lindau) C.B.Cl. 2L*(R & M 1986 det. LH)
Justicia nyassana Lindau 1S*(Linder 3764 det. EAH), 2Z*(R & M 1778 det. LH)
Justicia pseudorungia Lindau 1BS*(R & M 1824 det. LH)
Macrorungia pubinervia (T. Anders.) C.B.Cl. 1K*(R & M 2227 det. LH)
Phaulopsis imbricata (Forssk.) Sweet 3M
Pseuderanthemum hildebrandtii Lindau 6*(Linder 3775 det. EAH)
Pseuderanthemum tunicatum (Afzel.) Milne - Redh. 1K*(H 86/83 det. EAH)
Sclerochiton boivinii (Baill.) C.B.Cl. 1K*(Linder 3796 det. EAH)M*(R & M 2245, 2278 det. LH)N*, 4M
Sclerochiton holstii (Lindau) C.B.Cl. 1K*(R & M 2065 det. LH)
Stenandriopsis warneckei (S.Moore) Napper 6*(R & H 2029 det. LH)
Thunbergia usambarica Lindau 3M
Whitfieldia elongata (Beauv.) De Wild. & Dur. 1S*(R & M 1956 det. LH), 2L*(Linder 3758 det. EAH), 4, 5A, 6

AGAVACEAE

Dracaena deremensis Engl. 1BS*(R & M 1884 det. LH), 2L*(R & M 1757 det. LH), 4, 6*(Linder 3784 det. EAH)
Dracaena laxissima Engl. IBK*(R & M 2266 det. LH)M*(R & M 2267 det. LH)S 2KL, 3L, 4, 5A, 6
Dracaena usambarensis Engl. 2L
Sanseviera kirkii Baker

ALISMATACEAE

Sagittaria montevidensis Cham. & Schlechtd. subsp. *montevidensis* 2L*(Linder 3757 det. EAH)

AMARANTHACEAE

Achyranthes aspera L. var. *pubescens* (Moq.) C.C. Townsend 1K*(Linder 3798 det. EAH)

ANNONACEAE

Lettowianthus stellatus Diels 1S*(R & M 1927 det. LH)
Mkilua fragrans Verdc. 3L*(R & M 2006B), 5C*(R & M 2006A)
Monanthotaxis trichocarpa (Engl. & Diels) Verdc. 2L*, 3L*, 5A, 6
Monodora sp. cf. *grandidieri* Baill. 3L*(R * M 1905 det. LH)
Polyalthia stuhlmannii (Engl.) Verdc. 1K*(R & M 2280)

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Sphaerocoryne gracilis (Engl. & Diels) Verdc. 5C*(R & M 2007 det. LH)

Uvaria acuminata Oliv. 1S, 2L, 3M

Uvaria dependens Engl. & Diels 1N*(R & M 2230 det. EAH)

Uvariodendron sp. nr. *gorgonis* Verdc. 1K*(R & M 1726 det. EAH), 5C*(R & M 1740 det. EAH), 6*(R & M 1738 det. EAH)

APOCYNACEAE

Carvalhoa campanulata K. Schum. 1M*(R & M 2281), 5G*(R & M 2053 det. EAH), 6*(R & M 2282)

Landolphia kirkii Dyer 1M*(R & M 2221 det. EAH)S

Oncinotis tenuiloba Stapf s.l.*(H 86/87 det. Kew)

Pleiocarpa pycnantha (K. Schum.) Stapf 1K*(R & M 2129 det. LH), 3L*

Rauvolfia caffra Sond. 2L

R. mannii Stapf 1K*(Linder 3737 det. EAH)S*, 2L*(R & M 1994 det. EAH), 3L, 6

R. rosea K. Schum. 1K*(R & M 1958 det. LH)K/S*

R. volkensii (K. Schum.) Stapf 1K*(R & M 2288 det. LH)S, 2L*

Saba comorensis (Boj.) A.DC. (syn. *S. florida* (Benth.) Bullock) 1S, 3L, 4, 5A

Schizozygia coffaeoides Baill. 1M*(R & M 2196)S, 2Z*(R & M 1787 det. LH), 3L*(R & M 1950 det. LH)M, 6

Voacanga africana Stapf 3L*(R & M 1916 det. LH)

ARACEAE

Calopsis volkensii Engl. 1S*(R & M 1960 det. LH)

Culcasia orientalis Mayo 6

(*Culcasia 'scandens'*, a name with a confused application and which has been used for two species found in FTEA area T3, is very abundant everywhere in the forests).

Gonatopus boivinii (Decne.) Engl. 6*(Linder 3787 det. EAH)

BALSAMINACEAE

Impatiens usambarensis Grey-Wilson 1K*(R & M 2235 det. LH), 2L

Impatiens walleriana Hook. f. 1N*(Linder 3781 det. EAH)

BEGONIACEAE

Begonia oxyloba Hook. f. 1K*(R & M 2190 det. LH; Linder 3800 det. EAH)), 2L

BORAGINACEAE

Ehretia cymosa Thonn. 1S, 2L

BURMANNIACEAE

Gymnosiphon usambaricus Engl. 6*(R & M 2035 det. EAH)

BUXACEAE

Notobuxus acuminata (Gilg) Hutch. 5C*(R & M 1735 det. EAH: new record)

N. obtusifolius Mildbr. 2M*(R & M 2140 det. EAH)

N. sp. nov. (Rodgers & J. Hall 2505) 3M*(R & M 1736 det. EAH)

CAPPARIDACEAE

Capparis erythrocarpos Isert var. *rosea* (Klotzsch) De Wolf 1S

Capparis viminea Oliv. var. *viminea* 5S*(R & M 2043 det. EAH)

CELASTRACEAE

Pristimera graciliflora (Oliv.) N. Halle 5S*(R & M 2056 det. EAH)

Salacia lehmbachii Loes. var. *usambarensis* Loes. 1K*(R & M 2169 det. LH), 2L, 5A

COMMELINACEAE

Palisota schweinfurthii C.B.Cl. 1K*(Linder 3803 det. EAH)

Pollia condensata C.B.Cl. 1N*(Linder 3810 det. EAH)S, 2L, 5A, 6*(R & M 2286 det. EAH)

Stanfeldiella imperforata (C.B.Cl.) Brenan var. *imperforata* 1K*(R & M 2016 det. EAH)

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COMPOSITAE

Ageratum houstonianum Mill. 1N*(Linder 2735 det. EAH)

Crassocephalum bojeri (DC.) Robyns 2L

Vernonia pteropoda Oliv. & Hiern 1N*(Linder 3731 det. EAH)

CONNARACEAE

Agelaea heterophylla Gilg 1K* (H 86/41 det. EAH)

CUCURBITACEAE

Gerrardanthus lobatus (Cogn.) C. Jeffrey 1K*(R & M 2174 det. LH)

Momordica friesiorum (Harms.) C. Jeffrey 1K* (H 86/66 det. EAH)

Raphidiocystis chrysocoma (Schumach.) C. Jeffrey 1K*(R & M 2178 det. EAH)

CYCADACEAE

Encephalartos hildebrandtii A. Br. & Bouche 6

CYPERACEAE

Hypolytrum testui Cherm. 1K*(Linder 3797 det. EAH)

DICHAPETALACEAE

Dichapetalum ruhlandii Engl. 1M*(R & M 2318 det. LH)S, 3L, 5G*(H87/10 det. LH)

DIOSCOREACEAE

Dioscorea quartiniana A. Rich. 2Z*(R & M 2295 det. LH)

Dioscorea sansibarensis Pax 1K*(R & M 2166 det LH)

ERYTHROXYLACEAE

Erythroxylum emarginatum Thonn. 6

Erythroxylum fischeri Engl. s.l.* (H 86/200 det. EAH)

EUPHORBIACEAE

Acalypha engleri Pax 2K*(R & M 2159 det. LH)

Acalypha neptunica Muell. Arg. 3M*(R & M 1963 det. LH)

Acalypha ornata A. Rich. 1S, 2L, 3M, 4, 6

Acaphyla racemosa Baill. 1S*(R & M 1793 det. LH)

Argomuellera basicordata (Peter) R. Smith 5C*(R & M 2000 det. LH)

Drypetes subdentata Mildbr. 1K*(R & M 2074 det. LH)

Erythrococca usambarica Prain 1K*S*(Linder 3767 det. EAH; R & M 1810, 2212 det LH), 2L, 3L*(R & M 2124 det. EAH), 5A, 6

Exococaria madagascariensis (Baill.) Muell. Arg. 5A*(R & M 2003 det. EAH)

Hostia tenuifolia (Pax) Rauschert 5C*(R & M 2087 det. EAH)

Margaritaria discoidea (Baill.) Webster 5C*(R & M 2055 det. LH)

Meineckia phyllanthoides Baill. 3L*(R & M 1850 det. EAH)

Micrococca holstii (Pax) Prain 1K*(R & M 2111 det. EAH)N*(Linder 3770 det. EAH)

Micrococca scariosa Prain 5G*(R & M 2042 det. EAH)

Mildbraedia fallax (Pax) Hutch. 3M*

Phyllanthus inflatus Hutch. 1B*(R & M 2291 det. LH),K*(R & H 2292 det. LH), 3L

Phyllanthus valliifolius Forssk. 3L*(R & M 1928 det. EAH)

Pycnocoma macrantha Pax 1K*(R & M 2168 det. EAH)M* (R & M 2196), 5C*(R & M 1999 det. LH)

Suregada lithoxyla (Pax & K. Hoffm.) Croiz. (syn. *S. procera* (Prain) Croizat) 1K*(R & M 2073 det. LH)S, 2LM, 5A

Suregada zanzibarense (Baill.) Mill. 3L*(R & M 1907 det. LH), 5C*(R & M 2005 det. LH)

Tragia brevipes Pax 2L

Zimmermannia capillipes Pax 1K*(R & M 2176 det. EAH), 2L*(R & M 1995 det. LH)

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FLACOURTIACEAE

Flacourtia indica (Burm. f.) K*Merrill 2L

Grandidiera boivinii Taub. 1K*(*R & M 2292 det. LH)S*, 2L*(R & M 2292 det. LH), 3L*(R & M 2128 det. LH)

Ludia mauritiana Gmelin 2L*(R & M 2294 det. LH)

Scolopia zeyheri (Nees) Harv. 1S, 2Z*(R & M 1781 det. EAH)

FLAGELLARIACEAE

Flagellaria guineensis Schum. 5C*(R & M 2163 det. LH)

GESNERIACEAE

Streptocarpus caulescens Vatke 6*(Linder 3777 det. EAH)

Streptocarpus glandulosissimus Engl. 4

GRAMINEAE

Cyrtococcum multinode (Lam.) Clayton 6*(Linder 3773 det. EAH)

Leptaspis cochleata Thwaites 1K*(H 86/47 det. EAH), 2L*(R & M 2294 det. LH), 6

Olyra latifolia L. 1S, 2KL, 3L*(R & M 1901 det. LH)M, 5A, 6

Oplismenus hirtellus (L.) P. Beauv. 2Z*(R & M 2325 det. LH)

Panicum brevifolium L. 1N*(Linder 3726 det. EAH)

Paspalum conjugatum Berg. 1N*(Linder 3730 det. EAH)

Setaria chevalieri Stapf & C.E.Hubb. 1S*(R & M 1796 det. LH)

GUTTIFERAE

Vismia orientalis Engl. 3L*(R & M 1903 det. LH)

HIPPOCRATEACEAE

Hippocratea volkensii Loes. 1S

Salacia lehmbachii Loes. var. *usambarensis* Loes. 2L

ICACINACEAE

Iodes usambarensis Sleumer 1K*(R & M 2130 det. EAH)

Leptaulus holstii (Engl.) Engl. 1K*(R & M 2131 det. LH), 2L

LABIATAE

Achyrospermum carvalhi Guerke 2*(Linder 3759 det. EAH)

Hoslundia opposita Vahl 1B, 3LM, 4

Platostoma africana P. Beauv. 1N*(Linder 3734 det. EAH)

LILIACEAE

Asparagus buchananii Bak. 3L*(R & M 1931 det. EAH)

Chlorophytum filipendulum Bak. K*(H 86/21 det. EAH)N*(Linder 3727 det. EAH)

LOBELIACEAE

Lobelia fervens Thunb. 1N*(Linder 3733 det. EAH)

Lobelia longisepala Engl. 1A*(R & M 2206 det. EAH)

LOGANIACEAE

Mostuea brunonis Didr. 3L*(R & M 1853 det. EAH)

Strychnos henningsii Gilg 3M

Strychnos scheffleri Gilg & Busse 1KS*(R & M 1817 det. LH), 3L, 4

MALPIGHIACEAE

Triaspis mozambica A. Juss. 3L*(R & M 1877 det. LH)

MARANTACEAE

Marantochloa leucantha (K. Schum.) Milne-Redh. 1A*K*(H86/2 det. EAH) 4, 6

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MELASTOMATACEAE

Calvoa orientalis Taub. 1B*(R & M 1892 det. LH)K*S, 2L*(R & M 1984 det. LH)

Clidemia hirta (L.) D. Don 1BKM*(R & M 1983 det. LH)S (very common naturalized shrub)

Memecylon amaniense (Gilg) A. & R. Fernandes 2K*L

Memecylon brenanii A. & R. Fernandes 1S, 2L, 3L

Memecylon cogniauxii Gilg 1KN*(R & M 2019 det. LH), 2L, 3L, 4

Memecylon erubescens Gilg 1N*, 2L*(R & M 2020 det. EAH), 3*(R & M 1879 det. LH)LM, 4

Memecylon microphyllum Gilg 2L*(R & M 2071)

Memecylon semseii A. & R. Fernandes 1B, 2L*(R & M 1770 det. EAH), 3M, 6*(R & M 2031 det. EAH)

MELIACEAE

Turraea holstii Guerke 1K*(R & M 1947 det. LH)

Turraea robusta Guerke 3L

MENISPERMACEAE

Cissampelos mucronata A. Rich. 2Z*

Cissampelos nigrescens Diels 1M*

Tiliacora funifera (Miers) Oliv. 1K*(H 86/39, 86/44, 86/65, 86/74, det. EAH)

Triclisia sacleuxii (Pierre) Diels 5S*(R & M 2296 det. EAH)

MIMOSACEAE

Acacia schweinfurthii Brenan & Exell 1S, 2L, 3LM, 5A

Entada pursaetha DC. 1S, 2L, 6

MORACEAE

Dorstenia alta Engl. 1K* (H 86/217 det. EAH)

Dorstenia hildebrandtii Engl. var. *schlechteri* (Engl.) M. Hijman 2K*, 3L*, 5A

Dorstenia holstii Engl. 1K*(Linder 3736 det. EAH)M*, 2L*(R & M 1992 det. EAH), 6*(R & M 2030 det. EAH)

Dorstenia orientalis De Wild. 1S*(R & M 1847 det. EAH)

MUSACEAE

Ensete ventricosum (Welw.) Cheesm. 1B, 2L

OCHNACEAE

Ochna macrocalyx Oliv. 5C*(R & M 1988 det. LH)

Ouratea sacleuxii (V. Tiegh.) Farron 3L*(R & M 1933 det. EAH)

ORCHIDACEAE

Corymborkis corymbosis Thou. 1S*(Linder 3769 det. EAH)

Nervilia umbrosa (Rchb. f.) Schltr. 1S*(Linder 3762 det. EAH), 5G*(R & M 1973 det. LH)

Polystachya pudorina Cribb 1L*(Linder 3789 det. EAH)

PAPILIONACEAE

Canavalia cathartica Thouars 5C*(R & M 1978 det. LH)

Dalbergia lactea Vatke 1BS, 2L, 3LM, 6

Dolichos trilobus L. 1K*(R & M 2270 det. EAH)

Glycine wightii (Wight & Arn.) Verdc. 1A*(R & M 2205 det. LH)

Lablab purpureus (L.) Sweet 2L*(R & M 1989 det. LH)

Lonchocarpus bussei Harms 3L*(R & M 1908 det. LH)

Tephrosia aequilata Bak. 2L*(R & M 1805 det. LH)

Tephrosia vogelii Hook. f. 4

PASSIFLORACEAE

Basananthe hanningtoniana (Mast.) de Wilde 1N*(Linder 3748 det. EAH)

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PHYTOLACCACEAE

Hilleria latifolia (Lam.) H. Walt. 2L*(R & M 1756 det. LH)

PIPERACEAE

Peperomia fernandopoiana C. DC. 6*(Linder 3778 det. EAH)
Piper capensis L. 1BS, 2KL, 6
Piper umbellatum L. 1BS, 2KL, 3L, 5A

POLYGALACEAE

Polygala paniculata L. 1N*(Linder 3729 det. EAH)

PRIMULACEAE

Ardisiandra sibthorpioides Hook. f. 1M*(R & M 2234 det. EAH)

RHAMNACEAE

Gouania longispicata Engl. 1S

ROSACEAE

Rubus niveus Thunb. 3L (an introduced species)
Rubus pinnatus Willd. 1BS
Rubus rosifolius Sm. 1BK (introduced shrub, very common under *Maesopsis* stands)

RUBIACEAE

Canthium hispidum Benth. 2L*(R & M 1803), 5A
Chassalia albiflora K. Krause (syn. *C. buchwaldii* K. Schum.) 1K*(R & M 2023 det. EAH)M*R & M 2237 det. LH), 2L, 3M, 4
Chassalia discolor K. Schum. 2L*(R & M 1799 det. LH), 3L
Chassalia parvifolia K. Schum. 1*(R & M 2057 det. EAH)AK, 2L*(R & M 1798B det. LH), 4
Chassalia zimmermannii Verdc. 6
Chazaliella abrupta (Hiern) Petit & Verdc. 1*(R & M 2327 det. LH)AM, 2L*(R & M 2328 det. LH), 4
Cremaspora triflora (Thonn.) K. Schum. 1BKS*(R & M 2112 det. LH), 2K, 3L*(R & H 1893 det. LH)
Dictyandra arborescens Benth. & Hook. f. 1B*K*S*(R & M 1915 det. LH), 2K, 3L*,M
Didymosalpinx norae (Swyn.) Keay 5C*
Gardenia posoqueroides S. Moore 5S*(R & M 2008 det. LH)
Geophila obvallata (Schumach.) F. Didr. subsp. *ioides* (K. Schum.) Verdc. 5C*(R & M 2066 det. EAH)
Heinsia zanzibarica (Boj.) Verdc. (syn. *H. densiflora* Hiern) 3L
Ixora scheffleri K. Schum. & K. Krause 1K
Kraussia speciosa Bullock 1S*(R & M 1957 det. LH), 3L*(R & M 1925 det. LH)
Lagynias pallidiflora Bullock 1AS*(R & M 1943 det. LH), 4, 5, s.l.*(H 86/149 det. KEW)
Lasianthus kilimandscharicus K. Schum. 1BS, 2K
Leptactina platyphylla (Hiern) Wernh. 1S*(R & M 1887 det. LH)
Mussaenda arcuata Poir. 1K*
Pavetta abyssinica Fresen. (syn. *P. silvicola* Bremek.) 1S*(R & M 2145 det. LH)
Pavetta amaniensis Bremek. var. *amaniensis* 1N*(Linder 3747 det. EAH)
Pavetta holstii K. Schum. 1K*(R & M 2061 det. EAH), 3L, 5A, 6
Pavetta stenosepala K. Schum. 1A*(R & M 2198 det. EAH)
Pentas bussei Krause 3L*(R & M 2118 det. LH)
Polysphaeria multiflora Hiern 5A
Polysphaeria parvifolia Hiern 2K*(R & M 1783 det. LH), 3L
Psychotria brevicaulis K. Schum. 1M*(R & M 2204 det. EAH)
Psychotria cryptogrammata Petit 1S*(R & M 1815 det. LH)
Psychotria faucicola K. Schum. 1S*(Linder 3763 det. EAH), 6
Psychotria goetzei (K. Schum.) Petit var. *platyphylla* (K. Schum.) Petit 1M*(R & M 2208 det. LH)
Psychotria griseola K. Schum. 5A, 6*(R & M 2028 det. EAH)

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Psychotria holstii K. Schum. 1N*(Linder 3771 det. EAH)S*(Linder 3766 det. EAH)

Psychotria lauracea (K. Schum.) Petit 1S*(R & M 1942 det. EAH), 5G*(R & M 2044 det. LH)

Psychotria leucopoda Petit 1S*, 3L*(R & M 1878 det. LH), 4, 5C*(R & M 1980 det. LH), 6

Psychotria pandurata Verdc. 1A*(R & M 2011 det. EAH)

Psychotria peteri Petit 1K*S*(R & M 2041 det. EAH)

Psychotria capensis (Eckl.) Vatke ssp. _riparia_ (K. Schum. & K. Krause) Verdc. 1S*(R & M 1909 det. LH), 6

Psychotria tanganyikensis Verdc. var. _tanganyikensis_ 1A*K*(Linder 3794 det. EAH)

Psychotria usambarensis Verdc. 2L

Rutidea orientalis Bridson (syn. _R. syringoides_ (Webb) Bremek.) 1M*(R & M 2173 det. LH), 2L*(R & M 1802 det. LH)

Rytignia bagshawei (S. Moore) Robyns (syn. _Tricalysia bagshawei_ S. Moore) 3L*(R & M 1851 det. LH), 5C*(R & M 1975 det. LH)

Rytignia bugoyensis (K. Krause) Verdc. (syn. _R. butaguensis_ (De Wild.) Robyns) 1M*(R * M 2248 det. LH)

Rytignia flavida Robyns (syn. MIR. schumanni Robyns) 1B, 2L, 4

Taranna graveolens (S.Morre) Bremek. (syn. _T. nigrescens_ (Hook. f.) Hiern) 2KL

Taranna pavettoides (Harv.) Sim 1S, 2L, 3LM

Tricalysia acidophylla Robbrecht 6*(R & M 2967 det. LH)

Tricalysia anomala E.A. Bruce 1K*(R 1721 det. KEW)

Tricalysia pallens Hiern 1S*(R & M 1813 det. EAH), 4, 5A

Sericanthe odoratissima (K. Schum.) Robbr. 1A*(R & M 2197 det. EAH)K*(R & M 1746 det. EAH)S*

Vangueria infausta Burch. subsp. _rotundata_ (Robyns) Verdc. 1S*(R & M 1938 det. LH)

RUTACEAE

Clausena anisata (Willd.) Benth. 1KS, 2L

Diphasia morogorensis Kokwaro 2L*(R & M 1724 det. EAH by Kokwaro)

Teclea amaniensis Engl. 2K*(R & M 1785 det. EAH)L*(R & M 2306 det. EAH), 5A

Toddalia asiatica (L.) Lam. 1S, 2L*(R & M 2305 det. EAH), 3L

SAPINDACEAE

Deinbollia borbonica Scheff. 1S

Deinbollia kilimandscharica Taub. 1K*(R & M 2258 det. LH)S, 3L, SA

Paullinia pinnata L. 1S, 2L, 3L, 5A

SCROPHULARIACEAE

Harveya obtusifolia (Benth.) Vatke 1S*(R & M 2156 det. EAH)

SIMAROUBACEAE

Brucea tenuifolia Engl. 1K*(R & M 2249 det. LH)N*(Linder 3755 det. EAH)S*(Linder 3761 det. EAH), 2KL

Harrisonia abyssinica Oliv. 1S, 3LM

SMILACACEAE

Smilax anceps Willd. (syn. _S. kraussiana_ Meisn.) 1S, 2L

SOLANACEAE

Solanum goetzei Dammer 1S*(R & M 2265 det. EAH), 2Z*

Solanum indicum L. 2M*(R * M 2241 det. EAH)

Solanum kitivuensis Dammer 2M*(R & M 2177 det. EAH)

Solanum seaforthianum Andr. 5C*(R & M 2164 det. EAH)

STERCULIACEAE

Cola clavata Mast. 3M*(R & M 2103 det. EAH), 5A

Dombeya acutangula Cav. 1S*(R & M 1940 det. LH)

Dombeya shupangae K. Schum. 2L*(R & M 1899 det. LH)

THYMELAEACEAE

Dicranolepis usambarica Gilg 6*(R & M 2091 det. EAH)

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Peddiea fischeri **Engl. 2L, 6**

Synaptolepis kirkii **Oliv. 3L*(R & M 1876 det. LH)**

TILIACEAE

Grewia holstii **Burrett 3L*(R & M 1913 det. LH)**

UMBELLIFERAE

Heteromorpha arborescens **(Thunb.) Cham. & Schlecht. 4*(R & M 1966 det. LH)**

URTICACEAE

Boehmeria macrophylla **Hornem. (syn. *B. platyphylla* D. Don) 1N*(Linder 3760 det. EAH), 2L*(R & M 2311 det. LH)**

Elatostema monticola **Hoof. f. (syn. *E. orientale* Engl.) 1S*(Linder 3750 det. EAH)**

Elatostema **sp. cf. *E. welwitschii* Engl. 1K*(R & M 2153 det. LH)**

Laportea lanceolata **Engl. 6*(Linder 3779 det. EAH)**

Pilea **sp. 1N*(R & M 1770 det. LH)**

Urera cameroonensis **Wedd. 1N*(R & M 2000 det. LH)**

VERBENACEAE

Clerodendrum buchholzii **Guerke 1K*(H 86/59 det. EAH)**

Clerodendrum capitatum **Schum. & Thonn. 1A*S*(R & M 1809 det. LH)**

Clerodendrum cephalanthum **Oliv. 1A*(R & M 2160 det. LH)**

Clerodendrum rotundifolium **Oliv. 1S,2L*(R & M 2299 det. LH)**

Clerodendrum scheffleri **Guerke 2L*(R & M 2300 det. LH)**

Clerodendrum triplinerve **Rolfe 1K*(H86/45 det. EAH)**

Lantana camara **L. 1S, 3LM, 4, 5A (very common naturalized shrub)**

Vitex amboniensis **Guerke 1S*(R & M 1858 det. LH)**

VIOLACEAE

Rinorea angustifolia **(Thouars) Baill. subsp. *albersii* (Engl.) Grey Wilson 1BS, 2KL, 3L, 4, 5AG*(R & M 2297 det. EAH), 6**

Rinorea ferruginea **Engl. 1K*(R & M 2194 det. EAH)S*(Linder 3765 det. EAH), 2KL, 3L, 4, 5AG*(R & M 2046 det. EAH), 6**

Rinorea ilicifolia **(Oliv.) Kuntze 1M*(R & M 2244 det. EAH)**

Rinorea subintegrifolia **(P. Beauv.) Kuntze 1S*(R & M 1849 det. EAH), 2L, 4**

Rinorea **sp. nr. *R. orientalis* N. Robson K*(H 86/24 det. EAH)**

VITACEAE

Cissus oliveri **(Engl.) Gilg 1K* (H86/51 det. EAH), 6M**

Cissus quadrangularis **L. 3L*(R & M 1912 det. LH)**

ZINGIBERACEAE

Aframomum angustifolium **(Sonnerat) K. Schum. 1S, 2L, 6**

Costus sarmentosus **Bojer 4**

PTERIDOPHYTES

Adiantum raddianum **Presl. 1N*(Linder 3754 det. EAH) (introduced sp,)**

Asplenium buettneri **Hieron. 6(Linder 3772 det. EAH)**

Asplenium christii **Hieron. 1K*(Linder 3792 det. EAH)**

Asplenium geppi **Carr. 1K*(Linder 3741 det. EAH))**

Asplenium holstii **Hieron. 1N*(Linder 3753 det. EAH)**

Asplenium inaequilaterale **Willd. 1N*(Linder 3808 det. EAH)**

Asplenium macrophlebium **Bak. 1N*(Linder 3806 det. EAH)**

Asplenium paucijugum **Ballard 1K*(H 86/72 det. EAH)**

Asplenium pellucidum **Lam. 1K*(Linder 3793 det. EAH)**

Asplenium protensum **Schrad. 1K*(Linder 3795 det. EAH)**

Asplenium rutifolium **(Berg.) Kunze 2L**

Asplenium sandersonii **Hook. 1A*(R & M 2199 det. LH)K*(Linder 3795 det. EAH)**

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Asplenium theciferum (Kunth.) Mett. 2L*(R & M 2167 det. LH)
Blotiella hieronymii Kuhn 1N*(Linder 3405 det. EAH)
Blotiella stipitata (Alston) Faden 1K*(H86/20 det. EAH; Linder 3745, 3746 det. EAH)
Bolbitis gemmifera (Hieron.) C. Chr. 1N*(Linder 3809 det. EAH)
Cyathea manniana Hook. 1KS, 2L.
Cyclosorus quadrangularis (Fee) Tard. 1N*(Linder 3752 det. EAH)
Cyclosorus usambarensis sp. nov. aff. *elatus* (Mett.) Alson 1N*(Linder 3807 det. EAH)
Drynaria laurentii (Christ) Hieron. 1K*(H 86/77 det. EAH; Linder 3739 det EAH)
Dryopteris kilemensis (Kuhn) Kuntze 1K* (H 86/27 det. EAH)
Marattia fraxinea Gmel. 4
Microtrichomanes parvulum (Poir.) Copel. (syn. *Hymenophyllum sibthorpioides* (Bory.) Mett.) 1K*(Linder 3804 det. EAH)
Nephrolepis biserrata Schott 6*(Linder 3786 det. EAH)
Phymatodes scolopendria (Burm. f.) Ching 1K*(Linder 3742 det. EAH)
Pteris atrovirens Willd. 1N*(Linder 3751 det. EAH)
Pteris usambarensis Hieron. 1K*(Linder 3791 det. EAH)
Tectaria gemmifera (Fee) Alston 1N*(Linder 3782 det. EAH)
Trichomanes rigidum Swartz 1K*(H 86/217 det. EAH; Linder 3790 det. EAH)
Vittaria guineensis Desv. var *orientalis* Hieron. 1K*(Linder 3744 det. EAH)

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Acknowledgements

Many thanks to the Botanist-in-Charge (Christine Kabuye) and staff (especially E.P.K. Kay, J.G. Mutungah and H.J. Beentje) of the Herbarium, National Museums of Kenya, Nairobi, for assistance with nomenclature and identification of specimens.

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Pole collection in Kwamsambia Forest Reserve, 300 m. Note that larger trunks are split. September, 1986.

An outbuilding, showing the use of poles in its construction, and sugar cane at Amani. Credit DP.

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18. *Saintpaulia*

by Sylva Mather

The East Usambaras contain more species of African violets (*Saintpaulia*) than anywhere else in the world. The species generally grow on moist rocks, often protected from desiccation by overhanging forest. Forest clearance is likely to place populations in danger. Tanzania might benefit financially from 'African violet safaris' for specialist tourists.

During the year 1892, Baron Walter von Saint Paul Illaire, then District Commissioner of Tanga Province, German East Africa (as then named), found two wild plants with small blue flowers. One was growing in the Tanga area near the coast and was subsequently named *Saintpaulia ionantha*. The other was higher up in the East Usambara Mountains and is now named *S. confusa*. Thus, the genus *Saintpaulia*, or African violet as it is commonly known, was introduced to horticulture.

Since then, in hybrid form, the cultivars have enjoyed a quite spectacular and ever increasing popularity as indoor plants both in Europe and particularly in the United States of America.

One of the most interesting features of the species *Saintpaulia* is the relatively small geographical distribution of the genus. It is restricted to East Africa, occurring in no other part of the continent or of the world. It requires a very special environment and, even within the limited range of its distribution in East Africa, the individual species normally grow in close association with each other in small isolated colonies.

Four different species grow in various locations at a low-lying altitude near sea level on the Tanzania coast and on the coast of Kenya. Five others come from the Uluguru and Nguru mountains in the south of Tanzania. But the centre of distribution undoubtedly occurs in the Usambara mountains.

Of the twenty species so far classified and named the Usambaras account for eleven.

Eight species, including one from Mt Tongwe which forms part of the range, are from the East Usambara mountains. They are listed in Table 18.1

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Table 18.1 Saintpaulia species occurring in the East Usambaras

	Altitude (m)	Location	Habitat
S. confusa	900-1050	Near Amani, E. Usambara Mts	On damp gneiss rocks by riverbed
S. difficilis	900-1050	E. Usambara Mts	On rock by streamside in rain forest
S. diplotricha	1000	Mt Mlinga E. Usambara Mts	On rocks by streamside
S. intermedia	1000	Kigongoi, E. Usambara Mts	On rocks
S. grotei	950-1000	Near Amani, E. Usambara Mts	On rocks near waterfall
S. magungensis *	900	Mt Mlinga, E. Usambara Mts	On gneiss cliff in rain forest shaded by trees 40-50 m tall
S. pendulis	?	E. Usambara Mts	On rocks in evergreen rain forest
S. tongwensis	400-800	Mt Tongwe, E. Usambara Mts	On gneiss rocks on the rocky peak (very rare, possibly extinct); in patch of rain forest

** There are two distinct varieties of S. magungensis, var. minima and var. occidentalis.*

Note: It should be made clear that the above descriptions of altitude, habitat etc. come mainly from Burtt (1958, 1963) and Johansson (1978). For authorities, see Johansson's paper. For a description of a search for African violets in the wild, see Punter (1958).

Whether all the species described above are in existence today in their natural environment is a matter for some speculation and considerable doubt. Certainly *S. magungensis*, first found in 1950 at Magunga in the foothills of the East Usambaras, is now thought to be extinct due to the planting of sisal in that area. The fate of *S. tongwensis* is also in doubt. And the three species growing on the coastal plain near Tanga, i.e. *S. diplotricha*, *S. intermedia* and *S. ionantha*, as well as *S. rupicola* at Kaloleni near Mombasa in Kenya, have become seriously depleted due to bush clearing and tree felling. These, however, could hopefully yet be preserved in small pockets.

It is particularly disturbing to note that the famous *S. ionantha* — the original species found by Baron Saint Paul growing "somewhere near Tanga" — was even in 1978 found only in one place (Johansson 1978). "During several visits in the Tanga area only a few specimens of *S. ionantha* were observed, all in the vicinity of the Amboni Caves". According to information just received, the dry evergreen forest trees that once overhung the towering limestone cliffs of the Amboni Caves, thus providing vital shade to *S. ionantha* which grew in the rock fissures of the vertical cliffs, have now been destroyed. *S. ionantha* may therefore now be lost.

[Editors' note: Information has been received from Jon Lovett that *S. ionantha* grows on the Uzungwas; even so, the loss of the species at Amboni would be serious.]

Clearly, despite their somewhat diverse habitats and environmental requirements, the *Saintpaulia* species as a whole share one common denominator — the most vital necessity for their survival and well-being — protective shade. When this is even partially withdrawn they cannot compete with other more robust plants, which quickly move in and take over. And, when fully exposed to the fierce rays of the tropical sun, the delicate leaves soon shrivel and the plants die.

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It seems then that with the exception of the five species in the Nguru and Uluguru Mountains, which are thought to be relatively less disturbed, the majority of the *Saintpaulia* species are now in great jeopardy.

Undoubtedly, the huge retail trade in African violet cultivars commands millions of pound annually both in Europe and America. And it would obviously be beneficial to Tanzania if ways and means could be found to turn at least part of this bounty to her own advantage. Unfortunately, the hybrid African violets are so easily produced by vegetative and seed propogation that this presents a limiting factor. However, experimentation with the species continues, as does research into their genetic potential, and the challenge to produce a truly yellow variety goes on unceasingly.

It is also quite possible that there are still undiscovered species growing in the remoter areas such as the Nguru, Uluguru, Uzungwa and Ukaguru mountains of Tanzania, which could prove of great value to hybridisers and possibly to the country too.

Another suggestion worth considering is the feasibility of forming a wild gene pool which could be a source of great benefit to those concerned with the further development of the African violet. For although all but two of the wild species are grown fairly extensively in cultivation in the United States, there is nothing like the real thing when it comes to strengthening or developing certain traits in a strain.

But I believe the greatest economic potential lies in the fact that, due to the tremendous popularity of the African violet especially in America, more and more people there are growing the wild species in private collections. It is fast becoming a cult and already members of the American African Violet Societies are showing interest in the possibility of undertaking safari tours to Tanzania in order to view *Saintpaulia* growing in the wild. This (with the proviso that strict measures would have to be introduced to inhibit collectors from helping themselves) could well lead to a whole new departure in tourism and consequently be a source of great economic value to the people of Tanzania.

Of course, before any of the above suggestions could be translated into action, the present threat to the *Saintpaulia* species would have to be taken seriously. And the threat to their continued survival has now reached critical proportions. Indeed the urgent need for protection and conservation of those species still surviving in their natural state cannot be over-emphasised. By virtue of their limited geographical distribution alone, they are unique in the Gesneriaceae family to which they belong.

But apart from their value to the scientific world, Tanzania could yet derive considerable financial reward from affording them the protection they now so urgently need.

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Saintpaulia growing on a forest-shaded moist rock near the summit of Mt. Mlinga, 1000 m. (Chapter 18). May, 1987.

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19. Some Useful Plants of the East Usambaras

By C.K. Ruffo

This chapter contains lists of plants occurring in the forests of the East Usambaras, which are used by the local communities for various purposes. The uses include plywood, timber, poles, fuelwood, ropes, tool handles, kitchen utensils, fruits and dyes. A list of medicinal plants is given in Chapter 20.

The plants are listed in groups, according to the local use. Except where otherwise stated, the lists are based on interviews or observations on the East Usambaras by the author. Vernacular names are given where known; almost all are Kishambaa.

1. Plywood and timber (List of species provided by Sikh Saw Mills (T) Ltd of Tanga):

Antiaris toxicaria	Mkuzi	*Khaya nyasica*	Mtondoo
Beilschmiedia kweo	Mfimbo	*Lovoa swynnertonii***	Mboto or Mbonto
Cephalosphaera usambarensistambara	Mtambara	*Maesopsis eminii*	Msizi
*Chrysophyllum gorungosanum**	Mkuti	*Newtonia buchananii*	Mnyasa
Chrysophyllum perpulchrum	Mkuti	*Odyendea zimmermannii*	Mbanku
Entandrophragma excelsum	Mbokoboko	*Syzygium guineense*	Mshikwi
Isoberlinia scheffleri	Mbarika		

* Not directly mentioned by Sikh Saw Mills but in practice they do not distinguish between this species and *C. perpulchrum*.

**not seen by the author, but being exploited by Sikh Saw Mills).

2. Plywood only (List of species provided by Sikh Saw Mills (T) Ltd of Tanga):

Anthocleista grandiflora	Mpumu	*Sterculia appendiculata*	Mfune
Rhodognaphalon schumannianum	Mwale	*Zanthoxylum gilletii*	Mfuakumbi

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3. Timber only

All species on this list are regarded as timber trees by the Forest Division but have not necessarily been used on the East Usambaras. Indeed, of all the species given, only *Ocotea usambarensis* has been mentioned by Sikh Saw Mills as being useful for timber. Pitsawyers are extremely selective in the species which they select and cut almost exclusively only four — *Khaya, Milicia, Newtonia* and *Ocotea.*

Albizia gummifera	Mshai	*Milicia excelsa*	Mvule
Allanblackia stuhlmannii	Msambu	*Mitragyna rubrostipulata*	Mromberombe
Aningeria aldofi-fredericii	Mkuti	*Ocotea usambarensis*	Mkulo
Bersama abyssinica	Mbamba	*Olea capensis*	Mzilagembe
Combretum schumannii	Mkongolo	*Parinari excelsa*	Muula
Cordia africana	Mfufu	*Podocarpus latifolius*	Mse
Diospyros abyssinica	Mtitu	*Prunus africana*	Mkomahoya
Diospyros mespiliformis	Mkea-kiindi	*Rapanea melanophloea*	Mshwizo
Ficalhoa laurifolia	Mkuka	*Strombosia scheffleri*	Msangana
Macaranga capensis	Mkumba	*Terminalia sambesiaca*	Mkulungu
Maranthes goetzeniana	Ng'anga	*Vitex doniana*	Mfuru
Markhamia hildebrandtii	Mtalawanda		

4. Building Poles

Trees are normally felled when they are about 10—15 cm diameter at breast height (dbh). If poles are collected for ceiling beams, then somewhat larger trees are selected (about 20 cm dbh) and the sapwood is trimmed off to leave the more resistant heartwood. Felling is at a height of about 40 cm, and the crown and small branches are removed before transportation.

Trees with straight trunks are desired. Notably straight trunks are, for instance, found in *Enantia kummeriae, Funtumia latifolia, Greenwayodendron suaveolens* and *Isolona heinsenii.* Among others on the list, *Cyathea manniana* and *Pterocarpus mildbraedii* are very resistant to termites. *Cyathea* is used for rafters and is perhaps not resistant to fungal attack.

Species selected tend to have wood which is regarded as being more durable. The main problems are termites and fungal attack. Pole cutting is very prevalent in the East Usambara forests but is naturally more concentrated near settlements. The intensity of pole cutting is highest on ridges, partly because this is where paths in the forest tend to lie and the forest is easiest to walk through, and partly because trees are often straighter. Also, the soil on ridges is relatively poor, which is liable to make tree growth slower and the wood harder.

The biggest use of poles is in the construction of houses and outbuildings and a further use is for fencing. Houses on the East Usambaras are constructed as follows. A platform is prepared and a plan of the normally rectangular structure, about 6 x 4 m in external dimension and normally with internal partitions forming three rooms, is made on the ground. Post holes are then dug to a depth of about 30 cm and at about 30 cm intervals. Poles, about 2.5—3 m tall, are put in place. Including waste, about 100 poles are needed for external and internal vertical supports. The poles are bound together with withies and natural ropes. The withies are obtained by cutting small trees of the same species as used for the poles, but only about 3 cm dbh. The ropes are obtained from small climbers.

While making the vertical framework, door and window frames are put in place. These consist of sawn wood obtained from local carpenters. The sloping triangular roof is then added. Rafters, about 1 m apart and overlapping the sides of the house, are put in place together with ceiling supports. A total length of poles of about 150 m is required for the roof. Thus the total length of poles required for the whole construction is about 375 m.

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Walls are plastered with mud and smoothed, and corrugated iron sheets placed on the roof. The doors and windows are made out of planks by a carpenter.

The quantity of poles needed for a single house is large and their cutting in the forest is often a major influence on forest ecology. A considerable number of the preferred species can grow to form tall trees and their regeneration is threatened. According to the forest regulations, poles can be collected from forest reserves under licence. For personal use, there is no fee.

The solution to the problem lies in creating plantations of suitable species outside the forest reserves. Trees known to be suitable for this purpose include *Casuarina*, *Eucalyptus* and *Grevillea*, but others should be tried, especially some of those indigenous to the area.

The following is a list of forest species used for building poles:

Alchornea hirtella	Zasa	*Greenwayodendron suaveolens*	Ng'wati
Aulacocalyx diervilleoides	Msiwa	*Harungana madagascariensis*	Mkuntu
Blighia unijugata	Mzindanguruwe	*Ilex mitis*	Ganda-na-mto
Bridelia micrantha	Mwiza	*Isolona heinsenii*	Mzikoziko
Celtis mildebraedii	Kimungwe	*Lasianthus kilimandscharicus*	Nghuyu
Celtis wightii	Mjambegha	*Markhamia hildebrantii*	Mtalawanda
Combretum schumannii	Mkongolo	*Millettia dura*	Mhafa
Cremaspora triflora	Msiwa	*Millettia sacleuxii*	Mlanga
Cola clavata	Muungu	*Olea capensis*	Mzilagembe
Cola greenwayi	Muungu	*Oxyanthus speciosus*	Mkwinga
Cola usambarensis	Muungu	*Pauridiantha paucinervis*	Mnavilavi
Cyathea manniana	Long'e	*Pterocarpus mildbraedii*	Hampa
Cynometra spp.	Mkwe	*Pterocarpus tinctorius*	Mkula
Dasylepis integra	Kigwande	*Schefflerodendron usambarense*	Msase
Diospyros abyssinica	Mtitu	*Tarenna nigrescens*	Mshanghashachole
Enantia kummeriae	Muaka	*Teclea simplicifolia*	Mndizi
Funtumia latifolia	Kilimboti		

5. Ropes and twine

These are all climbers; bark rope is not used on the East Usambaras.

Adenia cissampeloides	Ghole	*Tiliacora funifera*	Usisi
Landolphia kirkii	Ugoroto Mpia-mzitu	*Triclisia sacleuxii*	Usisi

6. Fuelwood

Wood is virtually the only fuel used for domestic purposes on the East Usambaras. Very small amounts of charcoal are made at Bombani and Mlesa and probably elsewhere. Some is used in local hotels, but from Bombani the bulk is sent to Tanga. Paraffin is used for lighting but not cooking. Electricity supplies some of the larger settlements, but again its use for cooking is very restricted.

Two types of fuel are required, one to start the fire, consisting of more readily inflammable plant material, and the other to maintain the fire when lit. Grass, as well as some types of wood, is used for the first purpose. Fallen self-pruned branches of *Maesopsis* as well as *Trema* are regarded as useful for starting fires. These are light-wooded species. Species with dense wood are better for maintaining fires, once lit.

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Fuelwood is gathered by women and children and at present can usually be found close to homes. The time required for gathering and transportation is much less than in some other parts of Tanzania. Only dead wood is gathered. There is no necessity to collect and dry live wood, as happens in places in the more treeless West Usambaras.

The removal of dead wood from the forest will influence forest ecology in various ways, for example in removing nutrients, lowering organic matter influx into the soil and interfering in the natural pattern of a tree fall. Fuelwood removal also encourages the spread of *Maesopsis*, which cannot normally establish itself in the crown area of a fallen tree, but can do so if wood is gathered from this area (Chapter 27). It would be desirable to know more about the influence of fuelwood gathering on forest systems but in any case the establishment of fuelwood plantations is desirable.

The following list consists of species, the wood of which is known to be obtained from the East Usambara forests for use as a longer-burning fuel.

Albizia glaberrima	Mshai	*Markhamia hildebrantii*	Mtaanda
Albizia gummifera	Mshai	*Millettia dura*	Mhafa
Bridelia micrantha	Mwiza	*Milletia sacleuxii*	Mlanga
Combretum schumannii	Mkongolo	*Morinda asteroscepa*	Mromberombe
Craibia zimmermannii	Mhande	*Myrianthus holstii*	Mkonde
Cremaspora triflora	Msiwa	*Newtonia buchananii*	Mnyasa
Cynometra spp.	Mkwe	*Newtonia paucijuga*	Myovu
Dialium holtzii	Mhetele	*Ocotea usambarensis**	Mkulo
Englerodendron usambarense	Mzumba	*Parinari excelsa*	Muula
Erythrophleum suaveolens	Mkokola	*Pauridiantha paucinervis*	Mnavilavi
Haplocoelum inoploeum	Mhale	*Rytigynia schumannii*	Ntuavuha
Harungana madagascariensis	Mkuntu	*Schefflerodendron usambarense*	Msase
Isoberlinia scheffleri	Mbarika	*Sorindeia madagascariensis*	Mkwingwina
Lasianthus kilimandscharicus	Nghuyu	*Syzygium guineense*	Mshihwi
Maranthes goetzeniana	Ng'anga		

* off-cuts from timber operations

7. Toolhandles

Species preferred are those with straight stems and strong and light wood. Stems about 7 cm dbh are cut and then reduced to about 4 cm.

Beilschmiedia kweo	Mfimbo	*Greenwayodendron suaveolens*	Ng'wati
Blighia unijugata	Mzindanguruwe	*Ilex mitis*	Genda-na-mto
Bridelia micrantha	Mwiza	*Isoberlinia scheffleri*	Mbarika
Celtis mildbraedii	Kimungwe	*Isolona heinsenii*	Mzikoziko
Celtis wightii	Mjambegha	*Julbernardia magnistipulata*	Mkwe
Cola clavata	Muungu	*Markhamia hildebrandtii*	Mtalawanda
Cola greenwayi	Muungu	*Millettia dura*	Mhafa
Cola usambarensis	Muungu	*Oxyanthus speciosus*	Mkwinga
Cordia africana	Mfufu	*Polyalthia stuhlmannii*	Kihambie Mzonozono
Cynometra spp.	Mkwe		
Diospyros mespiliformis	Mkea-kiindi	*Rawsonia lucida*	Kigwandi
Enantia kummeriae	Muaka	*Sorindeia madagascariensis*	Mkwingwina
Englerodendron scheffleri	Mzumba	*Teclea simplicifolia*	Mndizi

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8. Wooden spoons

Wood should be moderately soft, have low permeability and should take a smooth finish.

Aningeria aldofi-fredericii	Mkuti	*Markhamia hildebrandtii*	Mtalawanda
Cola clavata	Muungu	*Memecylon erubescens*	Mtongambago
Cola greenwayi	Muungu	*Morinda asteroscepa*	Mromberombe
Cola usambarensis	Muungu	*Pachystela msolo*	Msambia
Diospyros mespiliformis	Mkea-kiindi	*Polyalthia stuhlmannii*	Kihambie, Mzonozono
Enantia kummeriae	Muaka		
Greenwayodendron suaveolens	Ng'wati	*Sorindeia madagascariensis*	Mkwingwina
Isoberlinia scheffleri	Mbarika	*Turraea holstii*	Mleleawana
Isolona heinsenii	Mzikoziko	*Xymalos monospora*	Kidimdim
Leptonychia usambarensis	Mzonozono		

9. Wooden cups

Wood should be light, easily carved and preferably not too permeable.

Afrosersalisia cerasifera	Mohoyo	*Lannea welwitschii*	Mumbu
Commiphora zimmermannii	Mbombwe	*Polyscias fulva*	Kogo
Funtumia latifolia	Kilimboti	*Rauvolfia caffra*	Mweeti

10. Edible fruits

Ancylobothrys petersiana	Vitoria	*Rubus spp.*	Mshaa
Alsodeiopsis schumannii	Mnozambeyu	*Saba florida*	Mbungo
Cola scheffleri	Msamaka	*Sorindeia madagascariensis*	Mkwingwina
Landolphia kirkii	Ugoroto	*Syzygium cordatum*	Mshihwi
*Maranthes goetzeniana**	Ng'anga	*Syzygium guineense*	Mshihwi
Myrianthus holstii	Mkonde	*Vangueria infausta*	Mviru
Pachystela msolo	Msambia	*Vangueria linearisepala*	Mviru
Parinari excelsa	Muula	*Vangueria tomentosa*	Mviru

* eaten by children

Other forest plants such as *Aframomum angustifolium* and *Zanha golungensis* have potential but are not or little used.

11. Edible fat from fruit

Allanblackia stuhlmannii	Msambu

Allanblackia fat is a well known product of the Usambara forests. Seeds are collected from the forest and also from trees deliberately left standing when forest is cleared for cultivation. Some seeds are bought by GAPEX (General Agricultural Products Export Company – a parastatal) and exported. There is a demand for *Allanblackia* seed in Kenya. For local consumption the seeds are pounded, boiled and the fat collected after cooling. It is a very good fat with a bright yellow colour.

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12. Dyes

Dyes are used locally for dyeing cloth and materials used for weaving mats and baskets. Pieces of cloth may be dyed in their entirety or in patterns by protecting areas by waxing or covering with plastic. Mats and baskets are made out of palm leaflets *(Phoenix reclinata)*, which are dried and trimmed before dyeing. Dyes are also used for decorating houses (sometimes with murals), walking sticks and spoons. Body painting is confined to women, who use mostly red dyes (from *Impatiens sodenii* and the introduced non-forest plant *Lawsonia inermis*) for decorating finger nails, toe nails, hands, feet and lips. Women will sometimes draw a crescent moon and a star on their palms with these dyes.

Dyes are extracted from bark, roots or fruits by boiling in water. The dye is extracted from *Lawsonia* and usually *Impatiens* by pounding the plants and soaking in cold water. Most dyes need to be fixed and this is done by adding lemon juice and salt.

The following plants found in the East Usambara forests are used to produce dyes:

Species	Vernacular	Part used	Colour
Bridelia micrantha	Mwiza	bark	red
Allanblackia stuhlmannii	Msambu	bark/fruit	yellow
Cephalosphaera usambarensis	Mtambara	bark	red
Enantia kummeriae	Muaka	bark	yellow
Ensete ventricosum	Tambwe	stem	brown
Garcinia spp.	Mudee-mzize	bark	yellow
Harungana madagascariensis	Mkuntu	bark	yellow
Impatiens sodenii	Jamto	leaves	red
Lannea welwitschii	Mumbu	bark	red
Maranthes goetzeniana	Ng'anga	bark	red
Milicia excelsa	Mvule	bark	red
Mitragyna rubrostipulata	Mromberombe	bark/wood	yellow
Morinda asteroscepa	Mromberombe	bark/wood	yellow
Newtonia buchananii	Mnyasa	bark	brown
Pterocarpus mildbraedii	Hampa	bark	red
Pterocarpus tinctorius	Mkula	bark	red
Rubia cordifolia	Ukakaka	roots	black
Symphonia globulifera	Mziwaziwa	bark	yellow
Syzygium cordatum	Mshihwi	fruits	purple
Syzygium guineense	Mshihwi	fruits	purple
Toddalia asiatica	Mdongonyezi	fruits	yellow

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13. Pestles and mortars

Large pestles and mortars are used for grinding grain, especially maize. Small pestles and mortars are used for grinding dyes and medicine. Pestles are made out of heavy hardwood; lighter wood can be used for mortars.

Pestles		Mortars	
Blighia unijugata	Mzindanguruwe	*Albizia glaberrima*	Mshai-Mamba
Bridelia micrantha	Mwiza	*Albizia gummifera*	Mshai
Celtis mildebraedii	Kimungwe	*Allanblackia stuhlmannii*	Msambu
Celtis wightii	Mjambegha	*Beilschmiedia kweo*	Mfimbo
Combretum schumannii	Mkongolo	*Bersama abyssinica*	Mbamba
Craibia zimmermannii	Mhande	*Cordia africana*	Mfufu
Dialium holtzii	Mhetele	*Cynometra spp.*	Mkwe
Dasylepis integra	Kigwande	*Diospyros mespiliformis*	Mkea-kiindi
Diospyros abyssinica	Mtitu	*Isoberlinia scheffleri*	Mbarika
Erythrophleum suaveolens	Mkokola	*Milicia excelsa*	Mvule
Harungana madagascariensis	Mkuntu	*Mitragyna rubrostipulata*	Mromberombe
Millettia sacleuxii	Mlanga	*Morinda astroscepa*	Mromberombe
Prunus africana	Mkomahoya	*Newtonia buchananii*	Mnyasa
Pterocarpus mildebraedii	Hampa	*Rauvolfia caffra*	Mweeti
Pterocarpus tinctorius race	Mkula	*Sorindeia madagascariensis*	Mkwingwina
Schefflerodendron usambarense	Msase	*Trichilia roka*	Mgolimazi
Teclea simplicifolia	Mudizi	*Zanthoxylum gilletii*	Mfuakumbi
Terminalia sambasiaca	Mkulungu		

14. Balls and bird-lime

Balls and bird-lime are made from latex obtained by tapping from stems. For balls, the latex is extracted, collected, moulded and inflated. The outer layer of the ball may then be coated with a thin layer of fresh latex obtained from the Para Rubber Tree (*Hevea brasiliensis*). Bird-lime is made by mixing the latex obtained from any one species with a small amount of any fatty oil.

Antiaris toxicaria	Mkuzu	*Funtumia latifolia*	Kilimboti
Ficus exasperata	Msasa	*Landolphia kirkii*	Mpia-mzitu
Ficus sur	Mkuyu	*Saba florida*	Mbungo

15. Fibre for weaving and thatching

The use of *Phoenix* fibre for baskets and mats has already been described under "dyes". *Phoenix* and also *Ensete* are used for thatching.

Ensete ventricosum	Tambwe	*Phoenix reclinata*	Mkindu, Msaa

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16. Honey production

It is guessed that the following species are amongst those which are important as sources of nectar or pollen for bees. Systematic observations of bee visits to flowers have not been made.

Acacia schweinfurthii	Kerefu	*Lannea welwitschii*	Mumbu
Albizia glaberrima	Mshai-Mamba	*Maesa lanceolata*	Mdami
Albizia gummifera	Mshai	*Maranthes goetzeniana*	Ng'anga
Allanblackia stuhlmannii	Msambu	*Milletia dura*	Mhafa
Anthocleista grandiflora	Mpumu	*Newtonia buchananii*	Mnyasa
Antiaris toxicaria	Mkuzu	*Parinari excelsa*	Muula
*Caesalpinia decapetala**	Msoo	*Phoenix reclinata*	Mkindu, Msaa
Bridelia micrantha	Mwiza	*Polyscias fulva*	Fumbati, Kogo
Clausena anisata	Mjavikali	*Pterocarpus mildebraedii*	Hampa
Combretum schumannii	Mkongolo	*Pterocarpus tinctorius*	Mkula
Craibia zimmermannii	Mhande	*Rauvolfia caffra*	Mweeti
Cylicomorpha parviflora	Mtonto	*Schefflera sp.*	Zutwe
Cynometra spp.	Mkwe	*Schefflerodendron usambarense*	Msase
Englerodendron usambarense	Mzumba	*Sorindeia madagascariensis*	Mkwingwina
Ensete ventricosum	Tambwe	*Syzygium cordatum*	Mshihwi
Erythrophleum suaveolens	Mkokola	*Syzygium guineense*	Mshihwi
Garcinia spp.	Mndee-mzize	*Terminalia sambesiaca*	Mkulungu
Grewia spp.	Mkole	*Zanha golungensis*	Mkwanga
Harungana madagascariensis	Mkuntu	*Zanthoxylum spp.*	Mfuakumbi
Isoberlinia scheffleri	Mbarika		

*introduced species

17. Ornamental plants in the forest

Aframomum angustifolium	Samaka	*Ensete ventricosum*	Tambwe
Barringtonia racemosa	Mkuvukuvu	*Entada pursaetha*	Mgodogodo
Begonia spp.	Churwa	*Erythrococca usambarica*	Mkundangombe
Brucea tenuifolia		*Fernandoa magnifica*	Mluwa-luwa
Calvoa orientalis	Ngurusha	*Gardenia posoquerioides*	Pingwe
Carvalhoa macrophylla	Kiiga	*Iboza riparis*	Aake
Chassalia parviflora	Lusungosungo	*Impatiens sodenii*	Tuanange
Cordia africana	Mfufu	*Impatiens usambarensis*	Tuanange
Crossandra pungens	Msagisagi	*Justicia spp.*	Nyalala, Tikini
Cussonia spicata	Mntindi	*Kalanchoe spp.*	Gowongo
Cylicomorpha parviflora	Mtonto	*Lobelia spp.*	Sambae
Deinbollia kilimandscharica	Mbwakabwaka	*Markhamia hildebrandtii*	Mtalawanda
Dorstenia holstii	Mkunga-mzitu	*Millettia dura*	Mhafa
Dorstenia orientalis	Mkunga-mzitu	*Mkilua fragrans*	Mkirua
Dracaena laxissima	Umpoko	*Morinda asteroscepa*	Mromberombe
Dracaena steudneri	Longe	*Markhamia hildebrandtii*	Mtalawanda

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Millettia dura	Mhafa	*Psychotria spp.*	Msayu
Mkilua fragrans	Mkirua	*Rauvolfia mannii*	Pambuai
Morinda asteroscepa	Mromberombe	*Saintpaulia spp.*	Dughulishi
Mussaenda spp.	Lumpemba, Pekaki	*Sclerochiton boivinii*	Mgombola
Ochna spp.	Mtongolo	*Streptocarpus spp.*	Luwa-luwa
Ouratea reticulata	Kidada	*Tabernaemontana spp.*	Muambe
Ouratea warneckei	Kidada	*Turraea holstii*	Mlelawana
Parkia filicoidea	Mkundi	*Uvariodendron usambarense*	Mkenene
Plectranthus barbatus	Mzughu	*Whitfieldia elongata*	Mbonyati-ye-ngaa
Pollia condensata	Chombosi	*Zenkerella egregia*	
Polyalthia stuhlmannii	Mtawe	*Zimmermannia capillipes*	Kiseza-mzitu
Psiadia arabica	Paghasha		

This is mostly a list of suggestions. Most of the species are not yet used, but are regarded as having potential. Concerning their use in the East Usambaras the following comments can be made:

Cordia africana has been left during forest clearance for farmland near Kizara and Kwamsambia, probably partly for ornamental reasons.

Dracaena steudneri is used for decoration and live fencing.

Ensete ventricosum is used as an ornamental near houses.

Millettia dura is used as an ornamental tree.

Morinda asteroscepa is left during forest clearance, both for ornamental purposes and because it is believed that it conserves water.

Plectranthus barbatus is planted for ornamental purposes and also because it is medicinal.

Saintpaulia spp. (African violets) are not used ornamentally in the East Usambaras, even though *Saintpaulia ionantha*, the African violet in cultivation, is native near Tanga (Chapter 18)

Streptocarpus spp., like *Saintpaulia*, are used commercially elsewhere but not on the East Usambaras.

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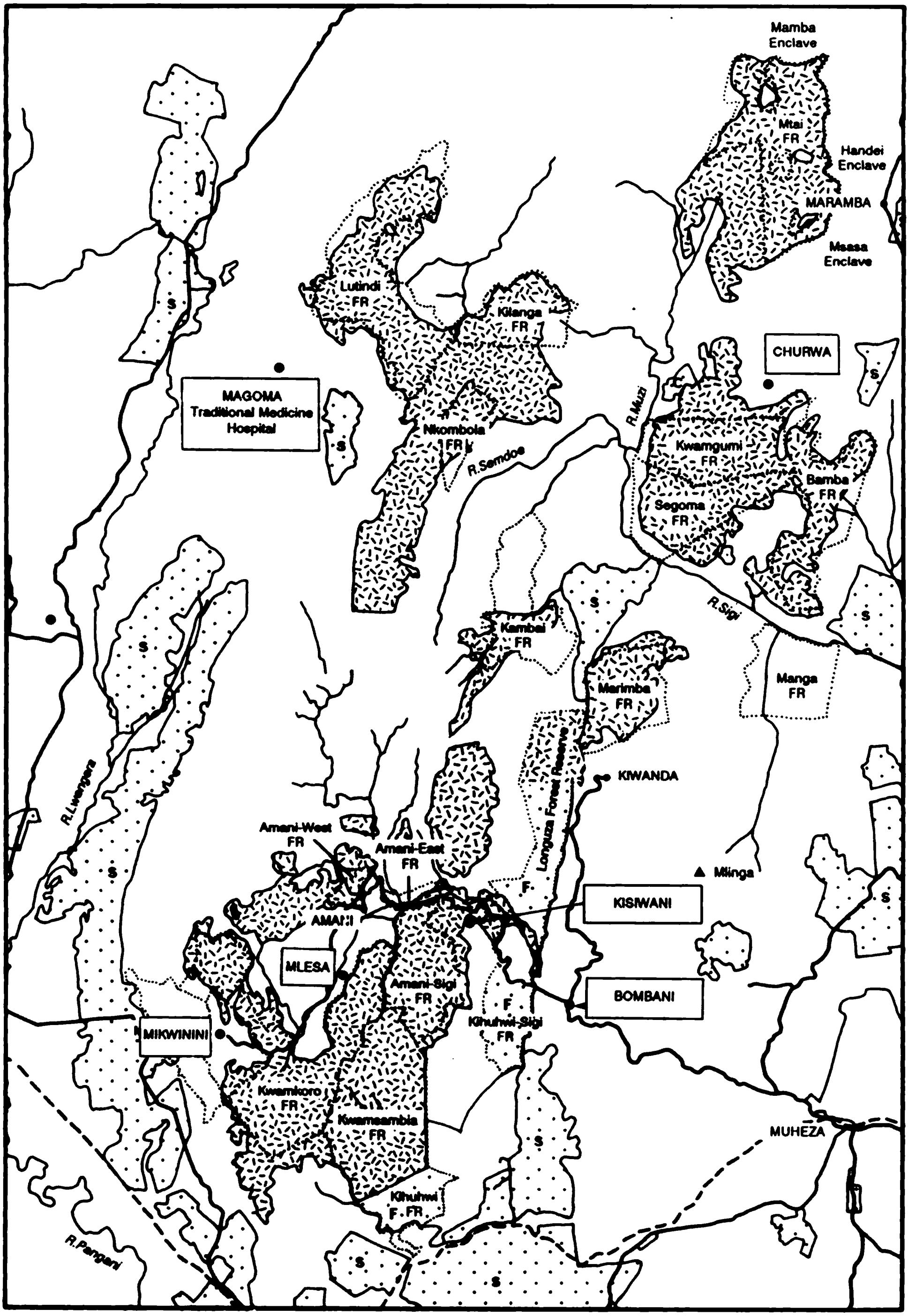

Figure 20.1 Map showing where the traditional doctors interviewed live.

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20. The Use of Medicinal Plants in the East Usambaras

by C.K. Ruffo, I.V. Mwasha and C. Mmari

Fourteen traditional doctors in the East Usambaras were interviewed; between them, they use 185 species of plants to treat 63 different diseases or conditions. 34% of the species are forest plants, the percentage of forest species used by any particular doctor varying between 0 and 67%. The highest use of forest plants occurs in more remote areas, near forests and far from towns. Older traditions may have survived in such places.

1. Introduction

The importance of medicinal plants in the East Usambaras and in many other parts of the world, especially in rural communities, cannot be overstated. It is a tradition which will remain for many centuries to come. Ayensu (1983) estimated that about 80% of the world's rural population depends on the herbalist to handle its medical problems.

Some traditional doctors, such as Doctor Mandondo of Magoma village in Korogwe District and Doctor Omari Hassani Kalaghe (well known by his trade name as Kihamia Makata) of Churwa village, East Usambaras, have their own traditional medicine hospitals where they treat their patients. They earn their living out of traditional medicines prepared from herbs and trees, some from the forests. Yet most of them are not aware that these forest plants are gradually disappearing (FAO 1986).

This report tries to assess the number of medicinal plants used by fourteen traditional doctors from five villages in the East Usambaras and gives some concluding remarks and recommendations. The report further gives an account of the procedure of the traditional doctors' work as found during the survey.

2. Guide to the list of medicinal plants from the East Usambaras

Interviews were carried out at five villages in the East Usambaras with the traditional doctors shown in Table 20.1. The locations of the villages are shown in Fig. 20.1.

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Table 20.1 The 14 traditional doctors interviewed and their villages.

Code no.	Village	Doctor
B1	Bombani	Esta Isaack
B2	Bombani	Abdallah Sefu
C1	Churwa	Shabani Mohamed
C2	Churwa	Omari Hassani Kalaghe
K1	Kisiwani	Dismas Kihiyo
K2	Kisiwani	Stephen Salimu
K3	Kisiwani	Mohamed Abdallah
L1	Mlesa	Danstantindo-Bendera
M1	Mikwinini	Margin Gube
M2	Mikwinini	Simon Salimu
M3	Mikwinini	Salum Ali Kizokwa
M4	Mikwinini	Adam Selemani
M5	Mikwinini	Hamdani Juma
M6	Mikwinini	Hassani Juma

The environments of the five villages are as follows:

Bombani	a large village in the lowlands of the East Usambaras. Lowland forest is found nearby at Kihuhwi, Kwamsambia and Longuza, but the immediate vicinity of the village is mostly farmland.
Churwa	a moderate-sized village in the lowlands between Mtai and Mhinduro mountains. It is among farmland, but both lowland and submontane forests are accessible.
Kisiwani	a small village right at the foot of the East Usambaras below Amani, with much lowland forest nearby.
Mlesa	a medium-sized village on the Amani plateau near Kwamkoro, close to much submontane forest.
Mikwinini	a small village on top of the Amani plateau on the edge of the western escarpment.

Interviews were conducted by C.K. Ruffo, I. Mwasha and C. Mmari in December 1986 and January 1987.

Doctors were requested in advance to produce specimens of plants when they were interviewed and Mr. C.K. Ruffo normally was able to identify these on the spot. A few specimens were pressed and taken to Lushoto for checking.

In the list of plants given in this report, vernacular names are given in Kishambaa (SH) or Kiswahili (SW).

Those doctors using particular species are identified by code numbers (Table 20.1) and these codes are then followed by the diseases for which the plants are used and the parts of plants employed.

Abbreviations for plant parts are as follows: B (bark), F (fruit), L (leaves), R (roots), S (seeds). Forest species are marked with an asterisk.

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3. List of plants

ACANTHACEAE

Asystasia gangetica (L.) T.Anders. (TIKINI-SH) L1 (delayed afterbirth-R).

AGAVACEAE

*_Dracaena laxissima_ Engl. (UMPOKO-SH) M1 (epilepsy-R); M2 (infertility-R).

*_Dracaena steudneri_ Engl. (PAPATA-SH) M4 (madness-L); M6 (enlarged spleen-L).

AMARANTHACEAE

Achyranthes aspera L. (TULULA-SH) L1 (prolapse of rectum-R); M5 (chronic sores-L).

ANACARDIACEAE

Anarcardium occidentale L. (MKOROSHO-SW) C1 (preventing abortion-R).

Mangifera indica L. (MWEMBE-SW) C1 (convulsions-L; preventing abortion-R).

Rhus natalensis Bernh. (MHUNGUU-SH) B1, B2 (infertility-R).

*_Sorindeia madagascariensis_ DC. (MKWINGWINA-SH) L1 (schistosomiasis, tuberculosis-R).

ANNONACEAE

Annona muricata L. (MSTAFELI-SW) C1 (gonorrhoea-R); C2 (dementia, madness-L & R, R); L1 (epilepsy-R).

Annona senegalensis Pers. (MTONKWE-SH) B2 (infertility-R).

*_Monodora minor_ Engl. & Diels (MKUAKUA-SH) L1 (delayed afterbirth-R).

*_Uvaria acuminata_ Oliv. (MSHOFU-SH) C1 (convulsions-R).

APOCYNACEAE

*_Landolphia kirkii_ Dyer (UTOYO-SH) M2 (mastitis-R).

*_Saba florida_ (Benth.) Bullock (MUUNGO-SH) K2 (infertility-R); L1 (hypertension-L).

ARACEAE

*_Culcasia 'scandens'_ (KIANDAMA-SH) M4 (cleansing mother's milk-L); M6 (impotence-R).

ARALIACEAE

Cussonia arborea Hochst. ex A. Rich. (MTINDI-SH) C1 (bewitchment-L & R).

BASELLACEAE

Basella alba L. (NDELEMA-SH) L1 (frigidity-L).

BIGNONIACEAE

Kigelia africana (Lam.) Benth. (MLEGEA-SH) B1 (infertility-B); L1 (gonorrhoea-F).

*_Markhamia hildebrandtii_ (Bak.) Sprague (MTALAWA-NDA -SH) C2 (convulsions in children-L); C2, K3 (preventing abortion-R).

Stereospermum kunthianum Cham. (MKANDE-SH) B1 (infertility-B).

BOMBACACEAE

*_Rhodognaphalon schumannianum_ A.Robyns (MWALE-SH) C1 (bewitchment-L & R); M1 (diarrhoea-B).

BURSERACEAE

*_Commiphora zimmermannii_ Engl. (MNYANKWA-SH) K3 (preventing abortion-R).

CAESALPINIACEAE

Caesalpinia volkensii Harms (MSOO-SH) C2 (generalized body pains-B; preventing abortion-R).

Cassia singueana Del. (MHUMBA-SH) B2 (hastening child birth, toothache-R); C1 (convulsions-L & R, madness-L).

Tamarindus indica L. (MSISI-SH) B1, L1 (infertility-R); M4 (dementia-R).

CARICACEAE

Carica papaya L. (MPAPAI DUME (male pawpaw)-SW) L1 (neck tumour-R; M5 (impotence-R).

CELASTRACEAE

Maytenus senegalensis Loes. (MUOMOWASHOZI-SH) L1 (infertility-R).

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CHENOPODIACEAE

Chenopodium procerum Moq. (HANGAZIMU-SH) M4 (madness-L); (hastening birth-L).

CHRYSOBALANACEAE

**Magnistipula butayei* De Wild. (MLAWIA-SH) L1 (disinfectant for baby's umbilical cord-L).

**Parinari excelsa* Sabine (MUUA-SH) L1 (bewitchment-R).

COMBRETACEAE

**Combretum schumannii* Engl. (MKONGOLO-SH) C1 (epilepsy-L).

**Terminalia sambesiaca* Engl. & Diels (MKURUNGO-SH) B2 (infertility-R); C1 (infertility-L).

COMPOSITAE

Ageratum conyzoides L. (BEENGE-SH) C1 (madness-L).

Aspilia mossambicensis (Oliv.) Wild (NYANGAANYA-NGAA -SH) C1 (allergy-R; betwichment, generalized body pains-L & R; epilepsy-L); M5 (body sores-R).

Bidens pilosa L. (MBWEMBWE-SH) C1 (headache-L); L1 (epilepsy-R).

Brachylaena hutchinsii Hutch. (MKARAMBATI, MUHUHU-SH) L1 (schistosomiasis-R).

**Crassocephalum bojeri* (DC.) Robyns (EZA-SH) M3 (stomachache-L); M4 (dementia-L).

**Crassocephalum mannii* (Hook.f.) Milne-Redh. (MGULANGUZO-SH) M2 (measles-L.).

Helichrysum schimperi (Sch. Bip.) Moeser (MZUMBANGOZO-SH) M6 (childrens' scabies-R).

Lactuca capensis Thunb. (MSHUNGA-SH) C1 (allergy, convulsions-R; measles-L); C1 (convulsions-L & R).

Microglossa densiflora Hook.f. (MUUKA-SH) C1 (rashes-L); K2 (convulsions in children-L).

Microglossa oblongifolia O. Hoffm. (MSHASHU-SH) K3 (convulsions in children-R); M1 (epilepsy-R); M2 (toothache-R).

Sonchus oleraceus L. (MSHUNGA-PWAPWA -SH) M3 (earache-R); M4 (impotence-R).

Vernonia corolata (Willd.) Drake (HASHAANDA-SH) C1 (generalized body pains-L & R; hernia-R); M1 (rheumatism-R).

Vernonia iodocalyx O. Hoffm. (MHASHA-SH) C1 (generalized body pains-L & R); K1 (prolapse of rectum, peptic ulcers-R); K3 (chronic coughs and colds-R); L1 (rheumatism-R); M1, M2 (prolapse of rectum-R); M2 (toothache-R); M6 (breast irritation, convulsions-L).

Vernonia subuligera O. Hoffm. (TUGHUTU-SH) L1 (dysentery-R).

CONVOLVUCACEAE

Ipomoea batatas (L.) Lam. (VINDOO-SH) L1 (gonorrhoea-R).

CUCURBITACEAE

Cucurbita maxima (Duch.) Lam. (MABOGA-SW) C1 (impotence-R).

Cucurbita moschata (Duch.) Poire (UKOKO-SH) L1 (rheumatism-R); M2 (tapeworm-F).

Lagenaria siceraria (Molinia) Stanley (MBUYU-SH) K3 (asthma-S); L1 (allergy-R).

Telfairia pedata (Sims) Hook. (MKWEME-SH) K3 (aphrodisiac-S).

Zehneria scabra (L.f.) Sond. (FUIZA-SH) C1 (bewitchment-L & R; epilepsy-L).

CYPERACEAE

Cyperus alternifolius L. (ZIA-SH) C1 (allergy, preventing abortion-R; bewitchment-L & R).

Cyperus sp. (NDAGO-SH) L1 (allergy-R).

EBENACEAE

Diospyros sp. (MGOTO-SH) M4 (dementia-L).

EUPHORBIACEAE

Acalypha ornata Hochst. (MZINDU-SH) L1 (delayed labour-L).

Acalypha paniculata Miq. (MZINDU-SH) K1 (allergy-R); K1, K2 (infertility-R).

**Bridelia micrantha* (Hochst.) Baill. (MWIZA-SH) C1 (gonorrhoea-R); M1 (prolapse of rectum-R); M6 (allergy-R).

Euphorbia sp. (NDELENGWE-SH) M5 (body sores-R).

**Macaranga capensis* (Baill.) Sim (MKUMBA-SH) M6 (allergy-L).

Manihot esculenta Crantz (MHOGO-SW) L1 (asthma-R).

Margaritaria discoidea (Baill.) Webster (MKWAMBAWA NYIKA-SH) C2 (convulsions-L).

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Phyllanthus muelleranus (Kuntze) Exell. (MTULA-NKONDO-SH) C1 (convulsions-L & R); C2 (convulsions-L; dementia, madness- L & R); M1 (rheumatism-R); M2 (infertility-R); M4 (dementia-L).

*_Phyllanthus inflatus_ Hutch. (MKECHE-SH) C1 (bewitchment-L & R).

Ricinus communis L. (MBONO-SW) B1 (infertility-L); C1 (allergy, gonorrhoea, preventing abortion-R; rashes-L); L1 (tonsillitis-R); M5 (allergy-S).

*_Ricinodendron heudelotii_ (Baill.) Pierre ex Pax (TONDOO-SH) K3 (constipation, diarrhoea-R).

*_Sapium ellipticum_ (Hochst.) Pax (MKONGOLO-SH) C2 (generalized body pains-B); M1 (choronic coughs and colds - R); M3 (tuberculosis-R).

Securinega virosa (Roxb. ex Willd.) Baill. (MKWAMBA-SH) C1 (convulsions, rashes-L); C2 (dementia, madness-L & R; generalized body pains - B); L1 (asthma-R; delayed labour-L); M2 (convulsions, tapeworm-R); M4 (dementia-L).

Tragia brevipes Pax (MBAWA-SH) K1 (allergy-R); K3 (constipation, stomachache-R).

GRAMINEAE

*_Olyra latifolia_ (UFIHA-SH) C1 (allergy-R; convulsions-L & R); K3 (constipation, stomachache-R).

*_Oplismenus hirtellus_ (L.) P. Beauv. (UKOKA-SW) C1 (epilepsy, prolapse of rectum-L).

Pennisetum purpureum Schumach. (NGUGU-SH) L1 (hernia-R).

Pennisetum trachyphyllum Pilg. (NGOVAI-SH) M2 (baby born with sores-R).

Rottboellia exaltata L.f. (USHUSHI-SH) C1 (allergy, preventing abortion-R, convulsions- L & R; epilepsy, rashes-L); K1 (allergy-R).

Saccharum officinarum L. (MGHUA-SH) K2 (asthma-stem).

Sorghum bicolor (L.) Moench (MTAMA-SW) C2 (dementia-L); rheumatism-S).

GUTTIFERAE

*_Allanblackia stuhlmannii_ (Engl.) Engl. (MSAMBU-SH) L1 (impotence-L & R).

LABIATAE

Hoslundia opposita Vahl (MSHWEE-SH) B1 (infertility, stomachache, impotence-R); C2 (generalized body pains-B); K1 (malaria-B; wounds-L); K3 (chronic coughs and colds-R); L1, M6 (convulsions-R).

Hyptis pectinata Poit (HOZANDOGHOI-SH) C1 (epilepsy-L); C2 (generalized body pains-B, hernia-R); K1 (convulsions, fever-L); K3 (convulsions in children-R).

Iboza multiflora (Benth.) E.A. Bruce (ALAKE-SH) L1 (dysentery-R); M1 (enlarged spleen-R).

Ocimum americanum L. (MVUMBAMPUKU-SH) B1 (stomachache-L).

Ocimum suave Willd. (MZUMBASHA-SH) B1 (stomachache-L); K3 (asthma-L); L1 (convulsions-R).

Plectranthus barbatus Andr. (MZUGHWA-SH) C1 (prolapse of rectum-L); L1 (prolapse of rectum-R); M2 (toothache-R).

Pycnostachys umbrosa (Vatke) Perkins (DONONDO-SH) L1 (indigestion, loss of appetite-L).

LAURACEAE

*_Beilschmiedia kweo_ (Mildbr.) Robyns & Wilczek (MFIMBO-SH) C2 (dementia, madness-L & R); L1 (hernia-R).

Cinnamomum zeylanicum Nees (MDARASINI-SW) C2 (dementia, gonorrhoea-L).

*_Ocotea usambarensis_ Engl. (MUKULO-SH) C2 (dementia-L & R); (epilepsy, poison antidote, tonsillitis-R).

LILIACEAE

Albuca sp. (NKONYASA-SH) L1 (hernia-R).

Allium ascalonium L. (KITUNGUU SUMU-SW) K3 (aphrodisiac-bulbs).

Aloe sp. (SEYU-SH) L1 (fatigue-R).

Asparagus falcatus L. (MWINIKANGUU-SH) C1 (convulsions-L & R); K2 (convulsions in children-R).

LOGANIACEAE

*_Anthocleista grandiflora_ Gilg. (MPUMU-SH) L1 (asthma, kidney disease, tapeworm-R).

Strychnos innocua Del. (MTONGA-SH) L1 (infertility-R).

LORANTHACEAE

Tapinanthus subulatus (Engl.) Danser (NGULUKILA-SH) M5 (chronic sores-L).

LYTHRACEAE

Lawsonia inermis L. (MHENA-SW) C1 (bewitchment-L & R; impotence-R).

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MALVACEAE

Hibiscus esculentus L. (MBAMIA-SW) L1 (frigidity-R).

Hibiscus fuscus Garcke (MSASE-SH) C1 (madness-L); K1 (pneumonia-R); L1 (tuberculosis-R); M5 (impotence-R).

Sida acuta Burm. f. (LUVUVUNDI-SH) L1 (delayed afterbirth-R).

MELIACEAE

Azadirachta indica A. Juss. (MWAROBAINI-SW) L1 (external boils-B). (An introduced tree from tropical Asia known as Mwarobaini in Kiswahili because it is used for treating forty different diseases including boils, wounds and malaria.)

**Entandrophragma excelsum* (Dawe & Sprague) Sprague (MBOKOBUKO-SH) L1 (gonorrhoea, hernia-R).

**Khaya nyasica* Stapf ex Bak.f. (TONDORO-SH) L1 (tonsillitis-R).

**Trichilia roka* (Forsk.) Chiov. (MKWINGWINA-SH) L1 (impotence-L & R).

MIMOSACEAE

**Albizia gummifera* (J.F. Gmel.) C.A. Sm. (MSHAI-SH) C1 (gonorrhoea-R); L1 (delayed afterbirth-R).

**Newtonia buchananii* (Baker) Gilb. & Bout. (MNYASA-SH) L1 (tonsillitis-R).

MONIMIACEAE

Xymalos monospora (Harv.) Baill. (MUUNGAWIZA-SH) C1 (convulsions-L & R, impotence-R).

MORACEAE

Artocarpus heterophyllus Lam. (MFENESI-SW) L1 (epilepsy-R).

**Ficus exasperata* Vahl (MSASA-SH) K1 (pneumonia-R); L1 (asthma-R).

**Ficus sur Forssk.* (MKUYU-SH) C2 (preventing abortion-R).

**Ficus thonningii* Blume (MVUMO-SH) C1 (headache, madness-L); L1 (bewitched epilepsy-R).

Ficus sp. (MKUYU-SH) C1 (preventing abortion-R).

**Milicia excelsa* (Welw.) Berg (MVULE-SH, SW) C1 (convulsions, generalized body pains, infertility-L & R, madness-L); C2 (dementia, madness-L & R; preventing abortion-R); M2 (hernia-R); M6 (hydrocele-B).

Morus alba L. (MLOBE-SH) L1 (allergy-R).

**Myrianthus holstii* Engl. (MKONDE-SH) M4 (cleansing mothers' milk-L).

**Trilepsium madagascariense* DC. (MZUGHU-SH) C1 (impotence-R).

MUSACEAE

**Ensete ventricosum* (Welw). Cheesm. (TAMBWE-SH) L1 (schistosomiasis-R).

Musa sapientum L. (MBOKO-SH) C1 (convulsions-L & R; epilepsy-L; gonorrhoea-R); K1 (peptic ulcers, prolapse of rectum-R); K3 (convulsions in children-R); L1 (frigidity-R).

MYRISTICACEAE

**Cephalosphaera usambarensis* (Warb.) Warb. (MTAMBAA-SH) L1 (hernia-R).

Myristica fragrans Houtt. (MKUNGUMANGA-SH) C2 (gonorrhoea-L).

MYRSINACEAE

**Maesa lanceolata* Forssk. (MTEI-SH) M2 (hernia-R); M6 (gonorrhoea, syphilis-R).

MYRTACEAE

Eucalyptus maedenii F. Muell. (MKARATUSI-SW) L1 (gonorrhoea-R).

Eugenia caryophyllus (Spreng.) Bullock & Harrison (MKARAFUU-SW) C2 (convulsions-L); L1 (dementia, gonorrhoea-R).

Psidium guajava L. (MPERA-SW) K1 (diarrhoea-L); L (gonorrhoea, tonsilitis-R).

**Syzygium guineense* (Willd.) DC. (MSHIHWI-SH) L1 (epilepsy-R).

OLACACEAE

Ximenia americana L. (MTUNDWI-SH) C1 (madness-L).

OLEACEAE

**Olea capensis* L. (MZIAGEMBE-SH) C1 (infertility-R).

PALMAE

Cocos nucifera L. (MNAZI-SW) L1 (rheumatism-R).

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PAPILIONACEAE

Arachis hypogaea L. (KARANGA-SW) K3 (aphrodisiac-L).

Cajanus cajan (L.) Millsp. (MBALAZI-SH) C1 (epilepsy-L; gonorrhoea, preventing abortion-R); C2 (convulsions-L); K3 (constipation, stomachache-R); L1 (neck tumour-R); M2 (baby born with sores-R).

Crotalaria sp. (MTOAVIVUGO-SH) B2 (impotence-R).

Dalbergia melanoxylon Guill. & Perr. (MHINGO-SH, MPINGO-SW) L1 (schistosomiasis-R); M4 (dementia-R).

Desmodium sp. (KIBAAZIMZITU-SH) B1 (infertility-R).

Erythrina abyssinica (Lam.) DC. (MVUNGUMAGOMA-SH) B2 (leprosy-R).

Lablab niger Medic. (MGHOBE-SH) L1 (rheumatism-R).

Lonchocarpus bussei Harms (MFUMBII-SH) B2 (cancer-L, B & R).

Mucuna pruriens (L.) DC. (KIHUMPU-SH) K1 (allergy-R);

PASSIFLORACEAE

Adenia cissampeloides (Planch.) Harms (GHOLE-SH) C1 (hernia-R, preventing abortion-R); K3 (constipation, diarrhoea-R).

Passiflora edulis Sims (MKAKAA-SH) L1 (epilepsy-R).

PIPERACEAE

Piper capensis L.f. (NG'OKO-SH) M1 (epilepsy-R); M2 (infertility-R).

Piper nigrum L. (PILIPILIMANGA-SW) C2 (rheumatism-L & R); L1 (dementia-R).

POLYGONACEAE

Rumex usambarensis (Dammer) Dammer (NYWANYWA-SH) M4 (head sores-R); M5 (hastening birth-L).

PROTEACEAE

Grevillea robusta A. Cunn. (MKABELA-SH) L1 (bewitchment-R).

RHAMNACEAE

*_Maesopsis eminii_ Engl. (MHESI-SH) L1 (delayed labour-L; gonorrhoea-R).

RHIZOPHORACEAE

*_Anisophyllea obtusifolia_ Engl. & Brehm. (MSAA-MTI -SH) L1 (kidney troubles-R).

ROSACEAE

Rosa sp. (MAUAWARIDI-SW) C2 (gonorrhoea-L).

RUBIACEAE

*_Mitragyna rubrostipulata_ (K. Schum.) Havil. (MROMBEROMBE-SH) L1 (convulsions in children, kidney troubles-R).

*_Morinda asteroscepa_ K. Schum. (MROMBEROMBE-SH) L1 (convulsions in children-R).

Pentas bussei K. Krause (MNYAMPOME-SH) B1 (infertility-R); K1 (kidney troubles especially in women, pneumonia-R).

Polysphaeria sp. (MKAME-SH) M4 (dementia-L).

*_Vangueria infausta_ Burch. (MVIRU-SH) B1 (infertility-R); C1 (generalized body pains - L & R); K2 (asthma-R); L1 (impotence- L & R); M4 (impotence-R).

Vangueria tomentosa Hochst. (MVIRU-SH) C1 (convulsions - L & R); C2 (preventing abortion-R).

RUTACEAE

Calodendrum eickii Engl. (MHAMBO-SH) L1 (hypertension-R).

Citrus aurantifolia (Christm.) Swingle (MLIMAU-SW) L1 (tapeworm-R).

Citrus aurantium L. (MSHUZA-SH) C1 (headache-L); C2 (dementia - L & R; generalized body pains-B; hernia, rheumatism-R); K2, K3 (asthma, chronic coughs and colds-R); L1 (abdominal boils-L, kidney troubles-R); M1 (chronic coughs and colds-R); M2 (toothache-R); M3 (tuberculosis-R).

Citrus nobilis Lour. (MCHENZA-SW) L1 (tapeworm-R).

Citrus sinensis (L.) Osbeck (MCHUNGWA-SW) L1 (tapeworm-R).

*_Clausena anisata_ (Willd.) Harv. ex Benth. (MJAVIKALI-SH) B2 (infertility-R, leprosy-L & R); C2 (dementia, madness-L & R); gonorrhoea-L).

*_Fagaropsis angolensis_ (Engl.) Dale (MKUNGUNI-SH) M3 (tuberculosis-R).

*_Toddalia asiatica_ (L.) Lam. (MDONGONYEZI-SH) C2 (generalized body pains-B & R); K2, K3, M1 (chronic coughs and colds-R); M3 (tuberculosis-R).

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SAPINDACEAE

**Allophylus calophyllus* Gilg (MBANGWE-SH) C1 (convulsions, generalized body pains-L & R); K1 (asthma, kidney troubles especially in women-R); K2 (chronic coughs and colds-R).

**Blighia unijugata* Baker (MZINDANGURUWE-SH) L1 (epilepsy-R); M2 (baby born with sores, hernia-R).

Deinbollia borbonica Scheff. f. (MTAMBAA-KUZIMU -SH) L1 (abdominal boils-R).

Dodonaea viscosa (L.) Jacq. (MZUTWE-SH) M6 (impotence-R).

**Zanha golungensis* Hiern (MKWANGA-SH) M5 (allergy-L).

SIMAROUBACEAE

Harrisonia abyssinica Oliv. (MDADAI-SH) K1 (kidney troubles especially in women-R).

SMILACACEAE

**Smilax kraussiana* Meissner. (UKOKOZI-SH) M5 (baby's skin sores-R).

SOLANACEAE

Capsicum annum L. (PILIPILIHOHO-SW) L1 (dysentery-R).

Capsicum frutescens L. (PILIPILI KICHAA-SW) K3 (constipation, stomachache-R); L1 (prolapse of rectum, tonsillitis-R).

Solanum incanum L.(MTUA-SH) C1 (bewitchment, convulsions in children-L & R, hernia-R, madness-L); C2 (infertility-R); K1 (stomachache in adults only-R); K2 (convulsions in children-L & R); K3 (aphrodisiac-R); L1 (bewitchment, convulsions in children-R).

STERCULIACEAE

Dombeya rotundifolia (Hochst.) Planch. (MKILIKA-SH) B1 (infertility-R); C1 (convulsions-L & R, impotence-R); L1 (tuberculosis-R); M4 (hooping cough-L); M5 (hastening birth-L).

**Sterculia appendiculata* K. Schum. (MFUNE-SH) C1 (convulsions-L & R); C1, C2 (preventing abortion-R); L1 (impotence-L & R); M1 (schistosomiasis-R).

ULMACEAE

**Trema orientalis* (L.) Bl. (MSHINGA-SH) C1 (bewitchment-L & R; impotence, infertility-R).

UMBELLIFERAE

Steganotaenia araliacea Hochst. (MNYONGAMPEMBE-SH) L1 (frigidity-R).

VERBENACEAE

Clerodendrum capitatum (Willd.) Schum. & Thonn. (LULI-SH) M2 (mastitis-B).

Clerodendrum schefferi Guerke (MZUMA-SH) K1 (allergy-R); K2 (convulsions in children-L & R); K3 (convulsions in children-R); M1, M2 (prolapse of rectum-R).

Lippia ukambensis Vatke (MUUTI-SH) C1 (convulsions-L & R; infertility-R; madness-L); M5 (chronic sores-L).

**Premna chrysoclada* (Bojer) Guerke (MHASANYOYA-SH) C1 (convulsions-R).

Priva cordifolia (L.f.) Bruce (NKAMACHUMA-SH) C1 (convulsions-L & R; headsores, rashes-L).

**Vitex keniensis* Turrill (MGIMBU-SH) C1 (madness-L).

VITACEAE

Ampelocissus grantii (Bak.) Planch. (MTONGOTONGO-SH) C1 (bewitchment-L & R, epilepsy-L).

**Cissus integrifolia Planch.* (SHAGAMPA-SH) C1 (bewitchment-L & R; gonorrhoea, hernia-R; preventing abortion-R).

ZINGIBERACEAE

**Aframomum angustifolium* K. Schum. (SAMAKA-SH) L1 (schistomiasis-R); M2 (infertility-R).

Zingiber officinale L. (TANGAWIZI-SW) L1 (dementia-R).

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4. Numbers and percentages of forest plants used

Table 20.2 shows the numbers of medicinal plant species used by each traditional doctor as well as the numbers and percentages of forest plants. The total number of species used by the fourteen traditional doctors is 185, of which 63 (i.e. 34%) are forest plants. The table indicates also that there is more use of forest plants for medicine in those villages (Churwa, Mikwinini and Mlesa), which are far from the large towns of Muheza and Tanga. In these more remote villages older, very local, traditions may have survived to a greater extent.

Table 20.2 Number of species and forest species used by different doctors.

		Forest species used		
Doctor	Number of species used	Number of species	% of all species	Village average
B1	14	0	0	13
B2	8	2	25	
C1	58	20	34	48
C2	18	11	61	
K1	16	3	19	26
K2	11	4	36	
K3	22	5	23	
L1	85	26	31	31
M1	14	6	43	44
M2	21	9	43	
M3	6	4	67	
M4	14	5	36	
M5	14	2	14	
M6	10	6	60	
All doctors	185	63	34	

5. List of diseases and conditions treated

Table 20.3 summarises the diseases treated by all fourteen traditional doctors in five villages. The doctors use 185 plant species to treat 63 different diseases. Each doctor can treat an average of nine diseases using an average of about 3 species per disease. The table further confirms that traditional doctors who live further from Muheza Town (at Churwa and Mlesa) deal with more diseases than those living near Muheza (at Bombani and Kisiwani).

6. The procedure of the traditional doctor

6.1 The patient

When a person falls sick, he or she may decide to go to a traditional doctor or the patients relatives may send him or her to a nearby doctor for treatment. The decision to send the patient to the traditional doctor depends mostly on the kind and seriousness of the disease, the reputation of the traditional doctor and the distance from a nearby dispensary, clinic or hospital. However, it was learnt during the survey that some people prefer being treated by traditional doctors simply because they have become used to that kind of treatment, while others only decide to go there after failing to recover after getting hospital treatment.

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Table 20.3 List of diseases and conditions treated.

Disease or Condition	DOCTOR B1	B2	C1	C2	K1	K2	K3	L	M1	M2	M3	M4	M5	M6	Total
Abdominal boils	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Allergy	-	-	X	-	X	-	-	X	-	-	-	-	X	X	5
as an Aphrodisiac	-	-	-	-	-	-	X	-	-	-	-	-	-	-	1
Asthma	-	-	X	-	X	X	X	X	-	-	-	-	-	-	5
Baby's skin sores	-	-	-	-	-	-	-	-	-	-	-	-	X	-	1
Baby sores	-	-	-	-	-	-	-	-	-	X	-	-	-	-	1
Baby's umbilical cord	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Bewitchment	-	-	X	-	-	-	-	X	-	-	-	-	-	-	2
Body sores	-	-	-	-	-	-	-	-	-	X	-	-	X	-	2
Breast irritation	-	-	-	-	-	-	-	-	-	-	-	-	-	X	1
Cancer	-	X	-	-	-	-	-	-	-	-	-	-	-	-	1
Chronic coughs and colds-	-	-	-	-	X	X	-	X	-	-	-	-	-	3	
Chronic sores	-	-	-	-	-	-	-	-	-	-	-	-	X	-	1
Cleansing mother'smilk	-	-	-	-	-	-	-	-	-	-	-	X	-	-	1
Constipation	-	-	-	-	-	-	X	-	-	-	-	-	-	-	1
Convulsions	-	-	X	X	X	X	X	X	-	X	-	-	-	X	8
Delayed afterbirth	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Delayed labour (hastening birth)	-	X	-	-	-	-	-	X	-	-	-	-	X	-	3
Dementia	-	-	-	X	-	-	-	X	-	-	-	X	-	-	3
Diarrhoea	-	-	X	-	X	-	X	-	X	-	-	-	-	-	4
Dysentery	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Earache	-	-	-	-	-	-	-	-	-	-	X	-	-	-	1
Enlarged spleen	-	-	-	-	-	-	-	-	X	-	-	-	-	X	2
Epilepsy	-	-	X	-	-	-	-	X	X	-	-	-	-	-	3
External boils	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Fatigue	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Fever	-	-	-	-	X	-	-	-	-	-	-	-	-	-	1
Frigidity	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
General body pains	-	-	X	X	-	-	-	-	-	-	-	-	-	-	2
Gonorrhoea	-	-	X	X	-	-	-	X	-	-	-	-	-	X	4
Headache	-	-	X	-	-	-	-	-	-	-	-	-	-	-	1
Headsores	-	-	X	-	-	-	-	-	-	-	-	X	-	-	2
Hernia	-	-	X	X	-	-	-	X	-	X	-	-	-	-	4
Hydrocele	-	-	-	-	-	-	-	-	-	-	-	-	-	X	1
Hypertension	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Impotence	-	X	X	-	-	-	-	X	-	-	-	X	X	X	6
Infertility	X	X	X	X	X	X	-	X	-	X	-	-	-	-	8
Indigestion	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Kidney disease	-	-	-	-	X	-	-	X	-	-	-	-	-	-	2
Leprosy	-	X	-	-	-	-	-	-	-	-	-	-	-	-	1
Loss of appetite	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Madness	-	-	X	X	-	-	-	-	-	-	-	X	-	-	3
Malaria	-	-	-	-	X	-	-	-	-	-	-	-	-	-	1
Mastitis	-	-	-	-	-	-	-	-	-	X	-	-	-	-	1
Measles	-	-	X	-	-	-	-	-	-	X	-	-	-	-	2
Neck tumour	-	-	-	-	-	-	-	X	-	-	-	-	X	-	2
Peptic ulcers	-	-	-	-	X	-	-	-	-	-	-	-	-	-	1
Indigestion	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Pneumonia	-	-	-	-	X	-	-	-	-	-	-	-	-	-	1
Poisoning	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Preventing abortion	-	-	X	X	-	-	X	-	-	-	-	-	-	-	3
Prolapse of rectum	-	-	X	-	X	-	-	X	X	X	-	-	-	-	5
Rashes	-	-	X	-	-	-	-	-	-	-	-	-	-	-	1
Rheumatism	-	-	-	X	-	-	-	X	X	-	-	-	-	-	3
Scabies	-	-	-	-	-	-	-	-	-	-	-	-	-	X	1
Schistosomiasis	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Stomach ache	X	-	-	-	X	-	X	-	-	-	X	-	-	-	4
Syphilis	-	-	-	-	-	-	-	-	-	-	-	-	-	X	1
Tapeworm	-	-	-	-	-	-	-	X	-	X	-	-	-	-	2
Tonsillitis	-	-	-	-	-	-	-	X	-	-	-	-	-	-	1
Toothache	-	X	-	-	-	-	-	-	-	X	-	-	-	-	2
Tuberculosis	-	-	-	-	-	-	-	X	-	-	X	-	-	-	2
Whooping cough	-	-	-	-	-	-	-	-	-	-	-	X	-	-	1
Wounds	-	-	-	-	X	-	-	-	-	-	-	-	-	-	1
TOTAL	2	6	18	9	13	4	8	30	6	10	3	6	7	9	131

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6.2 Consultation with traditional doctor

When the patient has arrived at the traditional doctor's house, he or she will be warmly welcomed and be directed to a waiting room. The traditional doctor will then call the patient to a special room for interrogation and examination. The traditional doctor will need to know the general symptoms and signs of the disease. He will examine the diseased part by touching it with his hands before deciding on the appropriate remedy. The consultation procedure is similar to that described by Harjula (1980).

6.3 Decision on treatment

After the interrogation and examination, the traditional doctor may then decide on the type of treatment and kind of medicine to be given to the patient. It was also learnt during the survey that some of the traditional doctors such as Esta Isaack of Bombani village and Kihamia Makata of Churwa village sometimes consult their spirits overnight before deciding about treatment.

6.4 Preparation of medicine

The normal method of preparing medicine from leaves is to pound and boil them for about ten minutes or simply soak the leaves in cold water. The stem bark and roots may also be pounded and boiled or simply soaked in cold water after being washed or cleaned. The medicine is then ready for use. When these parts are required for scarification, they are usually burnt and the carbon is pounded and sieved. It was also found out during the survey that fresh leaves were much preferred by traditional doctors in preparing their medicine, maybe because many of the leaves contain volatile oils which disappear on drying.

6.5 Methods of treatment

The type of treatment which the traditional doctor employs depends on the disease and age of the patient. For normal (internal) diseases such as malaria, asthma, hookworm and tapeworm, a liquid medicine, which must be drunk, is used. The dosage for liquid medicine is normally a cupful or glassful taken three times per day for one week or until the patient is cured — children and babies get half or quarter of this dose. For strong medicine, however, a table-spoonful is used for adults and a teaspoonful for children. The other method of treatment is the use of warm and hot baths. Warm baths are used for treating external diseases such as scabies and rashes, while hot baths are used for diseases such as fevers and dementia. Scarification is also a common method of treatment. In this method, a powdered medicine is rubbed on the parts of the body where small cuts have been made using a razor blade or a sharp knife. Wounds and sores are usually treated using poultices. Other types of treatment include full bed rest, wearing pieces of wood, incarceration and reading of the Holy Koran.

6.6 Treatment fees

It was found out during the survey that most traditonal doctors have no fixed fees. However, the patient may be asked to pay a certain amount of money or a chicken in advance of treatment until the patient has been completely cured. After recovering, the patient may be required to pay another sum of money, a chicken, a goat or a cow, whichever may be deemed to be fair or appropriate. Sometimes, however, the ex-patient is given an option to give his or her doctor anything as a kind of honorarium.

6.7 Re-examination

After completing a full course of treatment, the patient has to see his or her traditional doctor for re-examination. The doctor will interrogate the patient and recheck the diseased organs in order to ascertain whether or not the disease has been cured. If both the patient and the traditional doctor become satisfied that the disease has been cured, the patient would be discharged; if not, then the doctor may decide on an alternative treatment or refer the patient to some other doctors for further treatment.

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6.8 Collection and storage of medicinal plants

The most important plant parts which are used by traditional doctors are leaves, stem bark and roots. The tender leaves are collected by plucking them with fingers and taken home in a sack or small basket. The stem bark is peeled off using a panga or axe. The roots are excavated using a small hoe or digging stick. The collection of medicinal plants is usually done in the evening or early in the morning, in order to enable the doctor to have time for preparing medicine for the patients and to avoid exposing the medicine or the doctor to the hot sun.

The medicinal plant parts (leaves, stem bark and roots) are dried in the sun, if stored for future use. When they are dry, they may be put into sacks, baskets or earth pots and stored in a dry place in a house. Sometimes these parts may be tied with a rope and hung over a fire place in the kitchen. As a matter of convenience, these parts may be pounded and the powdered medicine is then stored in bottles, tins, calabashes or animal horns.

6.9 Trade in traditional medicine

It was found out during the course of this survey that the sale of medicine in the surrounding towns in Tanga region was very common. Some medicines from the East Usambaras are also sold in other towns outside Tanga Region, such as Dar-es-Salaam, Morogoro, Same and Moshi. Some of the plants used by East Usambara doctors are imported, eg. *Rumex usambarensis* and *Vitex keniensis*, probably from the West Usambaras.

7. Recommendations

The survey of medicinal plants in five villages of the East Usambaras has revealed that 34% of the plants used grow in the forests. This amount is not small and is an argument for forest conservation (FAO 1983).

The following recommendations are given:

- that further studies on the use of medicinal plants on the East Usambaras be done;
- that traditional medicinal gardens be established in villages and botanic gardens in order to make the plants easily available. Studies should be undertaken on methods of propagation and tending;
- that traditional medicine be published in books, in order to enable the public to read about it;
- that more medicinal plants be collected and screened in order to ascertain their active principles;
- that conservation measures be taken in order to protect and conserve them in their natural habitats.

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21. The Botanical Importance of the East Usambara Forests in Relation to Other Forests in Tanzania

by Jon C. Lovett

Forests in the east of Tanzania near the Indian Ocean have many endemic species. They can be referred to as the Eastern Arc forests. The East Usambara forests are part of this group and are of particular importance, because they have a very humid climate allowing wet forest species to be common, because their topography allows extensive development of transitional (submontane) forest and because there is a substantial area of lowland forest still present.

1. Introduction

The East Usambara forests are part of a moist forest floristic unit which runs from south-east Kenya to southern Tanzania and which has been called the 'Eastern Arc' forests (Fig. 1.1; Lovett in press a; Lovett 1985a). The Eastern Arc forests are a series of discrete areas associated with high rainfall areas on ancient crystalline mountains. From north to south these are the Taita, Pare, Usambara, Nguu, Nguru, Uluguru, Ukaguru, Malundwe, Rubeho, Uzungwa, and Mahenge. These mountains are the first high ground encountered by the moist rain-bearing winds coming from the Indian Ocean and so have a relatively high rainfall of between 1,000 to 3,000 mm yr^{-1} on their east-facing slopes. Consequently, they are of great importance as areas of water catchment and much of the forest on them has been reserved by the Tanzanian government for water catchment purposes.

The volcanic mountains of Kilimanjaro, Meru, Hanang and Rungwe, and the forest relying on rainfall derived from Lakes Malawi and Tanganyika are excluded from the Eastern Arc type forests because they are different floristically, although they are biologically important and key areas for water catchment. The coastal forests are also rich in endemic species of plant and animal, but as they are less critical than the mountain forests for protection of water catchment areas, they have received less effective protection.

The most remarkable feature of the flora of the Eastern Arc forests is the high number of species restricted to the Eastern Arc group. Some 25–30% of the 2,000 or so species of plant found in the Eastern Arc forests are endemic (Lovett 1988a). This is an extremely high figure, comparable with that of the other endemic-rich forested area of tropical continental Africa in Cameroun and Gabon (Brenan 1978).

The reason for the high level of endemism is the geological and climatic history of tropical Africa (Lovett 1985b; Lovett in prep a). The Eastern Arc mountains were formed during the preliminary break-up of Gondwanaland and are at least 100 million years old. Consequently they were in existence when Africa drifted north during the Oligocene (27–38 Myr BP) and so forest would have been present on the mountains as Africa became drier following the closure of the Tethys Sea. The forests have also survived the more recent desiccations to the African continent during the global climatic fluctuations of the last 2 million years because the Indian Ocean has remained at a relatively stable tempera-

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ture. This is in marked contrast to other forest areas in Africa which have contracted considerably a number of times, most recently within the last 20,000 years. This is correlated to the last glacial epoch in Europe (Hamilton 1982).

The age of the forest, combined with their separation from the main tropical African forest areas in West and Central Africa by an arid corridor, has resulted in the evolution of the many endemic species of plant and animal which are restricted to the Eastern Arc. Among the endemic plant species there are a number of species of economic or potential economic importance (Lovett in 1988b). Examples of endemic forest trees used commercially are *Allanblackia stuhlmannii, Beilschmiedia kweo, Cephalosphaera usambarensis* and *Isoberlinia scheffleri*. Another genetic resource of great importance to the developing world are the wild species of coffee which occur in the forests. About 40% of the world's wild species of coffee occur in the forests of Tanzania, of which 25% are endemic. These endemic species could be of enormous importance in future coffee-breeding programmes.

[Editors' note: according to Bridson (pers. comm.) only two species of wild coffee *Coffea mongensis* and *Coffea* sp. B (of Kew Bull. 36, 1982) are known from the East Usambaras. The former also occurs on the Uzungwa Mountains, but the latter is known from only one gathering, made in 1939.]

2. Phytogeographic classification of the Tanzanian forests

The phytogeography of Africa is now comparatively well understood following the publication in 1983 of "The Vegetation of Africa" (White 1983). This publication is the culmination of twenty years' work by the Map Committee of the Association pour l'Etude Taxonomique de la Flore de l'Afrique Tropicale (AETFAT) and is the revision of an earlier vegetation map of Africa south of the Sahara. The classification system used is based on the distribution of plant species on a continent-wide basis and so, in relating the East Usambara forests to the other Tanzanian forests, it is important to fit them into this system.

Five major phytogeographic zones of Tropical Africa are represented in Tanzania. These are the Guineo-Congolian Region, which is represented in an impoverished form in the forests of the Lake Victoria Regional Mosaic; the Afromontane Region which is found on the mountains and represented by grassland, forest and thicket; the Somali-Masai Region which is represented by drier thicket and woodland; the Zambezian Region which is represented in the wetter woodland; and the Zanzibar-Inhambane Regional Mosaic which is a mixture of woodland, thicket, and forest in the east of Tanzania. Three of these zones contain forest, and the forest types occurring in each are described below. In addition to the "Vegetation of Africa" (White 1983), further information is given in Lovett (1985 b) and Lovett (in prep b).

3. Moist forests of the Lake Victoria Regional Mosaic

These occur in the higher rainfall areas around Lake Victoria and the northern part of Lake Tanganyika. Two types of closed canopy forest are recognised as occurring in Tanzania, these are:

- **Guineo-Congolian drier peripheral semi-evergreen rain forest:** Occurs around Lake Victoria as forest patches in secondary grassland, and as gallery forest in the northern part of Lake Tanganyika at an altitude of 800 – 1,550 m with an annual rainfall of 1,200 – 2,000 mm. The majority of species occurring in this forest type are widespread in the Guineo-Congolian Region. It is low in endemic species.
- **Guineo-Congolian swamp forest:** Occurs extensively on shores of Lake Victoria and as gallery forest in the northern part of Lake Tanganyika at an altitude of 1,130 – 1,200 m with an annual rainfall of 1,000 – 2,000 mm. The forests near the mouth of the Kagera River (Minziro) are a mixture of Guineo-Congolian and Afromontane species. It is low in endemic species.

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4. Moist forests of the Zanzibar-Inhambane Regional Mosaic

The Zanzibar-Inhambane Regional Mosaic extends along the eastern coast of Africa from southern Somalia to the mouth of the Limpopo River. It is a distinct phytochorion as a result of the humidity and precipitation coming from the Indian Ocean. It extends inland as far as the influence of the coastal climate and the moist forests are best developed north of the rain shadow created by Madagascar in Mozambique and south of the Tana River in Kenya. Consequently Tanzania is particularly important for this zone. There are three main types of forest represented in Tanzania which are:

- **Zanzibar-Inhambane lowland rain forest:** Occurs in Tanzania along the lower parts of the Eastern Arc mountains, notably the Usambara, Nguru, Uluguru, and Uzungwa, at an altitude of 300–800 m with a rainfall of 1,500–2,000 mm a year. This forest type is particularly rich in endemic species.
- **Zanzibar-Inhambane transitional rain forest:** Called transitional because it is intermediate between the lowland forests and Afromontane rain forest. It occurs on the Eastern Arc mountains at an altitude of 800–1,250 m with a rainfall of 2,000–3,000 mm a year. It is best developed in the eastern tip of the West Usambara, East Usambara, Nguru, Uluguru, and Uzungwa. This forest type is particularly rich in endemic species.
- **Zanzibar-Inhambane undifferentiated forest:** Occurs in drier or more seasonal areas than the lowland forest type and is termed undifferentiated as it varies from a high canopy forest to thicket over a short distance. It exists at altitudes of 300–800 m with a rainfall of 1,000–1,500 mm a year. In Tanzania it is found in many small patches along the coastal region, the most important of which are the Rondo plateau, Pugu Hills, and Zaraninge Plateau. It is particularly rich in endemic species.

5. Moist forests of the Afromontane Region

The Afromontane Region is one of the most widespread of the African phytogeographic regions, though it is one of the smallest in total area as it consists of 'islands' of mountainous vegetation linked together by common species. In Tanzania it occurs on the Eastern Arc mountains, on the volcanic mountains of Kilimanjaro, Meru, Hanang, and Rungwe, and the mountains in the south-west, notably Mbizi and Mahali. Two types can be recognised, with minor variants when a single species becomes dominant or is an important feature of the vegetation.

- **Afromontane rain forest:** Occurs on the mountains of eastern, southern and northern Tanzania at an altitude of 1,200–2,500 m with a rainfall of 1,250–2,500 mm a year. Forests of this type on the Eastern Arc mountains are rich in endemic species, wheras those on the Volcanic mountains of Kilimanjaro and Rungwe are not.
- **Afromontane undifferentiated forest:** This is a drier or more seasonal forest type than Afromontane rain forest and is termed undifferentiated as it changes rapidly between wetter and drier forest. It is found on most mountain areas of Tanzania at altitudes between 1,500–2,500 m with an annual rainfall of 1,000–2,000 mm. In the Eastern Arc mountains this forest type contains a number of endemic species, whereas on other mountains the degree of endemism is lower.
- **Other Afromontane forest types:** Variants of Afromontane forests are recognised due to the dominance of single species. In Tanzania these are: *Hagenia* forest; *Juniperus* forest; and bamboo forest.

6. Particular importance of the East Usambara forests

Using the definitions given above, the East Usambara forests are mainly Zanzibar-Inhambane lowland forest, Zanzibar-Inhambane transitional rain forest, with Afromontane rain forest at higher altitudes and Afromontane undifferentiated forest on the highest exposed ridge tops. Zanzibar-Inhambane undifferentiated forest also occurs along the fringes of the lowland forest and in river valleys

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running off the mountains. [Editors' note: There is some difference between J. Lovett and A.C. Hamilton on the types of forest represented on the East Usambaras. According to the latter, only two main types are present, lowland forest and submontane forest, equivalent to Zanzibar-Inhambane lowland rain forest and Zanzibar-Inhambane transitional rain forest of Lovett. See e.g. Chapter 22.]. The East Usambaras are in the Eastern Arc floristic group, and possess many species in common with the other areas which are restricted in distribution to the Eastern Arc mountains. In terms of plant species conservation, all the Eastern Arc mountains are important. Each mountain area has species restricted to it, in addition to species found on more than one or all of the Eastern Arc group. Thus conservation efforts should not be restricted to the East Usambaras. However, there are a number of characteristics of the East Usambaras which make them particularly important. In addition to the plant species restricted to the East Usambaras, there are three features unique to the East Usambaras not found in the other Eastern Arc mountains and which need to be given consideration. The unique features are: the near per-humid climate; the topography in relation to occurrence of forest type; and the occurrence of substantial areas of lowland forest.

6.1 Climate

Africa as a whole has a strongly seasonal climate. This is in marked contrast to the Far East and tropical South America where large areas are per-humid (fewer than two months with less than 100 mm of rain, no months with less than 60 mm of rain). It is in the per-humid areas that true tropical rain forest occurs.

However, in Africa there are some areas which are near to being per-humid. These are in the Guineo-Congolian Region in Central Africa around the Zaire basin, and in the East Usambaras (for Walter-Gaussen clima-diagrams see White 1983). It is the bi-modal rainfall distribution in the East Usambaras which is responsible for their near per-humid climate. This contrasts with other Eastern Arc mountains which have an extensive forest cover, for example the Uzungwa area, where there is a unimodal rainfall distribution with a marked dry season. The significance of this phenomenon to the conservation of the East Usambaras is that the moister forest types are more extensive here than in any other of the Eastern Arc mountains. This is an important consideration in gene-pool conservation, as the greater area of moist forest supports a greater number of individuals of the species of restricted distribution of the wetter forest type. A further consideration is that while tree species distribution is becoming better known, some other plant and animal groups are not so well studied and the near per-humid climate of the East Usambaras may prove to be an important factor in determining the distribution of these groups.

6.2 Topography

After the unusually humid climate of the East Usambaras, the second remarkable natural phenomenon of the mountains is the topography. Most of the other Eastern Arc mountains have a steep east-facing slope, so that the phytogeographical regions of the vegetation are compressed into narrow bands. For example, on the Uzungwa Mountains the Zanzibar-Inhambane transitional rain forest occurs over only a few hundred metres as the mountains are ascended. On the East Usambaras there is a plateau at about the altitude at which the transitional forest occurs. Consequently, this forest type is far more extensive there than elsewhere in the Eastern Arc Group. Moreau (1935) describes the transitional forest community as the "most luxuriant type of forest existing in East Africa", with narrow-crowned trees and a high diversity of canopy species. This forest type is the nearest structurally to that of the per-humid forests of the Far East and tropical South America.

6.3 Lowland forest

The Zanzibar-Inhambane lowland forest is nowhere extensive and, like the transitional rain forest, restricted to a narrow band on most of the other Eastern Arc mountains due to topography. The already restricted areas of this forest type have been further diminished by encroachment over many years for timber and agricultural land at lower altitudes. The lowland forest type has also suffered because it is

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not as important as the higher altitude forests for water catchment and so has not been consistently protected. It is extremely rich in endemic species, and so for biological conservation is important. Recent work has also shown that bird species migrate between higher altitude and lower altitude forest at different seasons (see Chapter 35) and so for bird conservation it is important to keep a high to low altitude forest continuum.

7. Conclusions

- The forests on the mountains and coast of eastern Tanzania are extremely rich in endemic species. The Eastern Arc mountain forests, of which the East Usambaras form a part, have 25 – 30 % endemism amongst the 2,000 plant species occurring in them.
- Phytogeographically, Tanzania has forests belonging to three different phytochoria. In the west of the country around Lake Victoria are Guineo-Congolian derived forests, in the east under the influence of the Indian Ocean climate are Zanzibar-Inhambane forests, and on the higher wet mountains are Afromontane forests.
- In Tanzania, the level of endemism on the Eastern Arc mountains in the Zanzibar-Inhambane and Afromontane forests is substantially greater than that in the Guineo-Congolian derived forests and Afromontane forests on volcanic mountains.
- The East Usambaras are an important part of the Eastern Arc mountain forest group because:
  - they are one of the few places in Africa with a near per-humid climate;
  - they have a substantial area of Zanzibar-Inhambane transitional rain forest;
  - they have a substantial area of Zanzibar-Inhambane lowland forest.

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Editors' note: the Usambara bryoflora and its biogeographical affinities

The Usambara bryoflora has been extensively studied by Pocs and associated workers (Bizot & Pocs 1974, 1982; Ochyra & Pocs 1985; Pocs 1975, 1985). The flora is rich, with an exceptional number of endemics. Its most interesting feature is the presence of many bryophytes which occur elsewhere in Madagascar or the Mascarenes. Only the Ulugurus in mainland Africa are thought to contain a similar number of 'Lemurian' species, but possibly some of the other, less explored Eastern Arc mountains could also be rich. The bryoflora of the East Usambara mountains and other Eastern Arc mountains, all composed of old non-volcanic rocks, contrasts with that of the young volcanoes such as Kilimanjaro, which have no or very few Madagascar/Mascarene species. Pocs suggests that the pattern reflects ancient connections predating separation of Madagacar and the Mascarenes from continental Africa by rifting, maybe as long ago as 100-140 Myr. Few higher plants display this pattern of geographical distribution, because of their later evolution.

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22. A Survey of Forest Types on the East Usambaras Using the Variable-Area Tree Plot Method

by A.C. Hamilton, C.K. Ruffo, I.V. Mwasha, C. Mmari and J.C. Lovett

A survey of forest types was carried out using variable-area tree plots in the East Usambaras. The results show that altitude (or factors relating to altitude) is by far the biggest determinant of the floristic composition of more mature patches of forest. Altitudinal variation in floristic composition appears to be continuous, but it is convenient to recognize two main types of forest, lowland (semi-deciduous) forest and submontane (evergreen) forest, with the altitudinal boundary between them lying at about 850 m. Many lowland forest species are widely found in lowland forest near the East African coast, while many submontane forest species occur elsewhere only on the Eastern Arc mountains. Floristically somewhat similar forest types occur in central Africa, but with a higher altitudinal boundary between them.

1. Description of the method

The variable-area tree plot method was devised by Professor J. Hall, formerly of Sokoine University, and has been used extensively to study the floristic composition of forests in eastern Tanzania by Professor Hall and Jon Lovett (Hall 1985). Its use in the present work will facilitate comparisons between the forests of the East Usambaras and those elsewhere.

Field instruction was given on the method by Jon Lovett and, within the framework of the overall sampling strategy (next section), plots were placed in the forests according to his techniques.

Plots are deliberately sited in more mature-looking patches of forest, a procedure which is obviously highly subjective but which in our opinion does result in a reasonable picture of forest variation given a relatively short period of field work (2 months in the present case). Forest areas which are avoided are those which represent early stages in the forest growth cycle and, in so far as this is possible, those which have been disturbed by man. A justification for avoiding patches of young forest is that pioneer species are relatively few in number and tend to be widely distributed; the occurrences of the more numerous and often more geographically restricted species belonging to more mature forest stages are likely to provide a more detailed guide to variations in forest composition. The high degree of human disturbance in many of the East Usambara forests makes a subjective approach to sampling in any case virtually unavoidable, given the objective of determing floristic composition within natural forest.

An arbitrary centre point is chosen within each forest patch and the nearest 20 trees to this point are located, identified and their diameters measured. Trees have to have a diameter at breast height (1.3 m above ground level) of 20 cm or more to be included. In practice in our work, the identities of most

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trees within plots were only established as recording proceeded, i.e. not when the positions of the centre points were originally chosen, and there seems to have been little bias towards selection of 'interesting' rather than 'typical' forest patches.

The size of each sample, which must be known for calculating estimates of basal area, is determined by measuring the distance to the twenty-first tree from the centre point and calculating area as that of a circle with this distance as radius.

Hall (1985) uses basal area as a measure of the importance of each species in a plot. In the present case, presence/absence and frequency records were used instead, since the number of plots was considered too few and their sizes too small to justify use of the more sophisticated basal area.

The floristic lists from the sample plots were compared with one another by means of ordination and classification procedures using a VAX computer at the University of Ulster, Coleraine. A variety of methods were tried, all giving similar results. The ordination programme DECORANA and the classification programme TWINSPAN are used to illustrate the results here. Both programmes are widely used to analyse this type of vegetation data and are regarded as among the 'best' of the numerous available methods (Gauch 1982).

The objective of an ordination analysis is to order the plots graphically along a limited number of dimensions (two in the present case), plots which are floristically similar being placed close together and those which are more dissimilar further apart. The first axis of the ordination is the direction of greatest variation in the data set, and so on. The positions of plots on the ordination axes can be compared to the values of a range of environmental variables relating to the plots to give indications of their possible influences on vegetational variation.

The objective of a classification is to place together in groups plots which are floristically similar. In this way various types of forest can be recognized, which is valuable for description and comparison.

2. Sampling strategy

In its original plan of work, IUCN envisaged that the variable-area tree method would be used to examine forest composition in areas inaccessible to mechanical logging. These areas might not be covered by the FINNIDA inventory survey which, it was hoped, would provide reliable floristic information (collected in a way broadly comparable to the variable-area tree plot method) in the accessible areas. A decision by the FINNIDA field staff in September 1986 to restrict inventory sampling to accessible areas did indeed give some justification to the initial IUCN approach.

There were indications at an early stage of the work that the inventory survey was likely to suffer from many misidentifications of trees and it was decided that it would be useful to use the variable-area method to gain a wider impression of floristic variation within the East Usambara forests. Either Lovett or Ruffo was present to help with tree identification when nearly every one of the variable-area plots was recorded and a rather high degree of accuracy in tree identification is believed to have been achieved. A limitation of the work is that only 65 plots were taken: it takes time to be sure of the identities of some of the trees.

Previous work in the Usambara forests (Moreau 1935) and our experience elsewhere in East Africa suggested that the floristic composition of more mature forest patches was likely to be related particularly to three environmental factors — altitude, aspect and catenary position. A sampling programme was devised with this in mind. It was intended to place samples along four altitudinal transects, two on the wetter east- or south-facing slopes and two on the drier west- or north-facing slopes. Two transects were to be on the main range and two on the isolated mountains to the east. The transects had necessarily to be positioned in the rather few places where forest descends from high to low altitude. On each transect samples were to be placed at 100 m altitudinal intervals in groups of three, one on a ridge, one on a slope and one in a valley.

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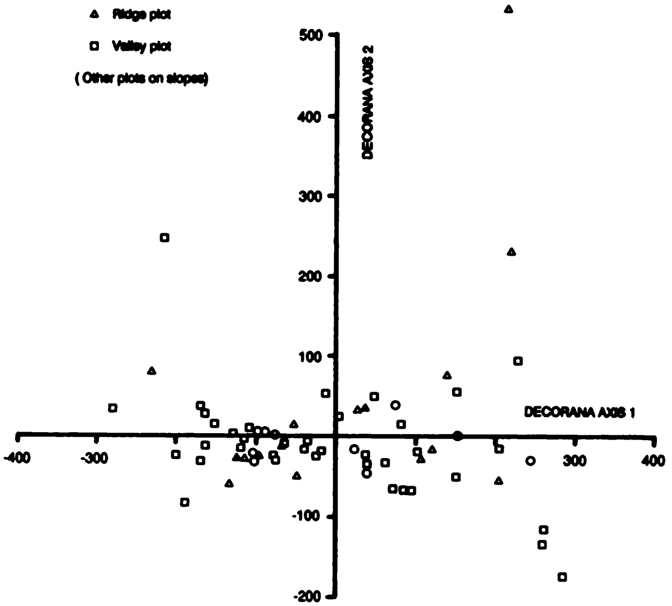

Figure 22.1 ***Ordination of variable-area tree plots from the East Usambara forests by DECORANA using presence/ absence records only. Only the first axis is ecologically meaningful, expressing an altitudinal gradient (see Fig 22.3).***

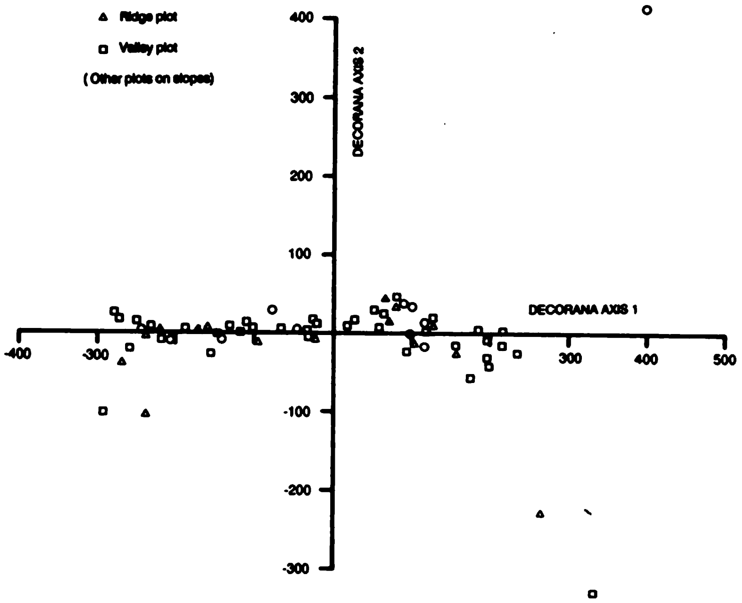

Figure 22.2 ***Ordination of variable-area tree plots from the East Usambara forests by DECORANA using species frequencies. Only the first axis is ecologically meaningful, expressing an altitudinal gradient (see Fig. 22.4).***

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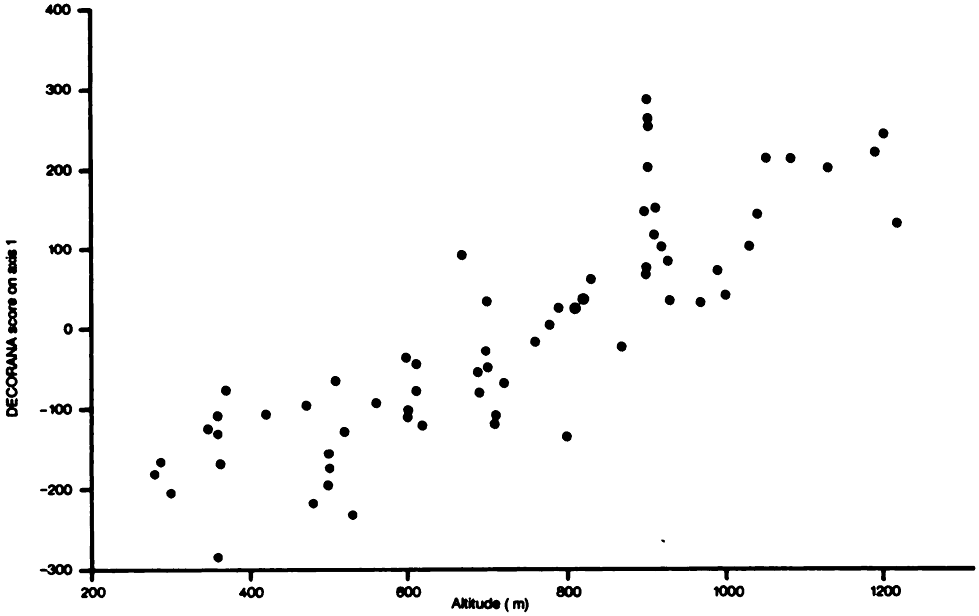

Figure 22.3 ***Relationship between altitude and the score on the first axis of a DECORANA ordination for variable-area tree plots from the East Usambara forests, using presence/absence data. The good correlation shows that much of the floristic variation in the forests is related to altitude.***

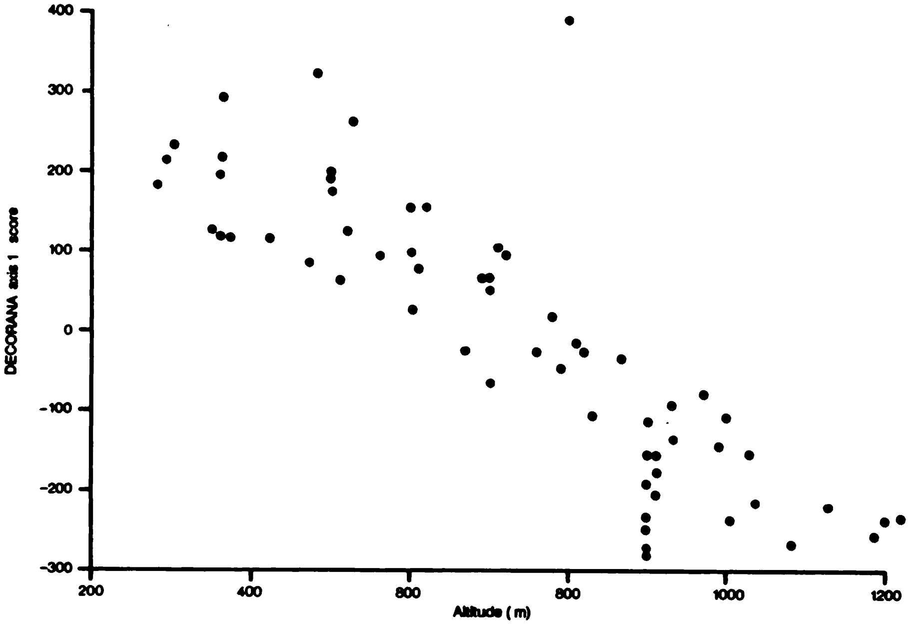

Figure 22.4 ***Relationship between altitude and the score on the first axis of a DECORANA ordination for variable-area tree plots from the East Usambara forests, using species frequencies. The reversal of the direction of slope of the relationship between the variables compared to Fig. 22.3 is not ecologically meaningful. As with Fig. 22.3, this shows that much of the floristic variation is related to altitude.***

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In the event, only three transects, with a total of 65 plots, were completed (Fig. 10.1). One transect was on the south of the main range, extending from Kwamsambia FR to Kwamkoro FR, with a few plots in West Amani FR. A second was on the north-west of the main range, mainly in Lutindi FR. The third was on the east side of Mt Mtai. The fourth transect was to have been on the west facing slopes of Mt Mtai, but this was not enumerated after it became apparent from an analysis of the data already available that floristic variation was very strongly related to altitude and that the effects of other factors, such as catenary position, on floristic composition were not likely to be revealed without the use of many more samples. Even then, the influence of relatively minor environmental factors on forest variation might not be clear given the subjective method used to position the plots.

Taking all three transects together, a reasonable distribution of plots in relation to altitude was achieved (altitudinal sampling range 290 – 1,220 m), but there was an uneven representation of ridge, slope and valley plots along the altitudinal gradient. This was principally due to the difficulty of finding relatively undisturbed forest on ridges and in valleys in some places, especially at lower altitudes. Also, valleys become topographically rare at high altitudes.

One of the 65 plots, on a high ridge on Mt Mtai, has been excluded from analysis of the data due to the suspected presence of planted trees. This plot was situated close to the site of an old resthouse dating to the German colonial period.

3. Results

3.1 Ordinations

All ordinations carried out on the data set, whether using presence/absence or frequency records, show that much of the floristic variation lies along one axis (Figs. 22.1 & 22.2). There is no clear relationship between topographic position and scores on either of the first two axes.

Scores of plots along the first axes of the ordinations are closely related to altitude (Figs. 22.3 & 22.4) and it is concluded that environmental factors associated with altitude are the principal causes of floristic variation in more mature patches of undisturbed forest on the East Usambaras.

The variation of floristic composition with altitude can be illustrated by plotting the frequencies of the common species in the plots against altitude (Fig. 22.5). The impression is of gradually changing floristic composition with altitude, though species vary in the extents of their altitudinal ranges.

3.2 Classification

All types of numerical classification tried resulted in recognition of a number of principal forest types forming altitudinal series, with some altitudinal overlap. Results of the TWINSPAN classification of the presence/absence data are shown on Tables 22.1 to 22.3. The four-forest-type level has been selected for the purpose of description, although it is emphasized that this is arbitrary and almost any number of forest types between 2 and 8 could equally well have been recognized. All four forest types are represented on all three transects.

The mean altitudes of the four forest types, as calculated from the altitudes of plots belonging to each, are 435, 612, 897 and 1,020 m (Table 22.2). There is a gradual change in species composition with altitude, as may be seen from Table 22.1 and as has already been shown by the ordination analyses. Many species are found in two altitudinally adjacent forest types, but the common species at least are completely different at the altitudinal extremes.

There is a slight suggestion that each of the forest types occurs at a slightly higher altitude on the north-west side of the main East Usambara range (Lutindi transect) compared to the south (Kwamsambia/Kwamkoro/Amani transect) (Table 22.3). The Mtai data are insufficient for comparison. On average, the mean altitudes of forest types are 150 m higher on the north-west than on the south. More data are required to verify this finding, which is not unexpected given the drier climate of the north-west.

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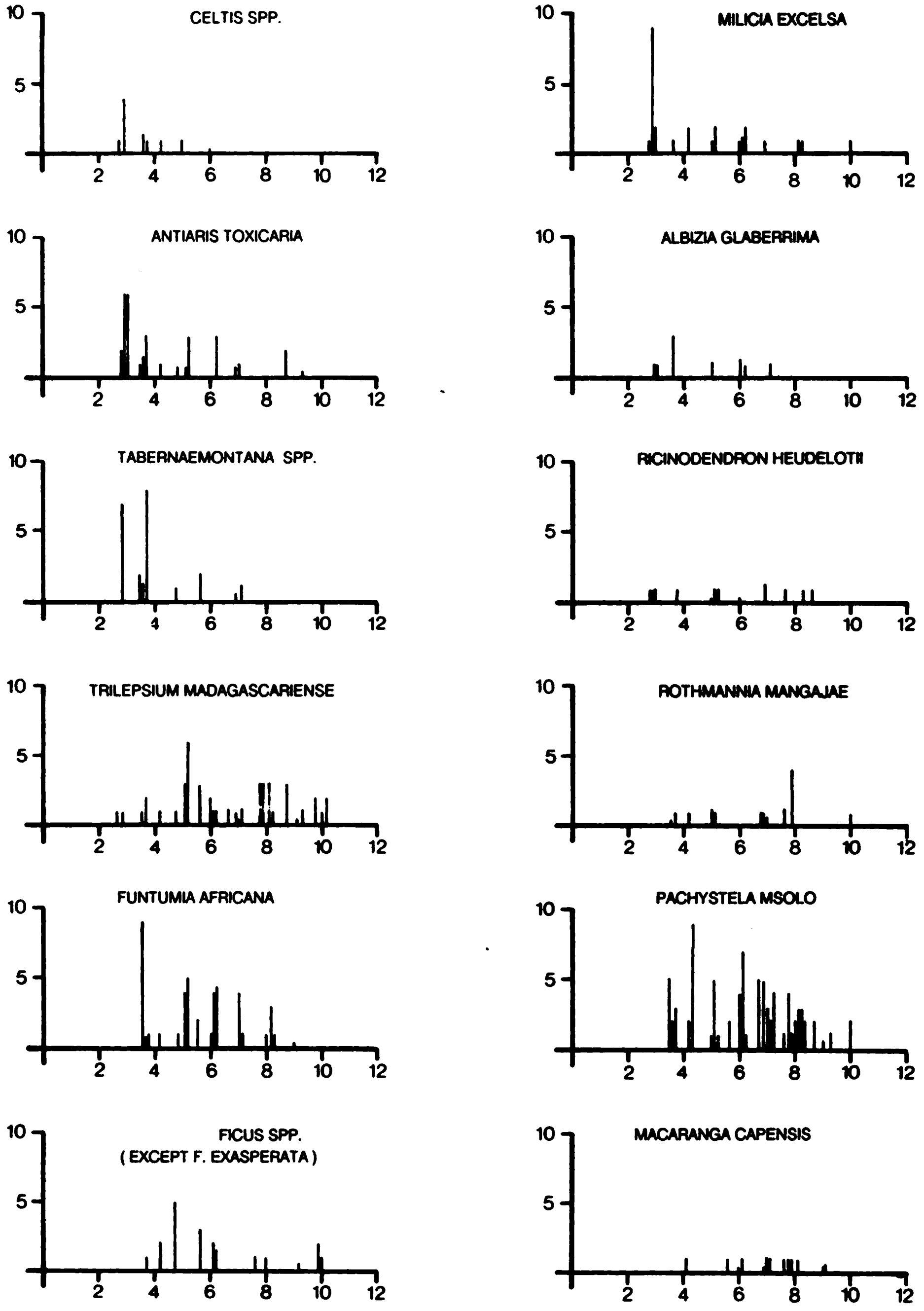

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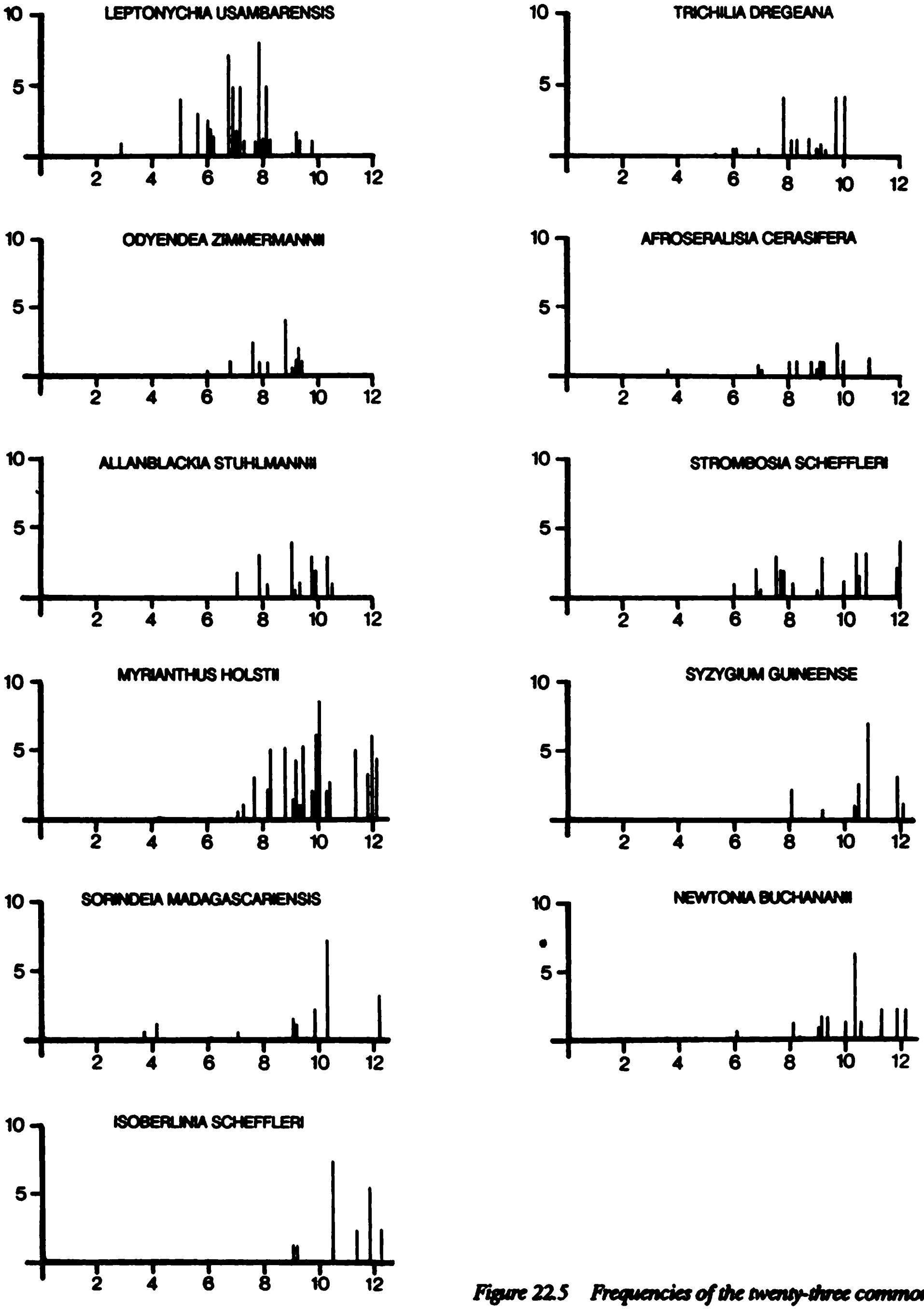

Figure 22.5 ***Frequencies of the twenty-three commonest species (or in a few cases genera) in the variable-area tree samples, plotted against altitude. The species are arranged in order of altitudinal representation.
A clear variation with altitude is shown.***

Table 22.1 Commonest species in the four forest types recognized in the TWINSPAN classification of the East Usambara forests, using presence/absence data from variable-area tree plots. The figures show the percentages of plots within each forest type containing the species.

Forest type 1:

Albizia glaberrima (55), *Celtis* spp. (55) *Antiaris toxicaria* (45), *Milicia excelsa* (45), *Terminalia sambesiaca* (45), *Zanha golungensis* (45), *Grewia goetzeana* (36), *Bequaertiodendron natalense* (36), *Ricinodendron heudelotii* (36).

Forest type 2:

Pachystela msolo (96), *Trilepsium madagascariense* (73), *Leptonychia usambarensis* (69), *Funtumia africana* (62),*Antiaris toxicaria* (46),*Ficus* spp. (36),*Milicia excelsa* (35),*Ricinodendron heudelotii* (31), *Tabernaemontana* spp. (31), *Macaranga capensis* (31).

Forest type 3:

Myrianthus holstii (93),*Allanblackia stuhlmannii* (71), *Trilepsium madagascariense* (54), *Odyendea zimmermannii* (50),*Pachystela msolo* (50),*Antidesma membranaceum* (43),*Leptonychia usambarensis* (43), *Trichilia dregeana* (43), *Afrosersalisia cerasifera* (36), *Strombosia scheffleri* (36).

Forest type 4:

Isoberlinia scheffleri (62),*Allanblackia stuhlmannii* (54),*Cynometra* spp. (54), *Sorindeia madagascariensis* (54), *Newtonia buchananii* (46), *Cola* spp. (38), *Strombosia scheffleri* (38), *Beilschmiedia kweo* (31), *Maesopsis eminii* (31), *Odyendea zimmermannii* (31), *Syzygium guineense* (31).

The figures show the percentages of plots within each forest type containing the species.

Table 22.2 Altitudes of the four forest types recognized in the TWINSPAN classification of the East Usambara forests, using presence/absence data from variable-area tree plots.

	Mean altitude(m)	Standard deviation(m)	Minimum altitude(m)	Maximum altitude(m)
Forest type 1	435	99	290	600
Forest type 2	612	154	280	870
Forest type 3	897	106	670	1040
Forest type 4	1020	91	900	1220

Table 22.3 Mean altitudes of the four forest types recognized in the TWINSPAN classification of the East Usambara forests in different areas. Altitudes are in metres. The number of samples is given in brackets.

	Area 1 Kwamsambia/ Kwamkoro/Amani	Area 2 Lutindi	Area 3 Mtai
Forest type 1	295(2)	515(2)	451(7)
Forest type 2	559(15)	683(8)	683(3)
Forest type 3	892(5)	910(8)	820(1)
Forest type 4	953(8)	1185(4)	1100(1)

Altitudes in metres. The number of samples is given in brackets.
The number of samples from higher levels on Mtai is too low for useful comparison. Note that forest types tend to occur at higher altitudes in Area 2 than Area 1; t-tests for Forest Types 2 and 3 reveal that there is no significant difference (at the 5% level) in the altitudinal occurrence of these forest types between Areas 1 and 2.

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3.3 Floristic diversity

The mean number of species per variable-area plot is about ten. There is no clear variation with altitude or catenary position (Fig. 22.6).

3.4 Basal area

Basal area shows a wide range of variation (Fig. 22.7), but tends to increase with altitude from about 25 m^2 ha^{-1} at 300 m to 50 m^2 ha^{-1} at 900 m. The increase parallels an increase in climatic moistness and is thus perhaps not unexpected, but it is also likely that values are sometimes depressed, especially in some of the lower altitude forests, through harvesting of timber.

The removal of poles is widespread in the forests but does not directly affect basal area as defined here, since usually only trees under 20 cm dbh are cut. However, in the longer term, pole removal will lower the recruitment of small trees into larger size classes.

Values for basal area are more or less similar to those reported in earlier studies in African forests. Pierlot (1966) has found a rather constant basal area for forests betwen 450 and 2,400 m in eastern Zaire of c. 35 m^2 ha^{-1}, while Hamilton and Perrott (1981) have measured a different but also rather constant basal area for forests between 2,000 and 3,300 m on Mt Elgon of around 55 m^2 ha^{-1}. Basal area in Mazumbai Forest, on the West Usambaras at 1,400–1,900 m altitude is 35.7 m^2 ha^{-1} (Hall 1985).

3.5 Distribution of endemic species

Species have been classified into four categories of endemism (Chapter 17), as follows:

- **Endemic status 1** – found only on the East Usambaras.
- **Endemic status 2** – found on the East Usambaras and at one or a few similarly restricted localities in eastern Tanzania or occasionally eastern Kenya, Mozambique or Malawi.
- **Endemic status 3** – more widely distributed in East African coastal forests. Not in the Guineo-Congolian forests of Central and West Africa (Zaire etc.).
- **Endemic status 4** – widely distributed in African tropical forests, usually also in Central or West Africa.

There are a few unclassified species, including those which have been introduced.

The percentages of species in the plots in each of these categories are plotted against altitude on Fig. 22.8. The following trends are revealed:

- Strict East Usambara endemics (category 1) are rare at all altitudes and there is no clear relationship with altitude.
- The percentage of near-endemics (category 2) increases with altitude.
- The percentage of widely distributed East Africa coast species (category 3) decreases with altitude.
- The percentage of widely distributed African species (category 4) varies little with altitude.

These results are confirmed by an analysis of the distribution patterns of the entire tree flora (Chapter 23) and floristic analysis of enlarged profile diagram plots (Chapter 25). For an explanation, see Chapter 23.

4. Comparison with previous work on forest types

Moreau (1935) classified the forests in the Amani area of the East Usambaras into two types, Lowland Forest and Intermediate Forest, with the boundary between them lying at c. 750 m. The present study has emphasized the continuous nature of floristic variation with altitude. Bearing this in mind, together with the necessity of classification for descriptive and comparative purposes and the

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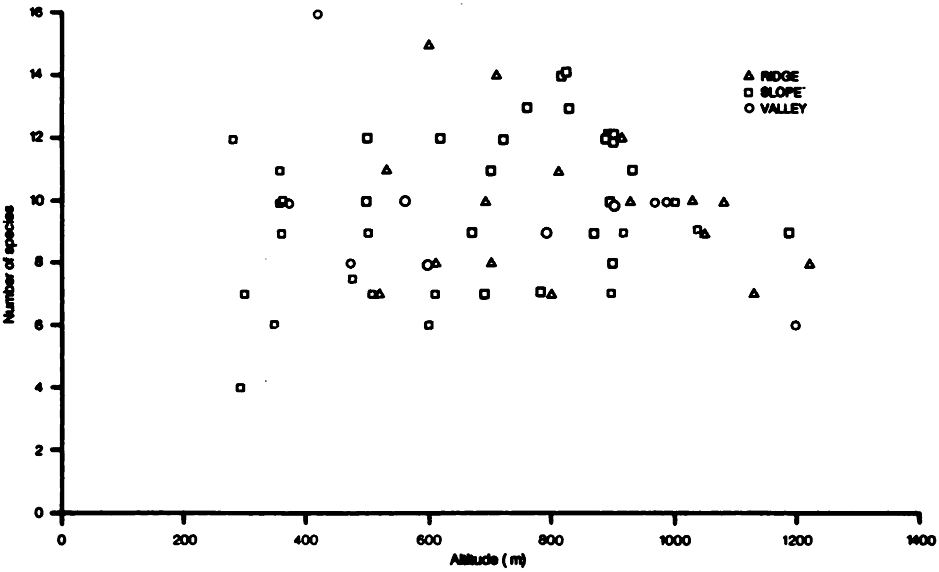

Figure 22.6 Relationship between number of species and altitude in variable-area tree plots. About the same number of species is found at all altitudes.

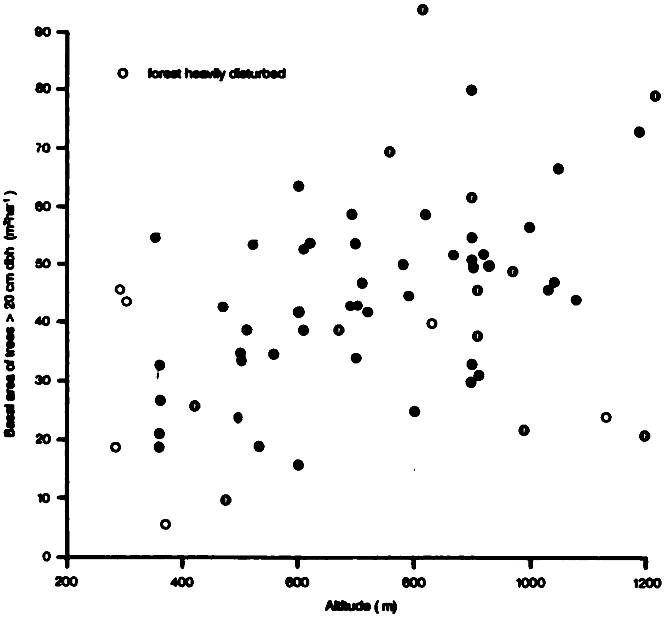

Figure 22.7 Relationship between basal area and altitude for variable-area tree plots. Basal area tends to increase with altitude.

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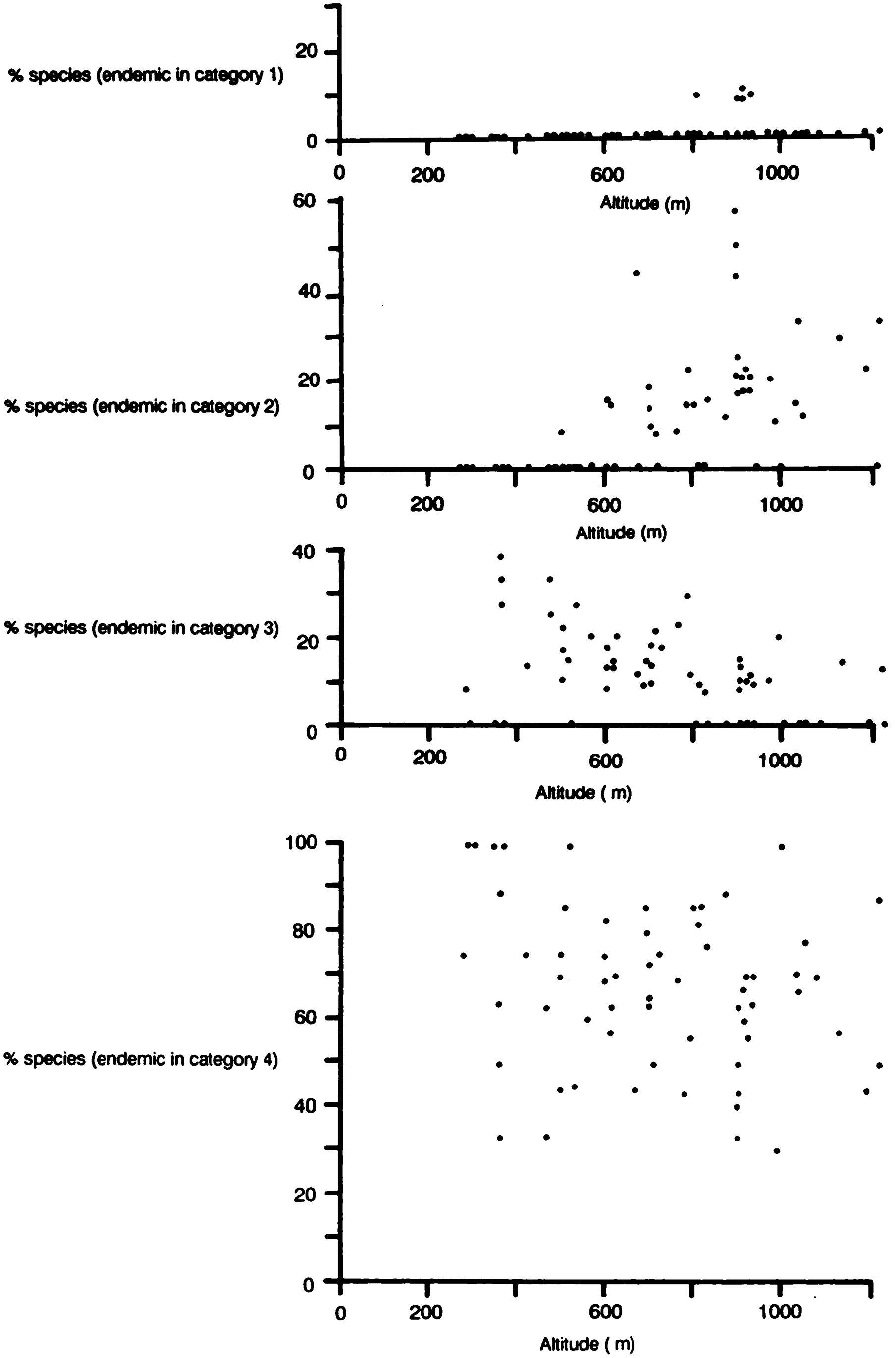

Figure 22.8 Percentage of species belonging to different endemic categories in variable-area tree plots at different altitudes.

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desirability of a simple scheme, there seems no reason to introduce a more complicated system of classification than that proposed by Moreau. However, the designation 'Intermediate Forest' is imprecise and a better term is 'Submontane Rain Forest' as suggested by Pocs (1976b). Moreau's Lowland Forest is equivalent to Pocs's Lowland Semi-Evergreen Rain Forest, but the simple terms 'lowland forest' and 'submontane forest' are adequate when discussion is limited only to the East Usambaras: these are the names used for the two forest types in this report. Other types of lowland and submontane forest do not occur, or are extremely local.

Brief descriptions of the two forest types in the East Usambaras are given in Dowsett *et al.* (1954), who misleadingly describe the Lowland Forest as evergreen.

Lowland forest on the eastern side of the Ulugurus is floristically similar to that on the East Usambaras, judging by a short list of species in Pocs (1976b). *Albizia gummifera, Antiaris toxicaria, Celtis wightii, Ficus* sp. and *Milicia excelsa* are mentioned as occurring on the Ulugurus: all of these are common in lowland forest on the East Usambaras, except for the first, which is essentially a submontane forest tree.

Small patches of lowland forest similar to those on the Usambaras and Ulugurus occur widely in a high rainfall zone running parallel to the East African coast, from eastern Kenya, through Tanzania and on into Mozambique. These forests have a considerable number of species not found further west in Africa (in the Guineo-Congolian forests of West Africa and Zaire) and are classified by White (1983) as Zanzibar-Inhambane (lowland and undifferentiated) forests.

Hawthorne (1984) has carried out a study of the coastal lowland forests of eastern Kenya and Tanzania and has noted that they are floristically variable, partly related to amount of rainfall. The East Usambara forests (which he did not visit) are similar to his wetter forest types (*Combretum schumannii — Sterculia appendiculata* and *Antiaris* types). The coastal forests of Kenya have been described by Dale (1939).

The submontane forest of the East Usambaras may be seen in a wider context, as a type intermediate between lowland and montane forest, although to a degree distinctive in its abundance of endemics and near-endemics. Submontane forest occurs on the lower parts of the West Usambaras, although not at such a low altitude as on the East Usambaras, and is floristically poorer. In Mazumbai Forest, for example, (1,380 – 1,920 m), *Newtonia, Ocotea, Parinari, Sorindeia* and *Syzygium* are all common (Hall 1985), as they are in submontane forest on the East Usambaras. Some characteristic species of the East Usambaras, such as *Cephalosphaera*, are lacking, and there are a few endemics (e.g. *Mammea usambarensis*). There are also some higher altitude montane species (e.g. *Myrica salicifolia*) which are not present on the East Usambaras.

Submontane forest occurs on the Uluguru Mountains and some of the other isolated old basement mountains of eastern Tanzania. On the Ulugurus, Pocs (1976b) has noted a floristic similarity to the Amani forests and has given *Afrocrania volkensii, Allanblackia kimbiliensis, Albizia gummifera, Cylicomorpha parviflora, Maesopsis eminii, Myrianthus holstii, Newtonia buchananii, Ocotea usambarensis, Parinari excelsa* and *Sapium ellipticum* as canopy species. All except *Afrocrania* are common in submontane forest on the East Usambaras. Submontane forest on the Ulugurus is found at 800 – 1,500 m (Pocs 1976b).

The lowland and submontane forests of eastern Tanzania have floristic similarities with forests in Central Africa, where the equivalent zones occur at higher altitudes. Lowland forests with abundant Moraceae, Sapotaceae and Ulmaceae, with many of the same species as occur on the East Usambaras, are found at altitude of 1,050 – 1,370 m in Uganda, (Hamilton 1984; Langdale-Brown *et al.* 1964), indicating a displacement of the upper boundary upward by an altitude of around 550 m. The lower limit of lowland forest cannot be seen in Uganda, since the whole country lies on the East African plateau, but similar types of lowland forest are widely found in Zaire and West Africa, right down to near sea-level. Submontane forests with abundant *Parinari excelsa, Strombosia scheffleri* and *Drypetes* *gerrardii* are found at altitudes of around 1,370 – 1,800 m in Uganda (*loc. cit.*). The lower altitudinal boundary of the submontane forest zone is about 500 m higher in Uganda than on the East Usambaras.

A factor which is likely to be important in determining these regional differences in the altitudes of forest zones is the exceptionally low maximum temperatures of higher levels of the East Usambaras (Moreau 1935) and other eastern Tanzanian forests (Pocs 1976a). The observed degree of vegetational depression on the East Usambaras is roughly as expected if it were due to temperature depression.

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Table 23.1 Numbers and percentages of lowland and submontane forest trees on the East Usambaras belonging to different endemic categories.

Endemic status & geographical range	Lowland species		Submontane Species		Spp. found in both lowland & submontane forests		Spp. of uncertain distribution as regards forest type		Totals	
	no.	(%)	no.	(%)	no.	(%)	no.	(%)	no.	(%)
1. East Usambara endemics	2	(3)	5	(5)	0	(0)	4	(18)	11	(5)
2. East Usambara near-endemics	8	(11)	26	(25)	0	(0)	8	(36)	42	(19)
3. Widely distr. E. African coastal spp.	20	(28)	7	(7)	2	(10)	2	(9)	31	(14)
4. Widely distr. African spp.	41	(58)	64	(62)	18	(90)	8	(36)	131	(60)
Endemic status uncertain	0	(0)	2	(2)	0	(0)	0	(0)	2	(1)
TOTALS	71 (33%)		104 (48%)		20 (9%)		22 (10%)		217	

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23. Distribution of Tree Species in the East Usambara Forests

by A.C. Hamilton

An analysis of the distribution of forest tree species occurring in the East Usambaras shows that about 40% of both lowland and submontane species are restricted to a belt of high rainfall running along the East African coast, mainly in Tanzania. The distribution of these 'East African coastal endemics' within this belt largely reflects the distribution of suitable habitats, i.e. submontane species occur much more locally than many lowland species. Within the East Usambaras, lowland forests away from the main range (e.g. Marimba, Mtai, Mhinduro) appear to be floristically richer than those on the main range (e.g. Kwamsambia). The richest place for submontane forest is the southern part of the main range (e.g. Amani-Sigi, Kwamsambia, Kwamkoro). The vegetation of rocky summits is distinctive.

1. Introduction

This is an analysis of the patterns of distribution shown by forest trees occurring in the East Usambara forests; it is based on the records of occurrence of the species in various parts of the area. The detection of distributional patterns is useful for determining which forests are biologically the most valuable for conservation of species and also permits the advancement of hypotheses to account for the patterns observed.

The information on tree distributions is given in Chapter 17, containing an annotated list of forest tree species (217 in all) known to occur in the East Usambara forests. In the list, species whose distributions are believed to be adequately understood are designated as lowland or submontane (or both), information is given on the distribution of each species within the East Usambaras and each species is allocated an endemic status. Four categories of endemic status are recognized (defined in Chapter 17 and in Table 23.1). Obviously, further information will modify the results of the analyses given here. The allocation of species to lowland or submontane categories is not too difficult for most species, but it should be realized that occasional specimens of many lowland forest trees occur in submontane forest and vice versa.

2. Numbers of lowland and submontane forest trees, according to endemic status

Out of the total of 217 tree species known from the East Usambara forests, 71 (33%) are classified as lowland, 104 (48%) as submontane, 20 (9%) as being found in both lowland and submontane forest and 22 (10%) as being too poorly known in terms of distribution to be classified (Table 23.1). Submontane forest has, therefore, a richer tree flora than lowland forest, though the number of species in lowland forest is still not inconsiderable (at least 91).

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The number of strict East Usambara endemics is 11 (5%), near-endemics 42 (19%), wide East African coastal species 31 (14%) and widely distributed African species 131 (60%). Two species (1%) are unclassified. The number of strict endemics is lower than has sometimes been thought and may well decline further as botanical exploration in Tanzania proceeds. During recent years a considerable number of species which were once believed to be confined to the East Usambaras have been found elsewhere, especially on less well known forested mountains such as the Uzungwas.

Lowland and submontane forests have roughly similar percentages of strict endemics (3% & 5% respectively) and widely distributed species (58 & 62 %) (Table 23.1). They differ, however, in the representation of near-endemics (11 & 25%) and widely distributed East African coastal species (28 & 7%). These findings are supported by the results of analyses of the floristic data from variable-area tree plots (Chapter 22) and expanded profile diagram plots (Chapter 25). What explanations can be offered for these patterns? Differences between lowland and submontane forest species mainly concern species belonging to endemic categories 2 and 3. Lowland forest species tend to be more widely distributed through the East African coastal belt than submontane forest species. This is not surprising since lowland forest probably once occurred very extensively in a strip 50 to 100 km wide running along the coast from Kenya through Tanzania to Mozambique (White 1983), while a suitable climate for submontane forest is found only on a few isolated mountains. Differences in the representation of endemic categories in lowland and submontane forest reflect differences in the natural occurrences of the two forest types.

The large percentages of both lowland (42%) and submontane (37%) species which are found only in the East African coastal forests (at whatever altitude) and not further west in Africa (that is, particularly in the Guineo-Congolian forests reaching across West Africa through Zaire as far as western Tanzania and western Kenya) suggest that the East African coastal forests have enjoyed a high degree of isolation for a long period of time. This point has been previously discussed by Faden (1974), Moreau (1966), Hamilton (1982), Kingdon (1971) and others. Some taxa of the East Coast forests, which are also found in Central Africa or have near relatives there, have fruits or seeds which are very unlikely to be capable of long-distance dispersal by such agencies as carriage by birds or transport by wind (e.g. *Allanblackia* and many Annonaceae). To account for their disjunct distributions, it would seem that well developed forest must once have extended across the interval between Central Africa and the East African coast. Judging by the direct evidence from climatic history and climatic modelling, such contact probably occurred millions or tens of millions of years ago (Hamilton in press).

Faden (1974) has argued that there have been at least two periods of contact between the East Coast forests and the Guineo-Congolian forests, a fairly recent one to account for the large number of plant species common to both and a more ancient one to account for similarities at the generic level. Could it be argued that the 60% of East Usambara species which are widely distributed in Africa (virtually all occur in the Guineo-Congolian forests) have moved to the East Usambaras from distant regions (or vice versa) fairly recently? I believe that some indeed may be recent immigrants, even given the almost certain absence of well developed forest forming an east-west connection. Some species may have been able to move through riverine forest or have been capable of long-distance jumps across intervals of unfavourable country. However, it is likely that some of these species have had isolated populations in East Africa for a long period of time, that is for millions or tens of millions of years. These East Coast populations are likely to be genetically distinctive and worthwhile conserving to maintain the full genetic diversity of the species. Faden is surely wrong in assuming a constant rate of evolutionary divergence in different species, as his argument implies.

Turning briefly to consider other organisms, it is notable that different groups of organisms differ greatly in their degrees of endemism on the East Usambaras. Amphibia, for example, have a much higher percentage of endemics than mammals (Rodgers & Homewood 1982; Schiotz 1981). The extent to which this is due to differences in dispersal ability or to differences in the rate of evolutionary divergence requires further research.

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Table 23.2 Numbers of species with different distribution patterns on the East Usambaras, grouped according to endemic status and whether they are lowland or submontane.

Forest type and endemic status (codes as on Table 23.1)		Species found only on main range			Species found only to east of main range	Species on main range & also to east	Species of uncertain distribution	Totals
		South end only	North end only	Both N & S				
Lowland species	1					2		2
	2				3	5		8
	3			1	4	15		20
	4			2	10	28	1	41
	uncertain							0
	Totals	0	0	3	17	50	1	71
Submontane species	1	3		1	1			5
	2	7	1	4		14		26
	3	1			5	1		7
	4	17	4	7	2	30	4	64
	uncertain	1				1		2
	Totals	29	5	12	3	50	5	104
Lowland submontane species	1							0
	2							0
	3					2		2
	4					16	2	18
	uncertain							0
	Totals	0	0	0	0	18	2	20
Type uncertain	1						6	6
	2			1	1	1	3	6
	3							0
	4		1		2		2	5
	uncertain						5	5
	Totals	0	1	1	3	1	16	22
Grand Totals		29	6	16	23	119	24	217

3. Large-scale patterns of distribution of forest tree species within the East Usambaras

Table 23.2 shows the numbers of lowland and submontane forest species belonging to different endemic categories with different patterns of distribution within the East Usambaras. The geographical areas used are the north (Lutindi, Kilanga and neighbourhood) and south (including Derema) ends of the main range, and the region to the east (Longuza, Marimba, Mlinga, Mhinduro, Mtai).

For lowland forest trees it is noticeable that a considerable number (17 species or 24%) are not known from the main range. Eleven of these are only known from the isolated mountains to the east, especially Mtai and Mhinduro. This suggests that lowland forests on the main East Usambara range, e.g. Kwamsambia, are floristically relatively impoverished. It is noted that the lowland forests of Marimba and on Mtai and Mhinduro emerge as floristically rather different from Kwamsambia according to a TWINSPAN analysis of the 1986/87 inventory results (Chapter 24), though, in contradiction to the results given in the present chapter, the TWINSPAN analysis suggests that Kwamsambia is floristically richer.

Submontane forest species show a very different pattern, with many species (46 species or 44%) being known only from the main range and not present on the isolated eastern mountains. It is probable that some of these species do actually occur on the isolated eastern mountains and await discovery, nevertheless the number is large enough to suggest that the pattern is real. There seem to be pockets of habitat suitable for the growth of many of these species on the eastern mountains, suggesting that

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the species have either found it difficult to move across from the main range or else, having done so, have been unable to survive. The most obvious difference between the main range and the eastern mountains is topographic, with the area suitable for submontane forest much more restricted on the eastern mountains. Perhaps areas are too small for populations of some species to have been able to survive.

Another interesting distributional feature shown by submontane forest trees is a concentration of species at the southern end of the main range. This area (especially the less disturbed area of Amani-Sigi, Kwamsambia and Kwamkoro forests) stands out as the most valuable to keep under forest for the conservation of submontane species. Apart from being floristically richer, many widely distributed species display differences in abundance in the southern and northern forests. After spending several weeks botanising in the northern and southern forests in 1986, Mr. C.K. Ruffo and myself decided to write a few notes on our general impressions. "There is a wider variety of species in the southern than the northern submontane forests. Among those species which are commoner in the south or even completely restricted to the south are *Albizia gummifera*, Annonaceae (all species), *Anisophyllea obtusifolia*, *Beilschiedia kweo*, *Diospyros abyssinica*, *Drypetes gerrardii*, *D. usambarica*, *Englerodendron usambarense*, *Entandrophragma excelsum*, *Isoberlinia scheffleri*, *Maesopsis eminii*, *Maranthes goeteniana*, *Millettia* spp., *Morinda asteroscepa*, *Ocotea usambarensis*, *Parinari excelsa*, *Schefflerodendron usambarense*, *Sorindeia madagascariensis* and *Zanthoxylum usambarense*."

These conclusions are supported by a TWINSPAN analysis of the inventory results (Chapter 24).

4. Vegetation of rocky summits

Rocky summits on the East Usambaras tend to have peculiar vegetation, probably related to a peculiar climate and to isolation. An abundance of terrestrial bryophytes and epiphytic lichens and bryophytes testifies to an unusually humid climate. A number of afromontane species occur only on these summits. *Rapanea melanophloeos* has been seen on Lutindi and Mtai summits; *Agauria salicifolia* is on the top of Mtai; *Podocarpus latifolius* is on Mlinga summit, growing with the endemic *Memecylon greenwayi*. There are two species of shrubby Ericaceae growing on Lutindi summit. *Encephalartos hildebrandtii*, *Pandanus chioliocarpus* and *Phoenix reclinata* are also characteristic.

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24. Some results of the 1986/87 Forest Division/FINNIDA Inventory

by A.C. Hamilton

The 1986/87 inventory revealed that the total area of forest on the East Usambaras was 23,101 ha, or a bit more if fragmentary patches are included. Of the 23,101 ha, 8,125 ha was on very steep slopes and according to the inventory field managers, should not be extractively exploited. Of the remaining 14,976 ha, only 3,025 ha consists of intact, more or less undisturbed forest. The largest block of intact forest is in Amani-Sigi, Kwamsambia and Kwamkoro Forest Reserves. A TWINSPAN classification is used to divide the forest into a number of types according to their floristic composition.

1. Field methods of the inventory

The reasons for this inventory, the third in the East Usambara forests in a decade, are discussed in Chapters 1 and 6.

Forests on the East Usambaras were located on photographs from an aerial survey flown in January/February 1986, and areas of more continuous forest cover were delineated for ground survey. Some forests patches, some of substantial size, were not marked for ground survey; the larger of these are shown on Fig. 1.3. They should be visited soon to assess their biological and other values, with the possibility that some new forest reserves should be considered.

Several thousand sample plots, laid out on a grid system, were visited within the forests and some of their characteristics were recorded. A decision was made to exclude places with very steep slopes, called 'inaccessible' areas because they are regarded as being incapable of being logged by mechanical means. These inaccessible areas are marked on Fig. 1.3. The managers of the inventory team considered that no extraction of forest produce should be allowed in these areas (only enforceable when they lie inside forest reserves).

Characteristics of the physical environment and of past and present land-use were recorded for each sample plot. These include altitude, topography etc. and evidence of logging and cultivation.

Trees were sampled in four subplots in each sample plot. All trees 19.5 cm diameter at breast height (DBH) were identified (if possible) and their diameters measured. Tree identification was by local villagers ('local botanists'), who received some help from professional botanists, notably Mr. C.K. Ruffo working for IUCN. Smaller trees were recorded in one subplot and the occurrence of seedlings of a few species noted. Tree volumes were assessed for sample trees in the sample plots.

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2. Accuracy of tree identifications

Several sample plots were carefully remeasured to assess the accuracy of the original recording. It was concluded that most physical measurements were made reasonably accurately.

The number of stems found to be incorrectly identified (out of a sample of about 400) varied between 6.7 and 35.0%, depending on the particular sample plot examined (mean 18.8%), and the number of species found to be incorrectly identified varied between 9.7 and 39.7 % (mean 22.2%). The checking of the inventory was undertaken in Kwamkoro Forest and Mr. Ruffo believes that the level of inaccuracy was probably higher in some other areas since the local botanists employed at Kwamkoro had been relatively keen and knew the species quite well. Reasons for error in identification (*fide* Ruffo) include carelessness (some of the local botanists were not very interested in the work), rushing (the inventory was extensive and required speed in recording) and linguistic problems. The names called out by the local botanists were written down by other (professional forestry) workers. Would they always distinguish between Mkogoo *(Sapium ellipticum)* and Mkongolo *(Combretum schumannii)*, between Tondoo *(Rhodognaphalon schumannianum)* and Mtondoo *(Khaya nyasica)*, and between Mkondogogo *(Alangium chinense)* and Mhandogogo *(Neoboutonia macrocalyx)*? Some tree species can bear more than one vernacular name. For example *Memecylon brenanii* is Kigwandi, or Ksekene, or Mtonte – furthermore, *Rawsonia lucida* is also Kigwandi. Does the forester really record *Memecylon brenanii* as Kigwandi or *Rawsonia lucida*? Some vernacular names cover more than one species. Mkuti is *Aningeria adolfi-friedericii*, or *Chrysophyllum gorungosanum*, or *C. perpulchrum*. Kimungwe is *Celtis mildbraedii* or *Cynometra* spp. When a local botanist calls out Kimungwe, does the recorder bother to check which species it actually is? (Information on problems with vernacular names from C.K. Ruffo and C. Mmari.)

In retrospect, the wisdom of including all tree species in this inventory can be questioned. Usually, forestry inventories only record timber trees; the present inventory had been broadened in scope, so that the distributions of all (including endemic or rare) species could be assessed. In future, a more reliable (and cheaper) method of recording the distribution of species unfamiliar to 'local botanists' (who generally only know the useful species) would be to employ a knowledgeable professional botanist to undertake a field survey.

How useful are the data on species occurrences from the inventory? For species familiar to the local botanists, the survey is likely to be reliable – this includes many of the commoner trees as well as those used commercially. Classifications of the forest by numerical means from the data will almost certainly be reasonably reliable so far as subdivision of the data set into groups is concerned, because, even though the level of misidentification is quite high, misidentifications are likely to be either systematically wrong or randomly wrong, neither of which will greatly affect the classificatory process. However, care is needed in assessing the characteristics of the groups revealed by numerical classifications.

3. Area of forest

The forest is divided into three blocks for the purpose of data analysis (Fig. 24.3). Various types of forest are recognized on the basis of their predominant status, these being intact forest (more or less natural unlogged forest or little logged forest), logged forest, forest with cultivation (often cardamom), poorly stocked forest, and forest with abundant *Maesopsis*. The areas of the forest according to blocks and status are shown on Table 24.1; reference can be made to Fig. 1.3 to see the exact areas of forest referred to here.

A major result is to demonstrate how small is the remaining area of intact forest, which would soon disappear if mechanical logging were to continue at the rate achieved in 1986 (about 1 ha day^{-1}). The largest extent of intact forest (excluding from consideration inaccessible areas) is in the south of the main range, in Amani-Sigi, Kwamsambia and Kwamkoro Forest Reserves.

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Table 24.1 Areas of different forest types (in hectares) according to status and blocks, in the area surveyed on the ground by the inventory crews.

	BLOCK 1	BLOCK 2	BLOCK 3	ALL AREAS
Accessible Forest:				
Intact forest	776	1567	682	3025
Logged forest	1431	3499	2239	7169
Forest with cultivation	1726	860	71	2657
Poorly stocked forest	0	122	1415	1537
***Maesopsis* plantation**	0	588	0	588
Barren lands	0	0	0	0
Total	3933	6636	4407	14976
INACCESSIBLE FOREST:				
Intact forest	584	184	1421	2189
Logged forest	702	1088	2091	3881
Forest with cultivation	929	79	0	1008
Poorly stocked forest	0	686	49	735
***Maesopsis* plantation**	0	0	0	0
Barren lands	0	50	262	312
Total	2215	2087	3823	8125
TOTAL FOREST:				
Intact forest	1360	1751	2103	5214
Logged forest	2133	4587	4330	11050
Forest with cultivation	2655	939	71	3665
Poorly stocked forest	0	808	1464	2272
***Maesopsis* plantation**	0	588	0	588
Barren lands	0	50	262	312
Total	6148	8723	8230	23101

4. Densities and volumes of species

The number of stems ha^{-1} and commercial wood volumes (m^3 ha^{-1}) of species in the three blocks are shown on Table 24.2.

One difference between the blocks is the greater abundance of lowland forest trees in Block 3, as shown by the relative abundance of *Antiaris*, *Bequaertiodendron*, *Celtis*, *Funtumia*, *Khaya*, *Malacantha*, *Markhamia*, *Milicia*, *Pachystela*, *Rhodognaphalon* and *Sterculia*. There is actually a greater extent of lowland forest in Block 3 than in either of Blocks 1 or 2, but the result is nevertheless partly an artifact of sampling – extensive higher altitude forests on Mtai and Mhinduro in Block 3 were not sampled because they were regarded as inaccessible.

Blocks 1 and 2, having about the same proportions of lowland and submontane forest, can be compared more directly. The two blocks are fairly similar, but with the following more abundant in Block 1 – *Albizia gummifera*, *Alsodeiopsis*, *Croton*, *Sterculia* and *Trema* – and the following more abundant in Block 2 – *Alchornea*, *Anisophyllea*, *Beilschmiedia*, *Bequaertiodendron*, *Cephalosphaera*, *Enantia*, *Greenwayodendron*, *Maesopsis* and *Maranthes*. In most respects, these results agree with the impressions of Ruffo and Hamilton (Chapter 23), but the result for *Albizia gummifera* is unexpected; possibly there is some confusion between different species of *Albizia*.

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Table 24.2 Densities and volumes of commoner species in the blocks covered by the 1986/87 inventory. All trees with dbh greater than 4.5 cm are included.

	Density (stems ha^{-1})				Volume (m^3 ha^{-1})			
	1	2	3	TOTAL	1	2	3	TOTAL
Sorindeia madagascar.	60.56	56.32	20.95	49.23	6.89	5.82	2.26	5.29
Leptonychia usambare.	36.18	39.78	37.18	38.16	3.25	3.45	2.54	3.18
Maesopsis eminii	1.23	54.64	0.17	26.91	0.55	23.21	0.06	11.47
Myrianthus holstii	36.92	25.96	5.23	24.20	16.29	13.22	1.95	11.45
Greenwayodendron sua.	8.71	33.12	9.35	20.71	1.81	8.04	1.40	4.75
Alsodeiopsis schuman.	40.93	15.43	4.66	20.08	2.17	0.83	0.32	1.09
Allanblackia stuhlma.	17.75	28.08	3.93	19.54	26.31	38.68	7.30	27.90
Markhamia hildebrand.	1.10	4.19	61.67	16.78	0.06	0.36	3.56	1.02
Alchornea hirtella	10.84	26.79	2.75	16.68	0.26	0.58	0.07	0.37
Macaranga capensis	22.33	17.25	7.80	16.47	6.36	4.28	1.65	4.25
Funtumia latifolia	7.51	11.15	33.51	15.36	2.72	3.04	5.20	3.46
Isoberlinia scheffle.	14.53	19.75	5.90	15.04	23.71	17.47	4.41	16.17
Bequaertiodendron na.	1.55	1.57	51.45	13.45	0.07	0.16	3.26	0.86
Strombosia scheffler.	11.79	16.84	2.25	12.01	9.00	12.23	2.17	8.98
Cephalosphaera usamb.	6.14	16.44	5.23	10.93	10.28	31.59	22.08	23.41
Antiaris toxicaria	6.30	8.26	18.77	10.17	3.40	12.58	27.41	13.47
Pacystela msolo	7.31	7.77	12.65	8.78	5.84	6.73	7.06	6.56
Afrosersalisia ceras.	6.68	12.07	2.92	8.42	7.84	10.53	2.98	8.01
Trilepsium madagasca.	4.34	7.47	8.58	6.85	3.68	3.90	2.87	3.60
Newtonia buchananii	9.11	6.80	0.79	6.04	42.90	25.96	3.54	25.46
Harungana madagascar.	6.86	6.90	1.59	5.65	1.48	1.16	0.18	1.02
Xymalos monospora	6.12	7.66	0.11	5.46	2.44	2.51	0.01	1.91
Celtis spp.	4.62	3.09	10.30	5.21	0.44	0.79	2.94	1.20
Odyendea zimmermanni.	4.81	6.87	1.24	4.98	8.27	10.94	2.53	8.23
Enantia kummeriae	2.80	6.09	4.75	4.85	2.53	4.04	1.79	3.09
Milicia excelsa	1.88	2.06	11.43	4.20	1.95	2.75	9.82	4.18
Syzygium spp.	2.18	2.28	9.32	3.90	6.46	5.61	2.59	5.14
Albizia gummifera	4.04	2.19	6.18	3.64	6.58	2.11	7.11	4.52
Parinari excelsa	4.10	4.89	0.35	3.61	11.81	22.64	1.44	14.66
Anthocleista grandif.	2.33	4.32	1.75	3.16	8.10	7.97	3.09	6.86
Beilschmiedia kweo	1.77	4.10	0.74	2.66	3.66	7.04	1.23	4.74
Sapium ellipticum	3.60	2.43	1.82	2.62	4.44	5.40	2.36	4.42
Malacantha alnifolia	0.00	1.05	8.08	2.40	0.00	0.33	2.37	0.71
Anisophyllea obtusif.	0.62	4.07	0.40	2.25	0.58	4.25	0.57	2.36
Ricinodendron heudel.	0.91	0.95	5.85	2.08	2.11	3.29	9.25	4.35
Maranthes goetzenian.	0.74	3.72	0.15	2.05	3.61	13.27	1.54	7.83
Polyscias fulva	2.06	2.70	0.04	1.90	0.61	1.13	0.05	0.73
Trema orientalis	2.40	1.12	1.08	1.47	0.75	0.25	0.17	0.37
Rhodognaphalon schum.	0.73	0.46	3.98	1.36	1.99	1.91	5.43	2.75
Khaya nyasica	0.93	0.66	1.46	0.92	2.25	1.94	4.04	2.52
Ocotea usambarensis	0.59	0.60	0.01	0.46	4.42	6.82	0.10	4.58
Sterculia appendicul.	0.26	0.09	1.46	0.46	1.16	0.47	3.59	1.39
Total (all species)	545.43	667.75	752.53	653.30	358.43	426.59	265.75	369.99

5. Abundance of Maesopsis

Much information has been obtained on the distribution and size characteristics of many tree species, but only one item is given here, a distribution map showing the abundance of *Maesopsis eminii* (Fig. 24.1), a species of particular interest on the Usambaras because of its invasive properties (Chapter 27) and probable ability to increase greatly the rate of soil erosion (Chapters 30 & 33). The map, which is regarded as reliable, shows a concentration of the species at the south end of the main range, with an occurrence also on north-east Mtai (where it has been planted). There are the apparent beginnings of spread to other places, for example the north end of the main range.

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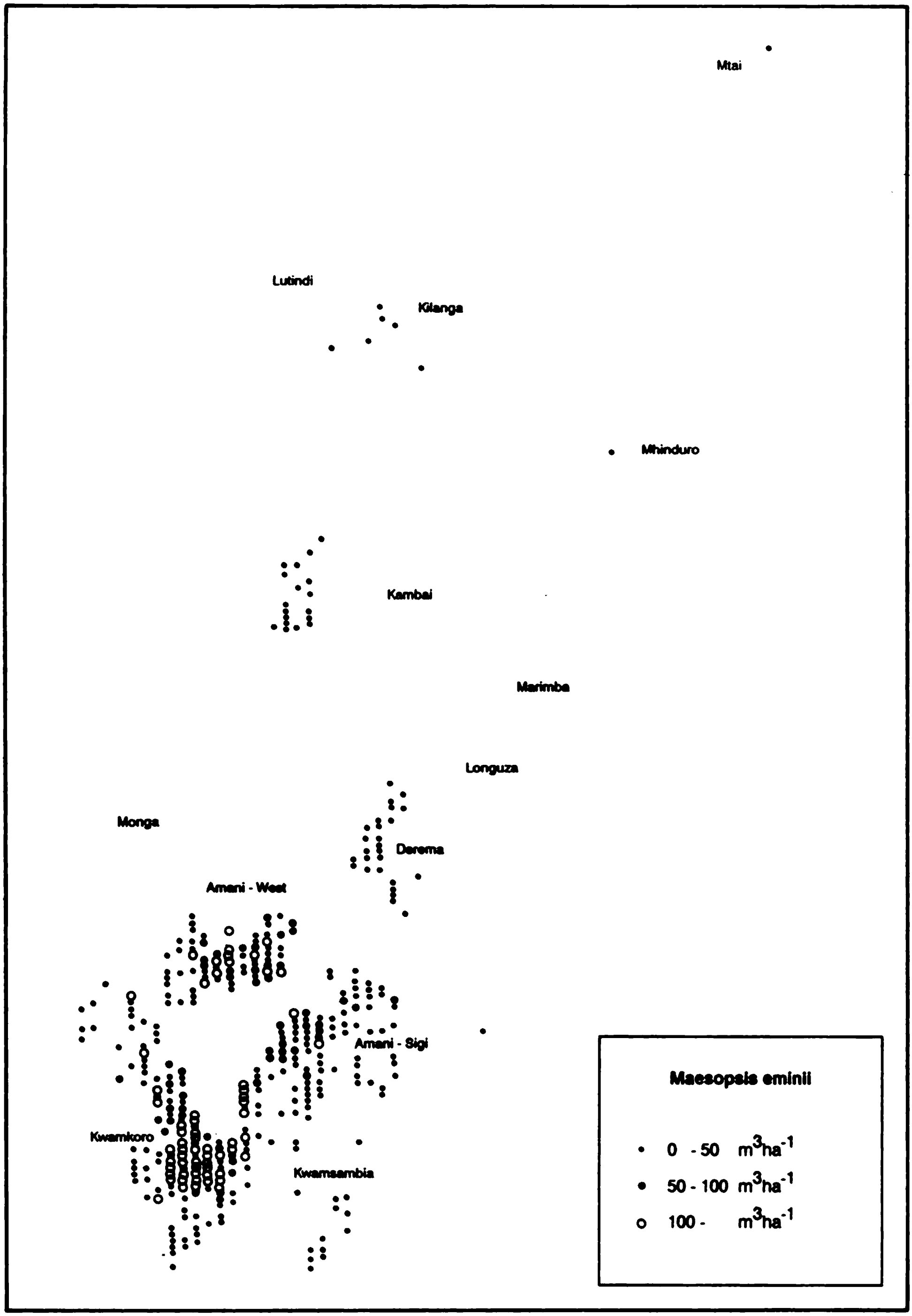

Figure 24.1 Distribution of Maesopsis, according to stem volume estimates of the 1986/87 inventory.

6. Abundance of seedlings

The most interesting result is confirmation that *Ocotea usambarensis* is not regenerating (Chapter 25). An attempt at an explanation is given in Chapter 3.

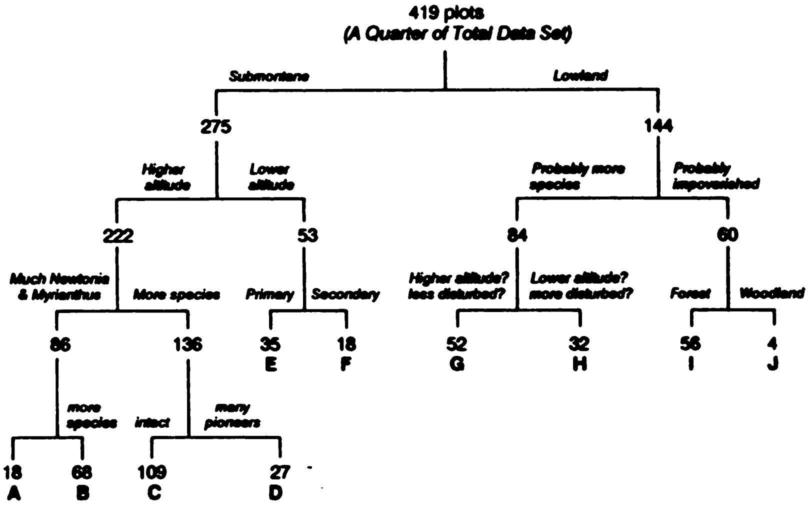

Figure 24.2 TWINSPAN classification showing division into nine forest types (A-I) and one woodland type (J).

7. Forest types by TWINSPAN analysis

Numerical classification of the data using TWINSPAN (Chapter 22) was carried out on both the entire area covered by the inventory and on Block 2 only. Only the results from the first analysis are considered in any detail here. The Block 2 classification revealed a clear set of altitudinally arranged forest zones, especially in Amani-Sigi and Kwambsambia Forest Reserves. The analysis of the whole area was based on a reduced data set, using 25% of the sample plots. The abundance of species in each cluster was taken as the percentage abundance of the stems.

The divisions and resulting groups in the classification (Fig. 24.2) express altitudinal variation, variation with disturbance and some geographical variation of other types, for example north-south variation within submontane forest on the main range. The number of divisions recognized on Fig. 24.2 and hence the number of vegetation types recognized and mapped (Fig. 24.3) is based on ease of description and explanation. In the descriptions of the vegetation types (A, B, etc.) below, the most common and faithful (i.e. regularly occurring) species are listed for each vegetation type in approximate order of abundance.

Vegetation type A (18 samples): This is submontane forest, restricted to the northern part of the main range (as far south as Derema). It seems to be poor in species and to occur mainly near forest margins. Common and faithful species are *Newtonia*, *Myrianthus*, *Isoberlinia*, *Macaranga* and *Sorindeia*. The first two of these, and also *Albizia gummifera* are all commoner than in B.

Vegetation type B (68 samples): This is submontane forest, only on the main range, except for one plot on Mtai. It is found (at high altitudes) in the south, but is more extensive in the north (where the general altitude is higher). It is floristically poorer than C, but richer than A. Common and faithful

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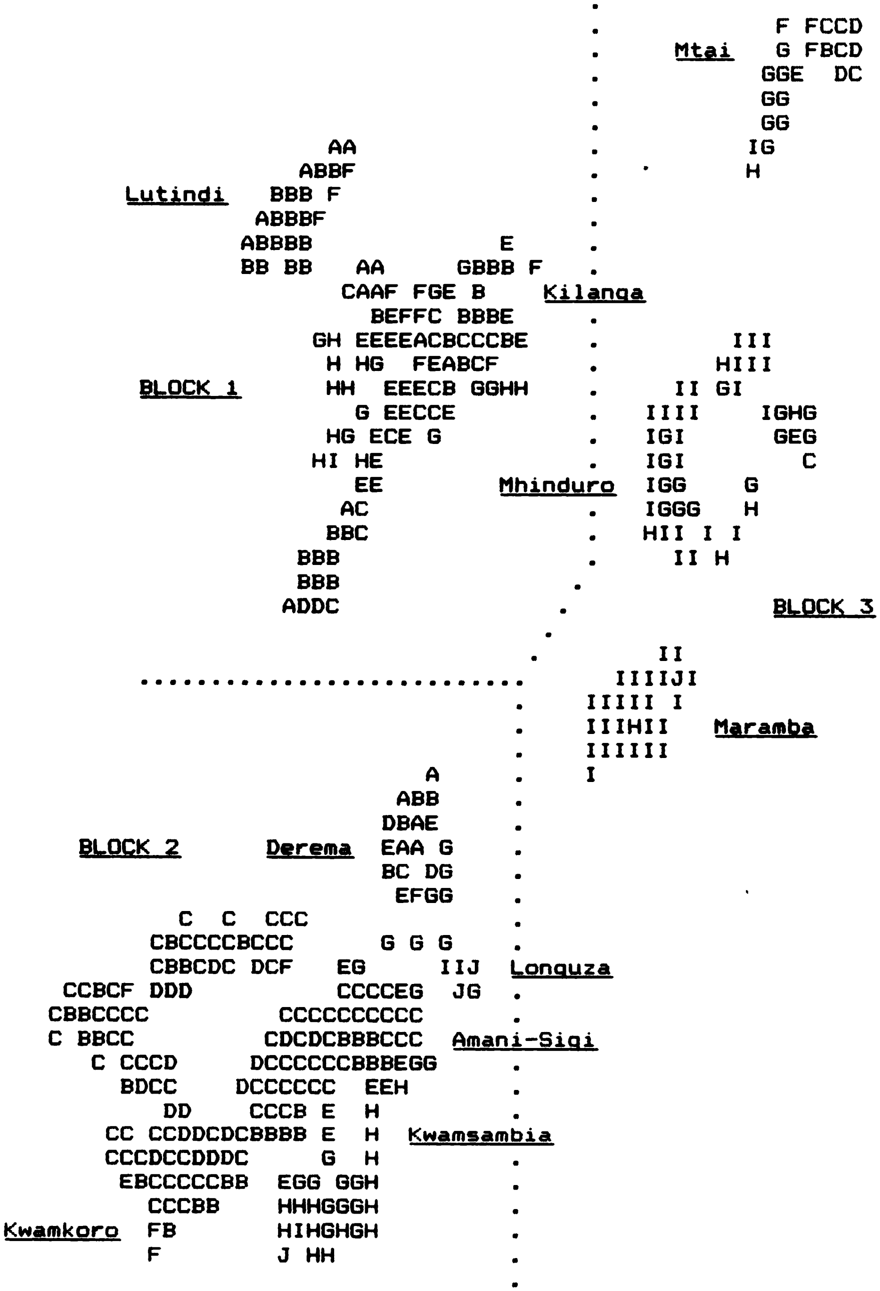

Figure 24.3 Distribution of nine forest types (A-I) and one woodland type (J), based on a TWINSPAN numerical classification of the floristic data from the 1986/87 inventory. Only 'accessible' (not very steep) areas have been surveyed. The three blocks are as used in analysing the inventory results.

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species are *Myrianthus*, *Sorindeia*, *Newtonia*, *Isoberlinia* and *Allanblackia*. A major difference with A is addition of *Allanblackia*, and to a lesser extent *Strombosia*.

Vegetation type C (109 samples): This is species-rich submontane forest, confined to the main range and north-east Mtai, except for one plot on Mhinduro (it must be more extensive here, but there was little sampling at high altitudes). Common and faithful species include *Allanblackia*, *Isoberlinia*, *Greenwayodendron*, *Strombosia*, *Cephalosphaera* and *Sorindeia*. Within this vegetation type, plots on the south-eastern corner of the main range (e.g. in Amani-Sigi) are rather distinctive, having more *Ocotea*, *Cynometra* and *Englerodendron*, and less *Sorindeia*, *Myrianthus*, *Maesopsis*, *Enantia*, *Leptonychia* and *Afrosersalisia*.

Vegetation type D (27 samples): This is submontane forest, rich in pioneers including *Maesopsis* (but not in all plots), *Macaranga*, *Harungana* and *Anthocleista*. Most of the plots are at the south end of the main range, in logged areas of Kwamkoro and neighbourhood.

Vegetation type E (35 samples): This seems to be lower altitude submontane forest. It is found in all areas; at the south end of the main range it is on the escarpment. The most common and faithful species are *Allanblackia*, *Myrianthus* and *Trilepsium*. Within this type, the main variation is that samples at the north end of the main range are floristically poorer, with less *Leptonychia*, *Cephalosphaera*, *Funtumia*, *Enantia* and *Pachystela*, and have more abundant *Newtonia*, *Myrianthus* and *Trichilia*.

Vegetation type F (18 samples): This is a rather heterogeneous group with a relatively high abundance of pioneers and secondary forest species, e.g. *Myrianthus*, *Ficus sur*, *Harungana*, *Macaranga*, *Sapium*, *Maesa* and *Bridelia*. As with type E, it probably tends to occur at relatively low altitudes within the submontane forest zone. The most common and faithful species are *Myrianthus* and *Ficus sur*. The type is widely distributed, but especially common at the north end of the main range.

Vegetation type G (52 samples): Vegetation types G, H and I are lowland forest. The analysis indicates that G and H are more species-rich than I, but confirmation is needed – problems of accurate identification could be particularly serious here. Trees which are much more abundant in G and H compared with I include *Funtumia*, *Leptonychia*, *Tabernaemontana*, *Pachystela*, *Ficus*, *Afrosersalisia* and *Macaranga*; species tending to be more abundant in I are *Lecanodiscus*, *Diospyros squarrosa*, *Bequaertiodendron*, *Terminalia*, *Cynometra* and *Teclea simplicifolia*. Vegetation type G is widely distributed, possibly tending to occur at somewhat higher altitudes (upper lowland forest). Common and faithful trees are *Pachystela*, *Antiaris*, *Funtumia*, *Leptonychia*, *Trilepsium* and *Milicia*. Some samples within G contain many secondary forest species.

Vegetation type H (32 samples): This seems to occur at lower altitudes than G and possibly could be more disturbed. It is found in all areas, but is especially common in Kwamsambia. Common and faithful species are *Antiaris*, *Pachystela*, *Milicia*, *Zanha* and *Markhamia*.

Vegetation type I (56 samples): This type of lowland forest is common in Marimba and on Mhinduro, with only a poor presence on Mtai and at the south end of the main range. Common and faithful species are *Bequaertiodendron*, *Markhamia*, *Grewia goetzeana* and to lesser extents *Diospyros squarrosa*, *Milicia*, *Antiaris* and *Zanha*. The main variation within this group appears to represent degrees of disturbance.

Vegetation type J (4 samples): This is woodland and forest margin vegetation.

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8. Conclusions

Obviously this analysis could usefully be taken further. The main conclusions so far are:

- The forests are altitudinally zoned. The analysis basically agrees with that of the variable-area tree plots (Chapter 22).
- There are major differences in floristic composition associated with secondary forest, for example in the logged area of Kwamkoro compared with near by more intact areas.
- Submontane forest is floristically different on the north and south ends of the main range, with more species in the south. This agrees with an analysis of records of species occurrence (Chapter 23).
- Lowland forest shows differences on the main range (mainly Kwamsambia) and to the east (Marimba, Mhinduro and Mtai). There is some evidence that Kwamsambia is floristically richer, though this is not conclusively shown and an analysis of floristic records suggests otherwise (Chapter 23). A complication is that tree identification has probably been particularly unsatisfactory for lowland forest.

Acknowledgements

The inventory was carried out by the Forest Division and the Finnish consultancy companies Silvestria and Finnmap. The project was funded by the Finnish International Development Agency (FINNIDA), with the IUCN component supported by the Norwegian Agency for International Development (NORAD).

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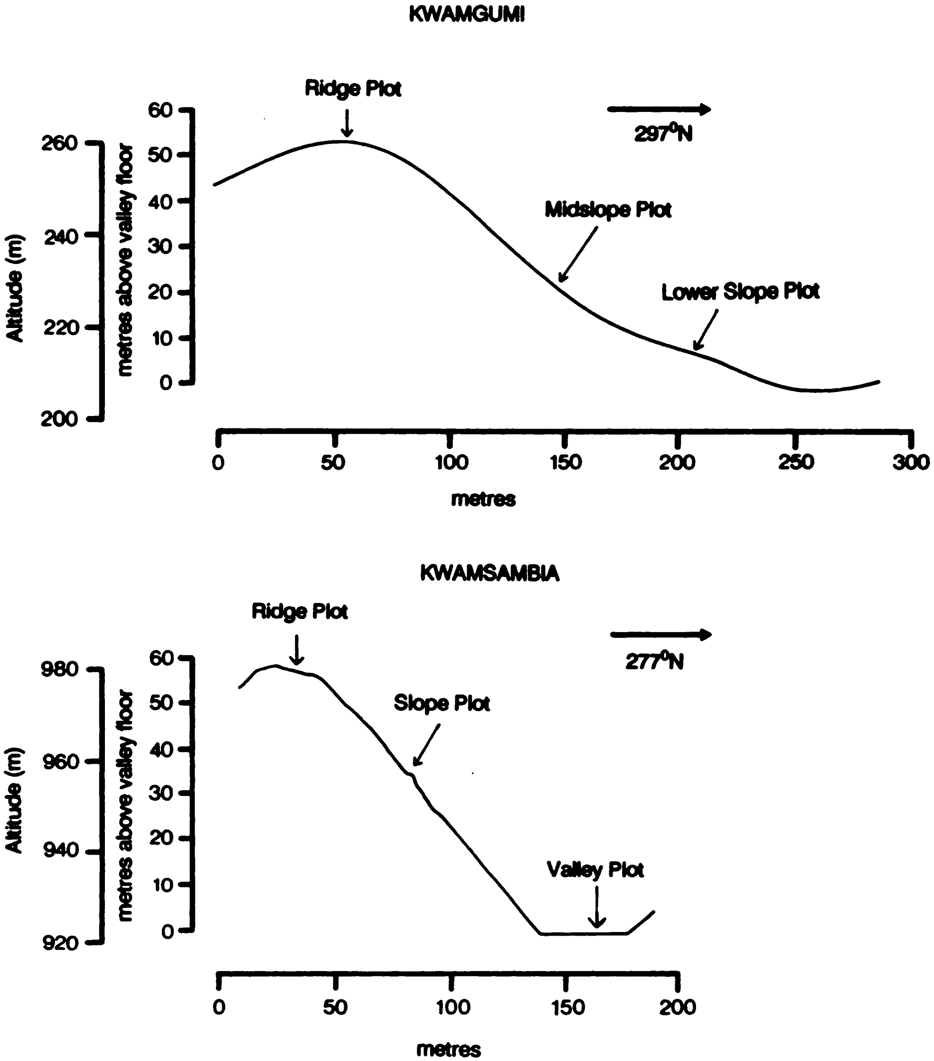

Figure 25.1 Surveyed transects showing topographic relationships of plots used for profile diagrams. The profile diagram plots run approximately at right angles to the above transects. The steeper slope at higher altitude is typical.

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25. Profile Diagrams of the East Usambara Forests

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Six profile diagrams are described from examples of lowland and submontane forest situated on different parts of catenas. The profile plots were expanded to sample larger areas and it was found that the number of species per unit area was about the same in all places sampled. There is little floristic similarity between lowland and submontane forests. Many species occur at low densities.

1. Introduction

A common method of describing and portraying the structure of tropical forest is through the medium of profile diagrams. Strips of forest, usually 7.5 m wide and 60 m long (as in the present case) are selected and the rooting positions of all trees over a certain size (4.8 cm diameter at breast height here) are noted. A drawing of the forest as seen from one side of the sample strip is made as accurately as time allows. We have measured, usually by triangulation, heights to the tops and bases of tree crowns and the positions of crowns as projected vertically downward onto the ground. For simplicity, lianes have not been included on the diagrams.

Six profiles have been drawn, three along each of two catenary sequences, one in lowland forest (Kwamgumi) and the other in submontane forest (Kwamsambia). Localities are shown on Fig. 10.1. Altitudes are 210–260 m at Kwamgumi and 920–980 m at Kwamsambia. Profile plots were placed at right angles to directions of slope and are thus more or less level. Drawings of surveyed transects of the topography are shown on Fig. 25.1, on which it can be seen that slopes are much steeper at Kwamsambia than at Kwamgumi, as is typically the case with submontane, as compared with lowland, forest on the East Usambaras.

Attempts were made to find forest undisturbed by man, but this is probably impossible with lowland forest on the East Usambaras. The forest at Kwamgumi is, however, relatively little disturbed, though there has been a little cutting of *Milicia*. The vegetation at Kwamsambia showed no certain evidence of human disturbance.

Soil pits were dug and described at each of the profile sites and samples were taken for laboratory analyses (Chapter 10). Pottery and charcoal were found in both the lowland and submontane forests, an indication that man has been active even in these forests, chosen for their low degree of disturbance (Chapter 8).

No attempts were made to position transects to include only big trees. Rather, sites were chosen as representative.

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2. Description of the profiles

Profile (a): Lowland ridge forest (Fig. 25.2)

The profile plot runs along the top of a virtually level ridge at an altitude of 260 m. Three rather well defined tree strata are often present.

The upper layer consists of scattered, large, emergent trees reaching heights of 35 m, characteristically with thick straight trunks bearing large branches spreading out widely well above the more continuous second tree layer. Most of these large trees are *Antiaris toxicaria*, with *Rhodognaphalon schumannianum* also seen. Most, possibly all, emergent trees at Kwamgumi belong to deciduous species.

The second tree layer, merging in places into the third tree layer, contains many trees with rather low foliage and spreading crowns. Trees attain 15–25 m. Common trees include *Cynometra engleri*, *Diospyros squarrosa*, *Malacantha alnifolia*, *Pterocarpus mildbraedii* and various species of *Celtis*.

The third tree layer reaches to 10 m and, unusually for East Usambara forests, consists largely of one species, *Craterogyne kameruniana*, a dark-foliaged, sometimes multi-stemmed small tree often with a leaning trunk.

Sub-tree vegetation is more open on this ridge than on lower parts of the catena. Two types are found along the profile plot. The greater part of the plot (from 15 to 60 m on the drawing) has a sparse ground cover with virtually no herbaceous plants and only a few scattered seedlings of trees (especially *Bequaertiodendron natalense* and *Cynometra*) and climbers *(Tiliacora funifera)*.

The left-hand end of the profile (0–15 m) is a gap created by a tree fall. There is much more light at ground level, resulting in a relatively dense growth of large grasses *(Olyra latifolia)*, shrubs *(Erythrococca*, *Whitfieldia)* and climbers *(Landolphia)*. Young trees growing up in this gap include *Canthium* sp., *Celtis mildbraedii*, *Chytranthus obliquinervis*, *Cola scheffleri*, *Fernandoa magnifica*, *Newtonia paucijuga*, *Rinorea ilicifolia*, *Teclea simplicifolia* and *Trilepsium madagascariense*.

Epiphytic bryphytes are inconspicuous here and elsewhere in this lowland forest. They are restricted to the very bases of some of the tree trunks.

Profile (b): Lowland mid-slope forest (Fig. 25.3)

This plot at an altitude of 230 m is virtually level along its length. There are scattered emergents with a similar shape and height (35 m) to those on the ridge. *Antiaris* is again the commonest species, with *Ficus sur* also seen.

It is sometimes difficult to distinguish definite tree strata below the emergents, but commonly there are two layers of smaller trees at any one spot. Taller species, reaching 15–25 m, include *Blighia unijugata*, *Celtis mildbraedii*, *C. wightii*, *Funtumia africana* and *Pachystela msolo*, while smaller species include abundant *Leptonychia usambarensis* and *Tabernaemontana* sp.

Sub-tree vegetation is denser than on the ridge, with abundant low *Culcasia* and less common *Dorstenia* in more shaded places and *Olyra* and various shrubs such as *Whitfieldia* to 3 m tall where the canopy is more open. Tree seedlings and saplings are common.

Profile (c): Lowland lower slope forest (Fig. 25.4)

The plot runs close to a valley along virtually level ground at 210 m. The valley bottom itself could not be sampled due to major human disturbance. Three tree strata can often be distinguished.

As elsewhere on the catena, there is an open emergent stratum 35 m tall, consisting largely of *Antiaris*. Cut stumps, now suckering, show that *Milicia excelsa* was also once present.

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The second tree layer, to 25 m tall, is not well developed along the actual line of the profile plot. *Celtis mildbraedii*, *Diospyros squarrosa*, *Funtumia africana* and *Trilepsium madagascariense* are common.

The lowest tree layer, to 15 m, is nearly continuous along the profile plot. There are many individuals of taller trees and much *Leptonychia usambarensis* and *Tabernaemontana* sp.

There is considerable variation in sub-tree vegetation associated with stages in the forest growth cycle. The areas at 0 – 7.5 m and 20 – 50 m along the plot are more mature forest and have open sub-tree vegetation with two layers. The upper layer, 1 – 2 m tall, contains *Olyra*, shrubs *(Monanthotaxis, Rinorea)* and young trees *(Cola scheffleri, Leptonychia)*; the lower layer, 40 cm tall, has *Asystasia*, *Culcasia*, *Dorstenia* and tree seedlings. The area between 7.5 and 20 cm along the plot has been opened up by an old tree fall. There is dense tall herb/shrub vegetation 3.5 m tall containing *Lantana camara* and *Olyra*; the trees *Croton sylvaticus*, *Ficus sur* and *Macaranga capensis* are growing up in the gap. The extreme right-hand end of the plot (52.5 – 60 m) is also the site of an old tree fall. Here there is a dense cover of young trees and climbers heavily shading an almost bare forest floor containing a little *Culcasia*.

Profile (d): Submontane ridge forest (Fig. 25.5)

At Kwamsambia and elsewhere in submontane forest virtually all trees belong to evergreen species, contrasting with the large numbers of emergent and other tall trees which are deciduous in the lowland forest. The trunks of nearly all trees are vertical and very straight; with the exception of emergents, they are relatively narrow. As with lowland forest, tall trees tend to occur in groups.

The ridgetop forest, at 980 m, has up to four ill-defined strata of woody plants.

Emergent trees, to 40 m tall, spread widely above the smaller trees. *Isoberlinia scheffleri* and *Ocotea usambarensis* are common, with less frequent *Newtonia buchananii* and *Parinari excelsa*. Some of the *Ocotea* trees are leaning at precarious angles and seem about to fall; many are shedding large branches creating small gaps.

Trees in the second layer are 20 – 30 m tall and have relatively narrow, and sometimes deep, crowns. *Allanblackia stuhlmannii* and *Greenwayodendron suaveolens* are common. This layer merges downwards into the next stratum, 10 – 20 m tall, containing small *Allanblackia* and *Greenwayodendron* and also *Drypetes gerrardii*, *Englerodendron usambarense*, *Strombosia scheffleri*, and others. Crowns are narrow and tend to have little depth. This layer merges downwards once again into the fourth woody stratum, up to 10 m tall, containing numerous individuals of many of the taller trees, abundant *Alchornea hirtella* (often widely leaning) and many shrubs of various sizes such as *Leptaulus holstii*, *Memecylon* spp., *Suregada procera* and many Rubiaceae, for instance species of *Chassalia and Rutidea*.

The ground is heavily shaded in most places along the profile plot and herbaceous vegetation is sparse, consisting mainly of an open cover of *Culcasia* 30 cm tall. The fall of an *Ocotea* branch has created a small gap at 30 – 37 m along the plot, and here *Dracaenia steudneri* is abundant, growing to 8 m, and there are scattered individuals of *Clidemia hirta* and the fern *Blotiella stipitata*.

The trunks of trees in this and the other two plots at Kwamsambia frequently carry epiphytic bryophytes and climbing *Culcasia* to heights of 10 – 15 m. There are occasional large climbers on the trees, including *Salacia lehmbackii*.

A remarkable feature of this and other submontane forests on the East Usambaras is the virtual total lack of regeneration of *Ocotea*.

Profile (e): Submontane slope forest (Fig. 25.6)

This forest, at 960 m, has many layers of foliage, generally without well defined tree strata. Up to four layers of woody plants are superimposed on one another.

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Emergent trees reach slightly over 40 m and include *Beilschmiedia kweo*, *Maranthes goetzeniana* and *Newtonia buchananii*. Below, there is a more continuous layer of smaller trees reaching 20–30 m, with consipicuously common *Greenwayodendron suaveolens*. This layer merges downwards into the next layer 10–20 m tall, again with much *Greenwayodendron*, and also *Drypetes gerrardii*, *Schefflerodendron usambarense*, *Strombosia scheffleri* and *Uvariodendron* spp.

There is usually a fairly dense layer of small trees and shrubs 1–10 m tall containing many small individuals of the tall species and also *Leptaulus holstii*, *Memecyclon* spp., *Mesogyne insignis*, *Xymalos monospora* and many Rubiaceae.

The profile plot has a clump of large trees casting heavy shade on its left. Next, at 8–22 m, there is a gap where the open conditions have encouraged the growth of the shrubs/small trees *Argomuellera* and *Dracaena steudneri* and the fern *Blotiella stipitata*. There is an area of more mature forest with dense shade at 22–50 m and there is little herbaceous vegetation expect for a thin covering of *Culcasia* and occasional patches of open *Dracaena*; tree seedlings are quite abundant. The crown area of a large, naturally fallen, *Greenwayodendron* has crashed across the profile plot at 50–60 m knocking another tree of *Greenwayodendron* off the vertical and destroying the crown of an *Anisophyllea obtusifolia* (now resprouting). This tree fall is recent and there is a mass of large and small branches and virtually no herbaceous vegetation. A few *Clidemia* shrubs and *Tiliacora* climbers (70 cm tall) have started to grow on the edges of the gap.

Profile (f): Submontane valley forest (Fig. 25.7)

The profile plot, at 920 m altitude, passes through two distinctly different environments, a flat river valley to the left containing small streams meandering over a sandy substrate and a raised section to the right with a normal, well-drained, clay-loam soil. The river valley is sometimes completely flooded and banks are being undercut, exposing tree roots.

The riverine forest at 0–30 m along the plot has a rather open and very irregular canopy. There is considerable shade cast by trees rooted on surrounding slopes. Canopy trees are rather short in stature, attaining only 30 m and include *Anthocleista grandiflora* and *Cephalosphaera usambarensis*. There is a dense lower tree/shrub stratum with abundant *Alchornea hirtella* and *Sorindeia madagascariensis* An unusual feature of many of the smaller trees is that they have been knocked over, presumably during times of flood, and their trunks now lie horizontally on the forest floor or at acute angles. They regrow readily with vertical shoots. Clearly, this is a very unstable environment for tree growth. An exceptional number of trees of all sizes have stilt roots, suggesting that they commenced growth rooted on fallen trunks (Chapter 27).

Tree ferns, *Cyathea manniana*, to 10 m tall, are locally abundant in the valley and on the nearby lower slopes. In the many open places there is a dense growth of tall herbs and shrubs including *Boehmeria platyphylla*, *Dracaena steudneri* and *Marantochloa leucantha*. These plants are themselves underlain by a dense lower herbaceous stratum of Acanthaceae and *Culcasia* 80 cm tall. Lianes are common on many of the trees.

An exceptional number of trees are rooted on the very edge of the river bank.

The patch of forest at 40–55 m on well drained clay-loam soil is structurally similar to the slope forest described previously with four layers of woody plants. A very large *Cephalosphaera usambarensis* 52 m tall soars over a second tree layer 30 m tall with *Allanblackia stuhlmannii*, *Cephalosphaera* and *Cynometra* sp. This layer merges downwards into a third tree stratum 20 m tall with much *Cynometra* and *Greenwayodendron suaveolens*. Underneath, this layer grades into a small tree/shrub stratum containing much *Alchornea hirtella*. The very open herbaceous layer at 80 cm contains *Blotiella stipitata*, *Culcasia* and *Trichomanes rigidum*.

The extreme right-hand end of the plot (52–60 m) is the site of an old tree fall and contains a shrub/climber tangle 4 m tall with much *Aframomum* over smaller *Clidemia* and various ferns.

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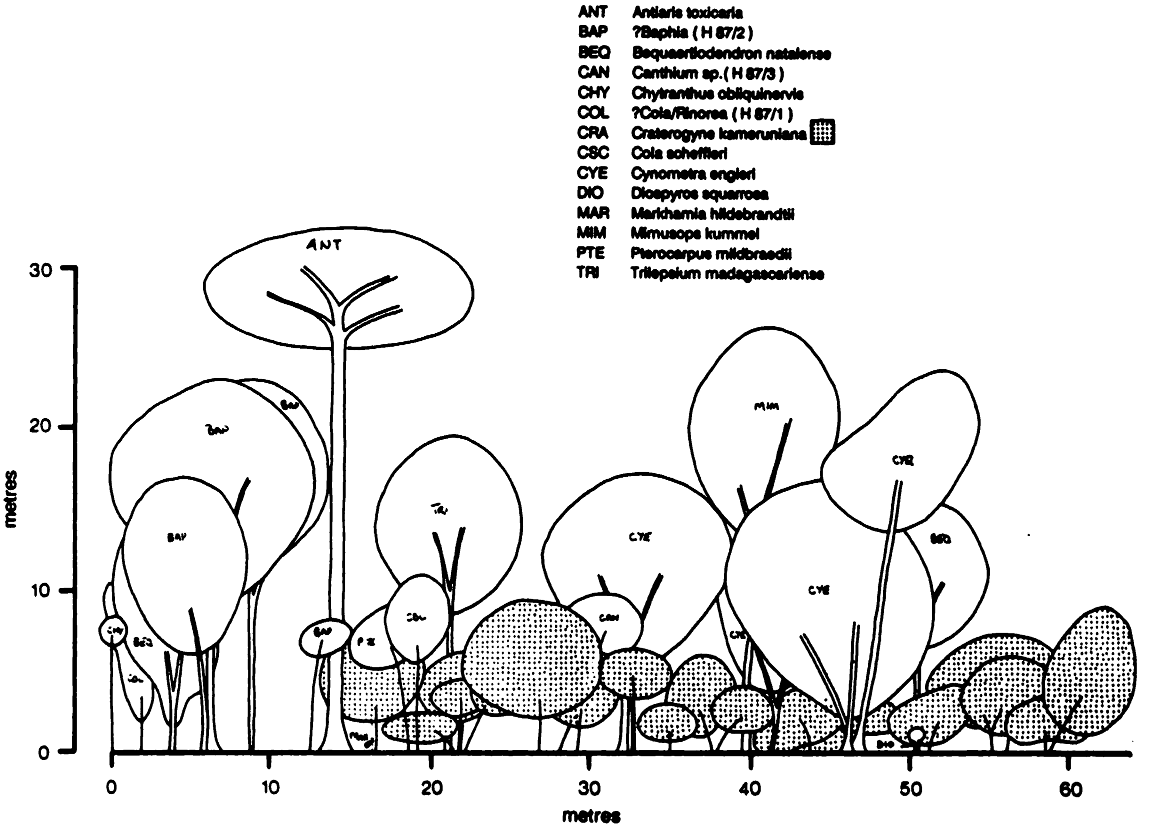

Figure 25.2 Profile diagram of lowland ridge forest at Kwamgumi. Altitude 260 m. Profile width 7.5 m.

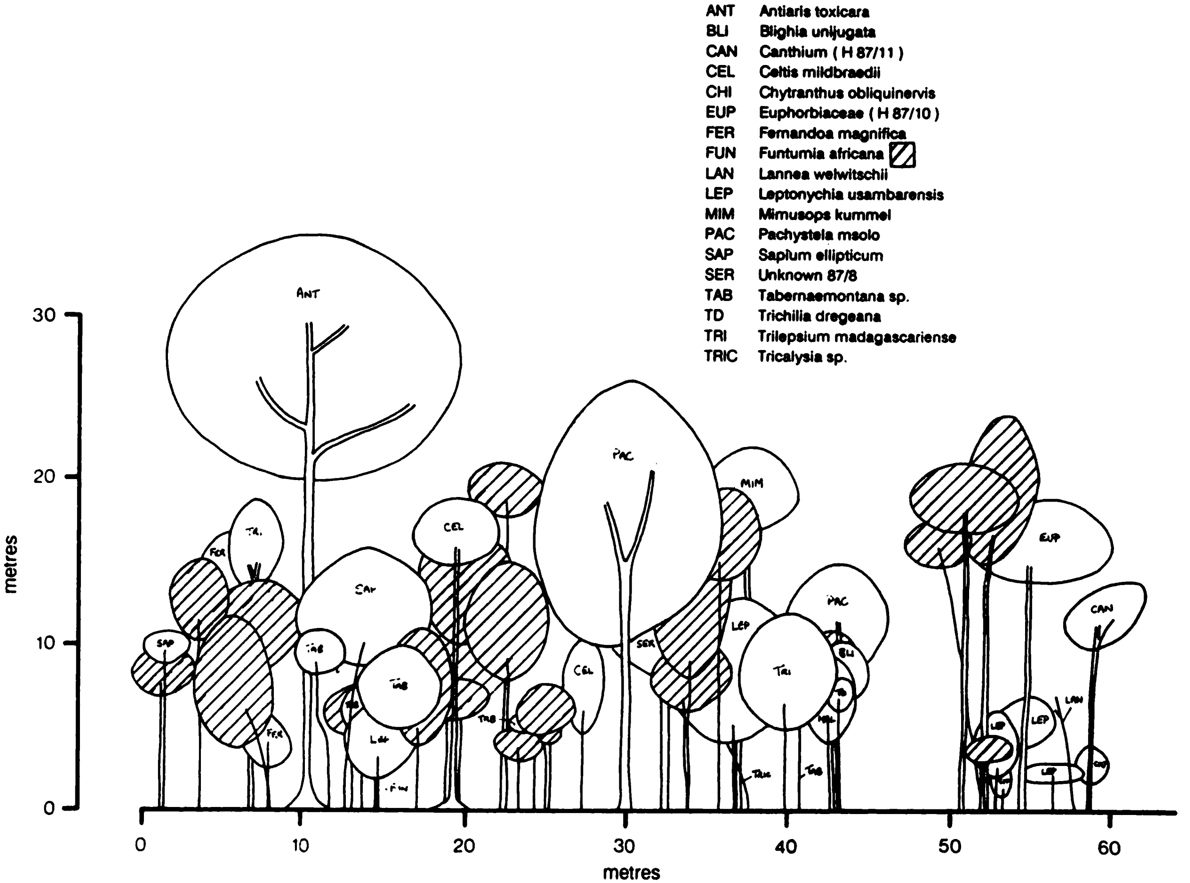

Figure 25.3 Profile diagram of lowland mid-slope forest at Kwamgumi. Altitude 230 m. Profile width 7.5 m.

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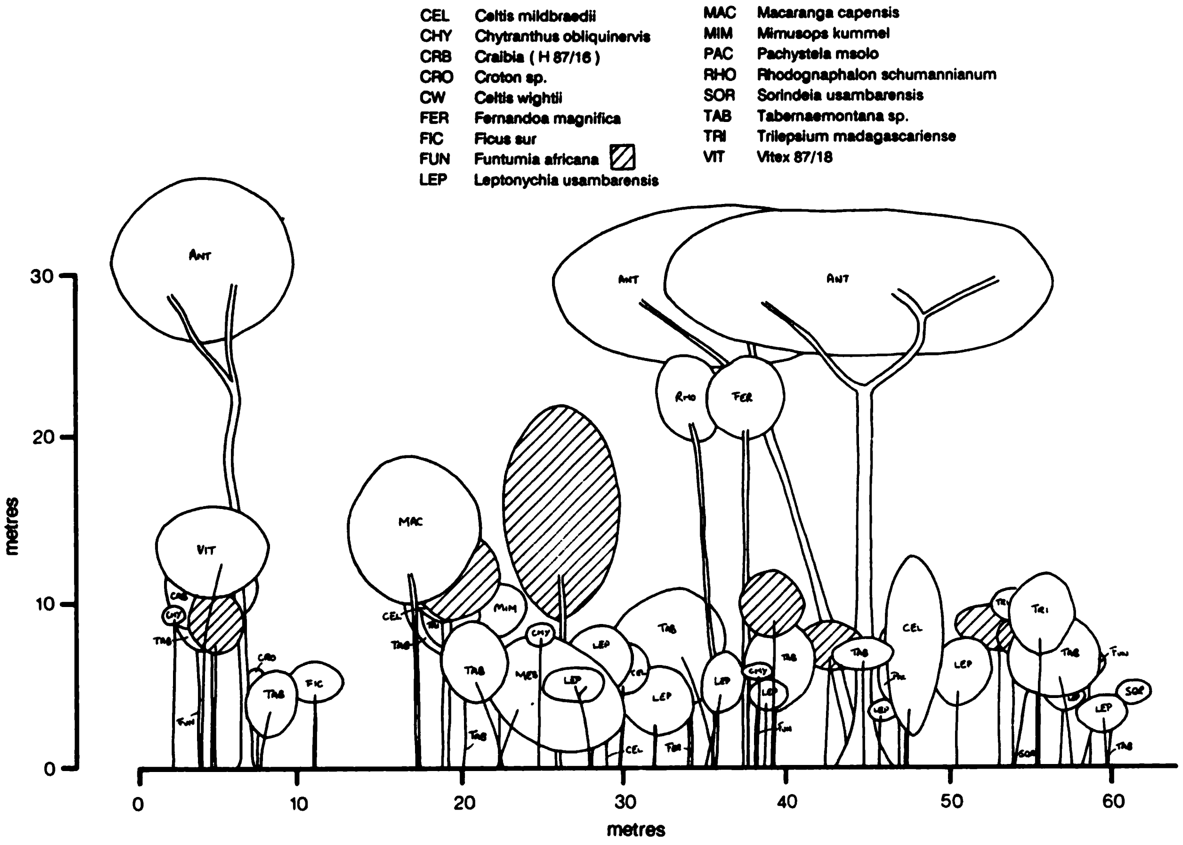

Figure 25.4 Profile diagram of lowland lower slope forest at Kwamgumi. Altitude 210 m. Profile width 7.5 m.

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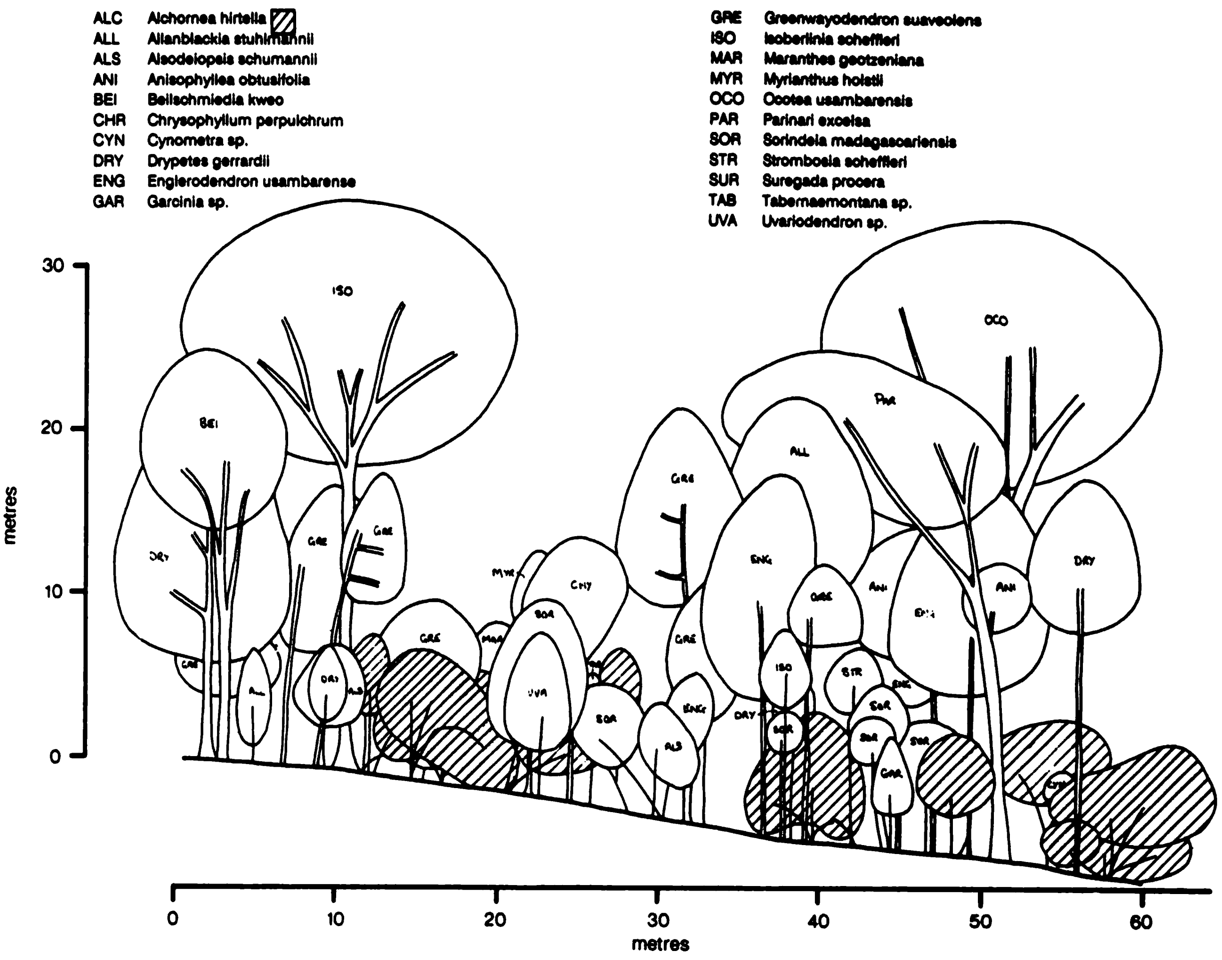

Figure 25.5 Profile diagram of submontane ridge forest at Kwamsambia. Altitude 980 m. Profile width 5.5 m.

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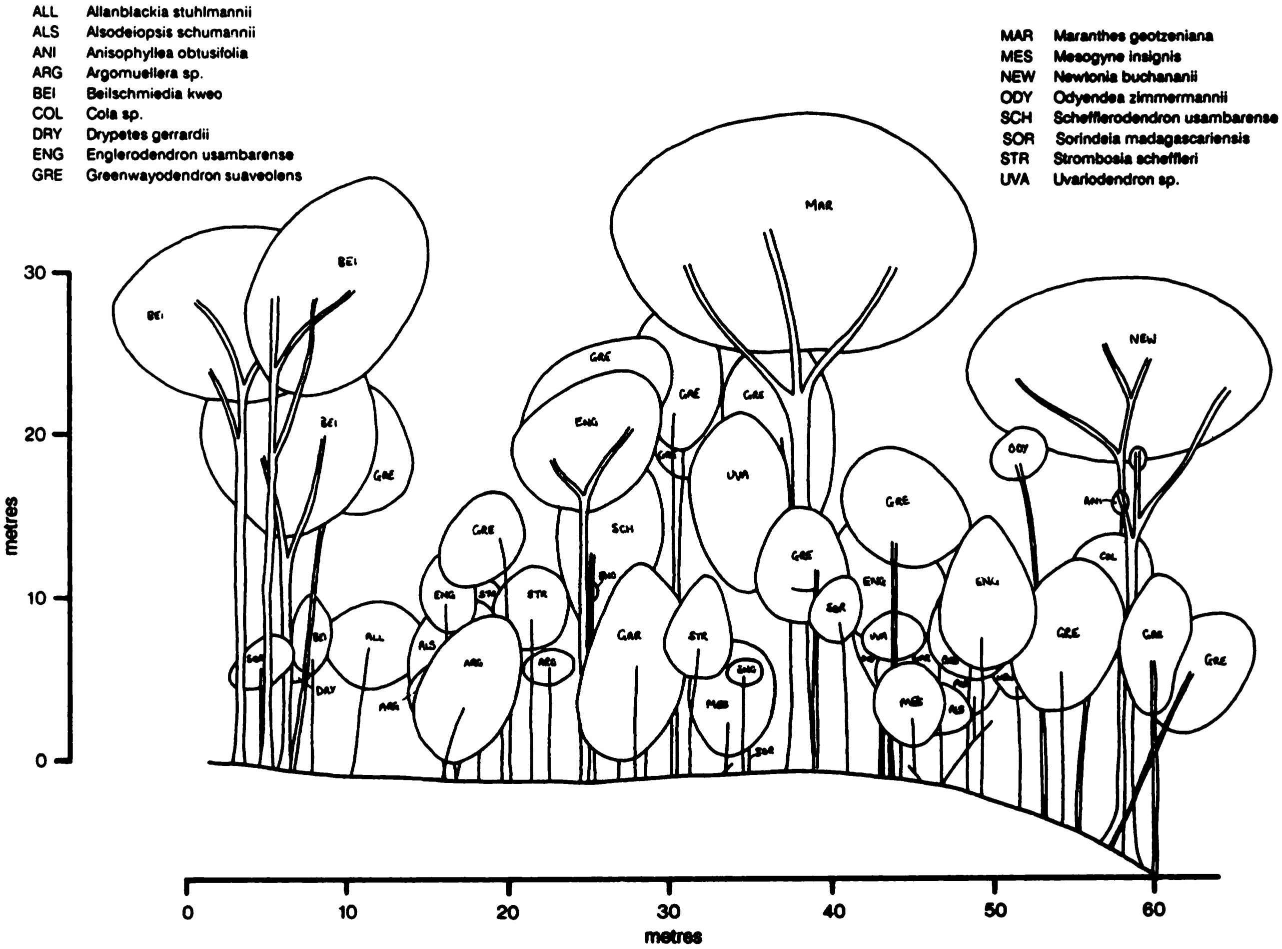

Figure 25.6 Profile diagram of submontane slope forest at Kwamsambia. Altitude 960 m. Profile width 7.5 m.

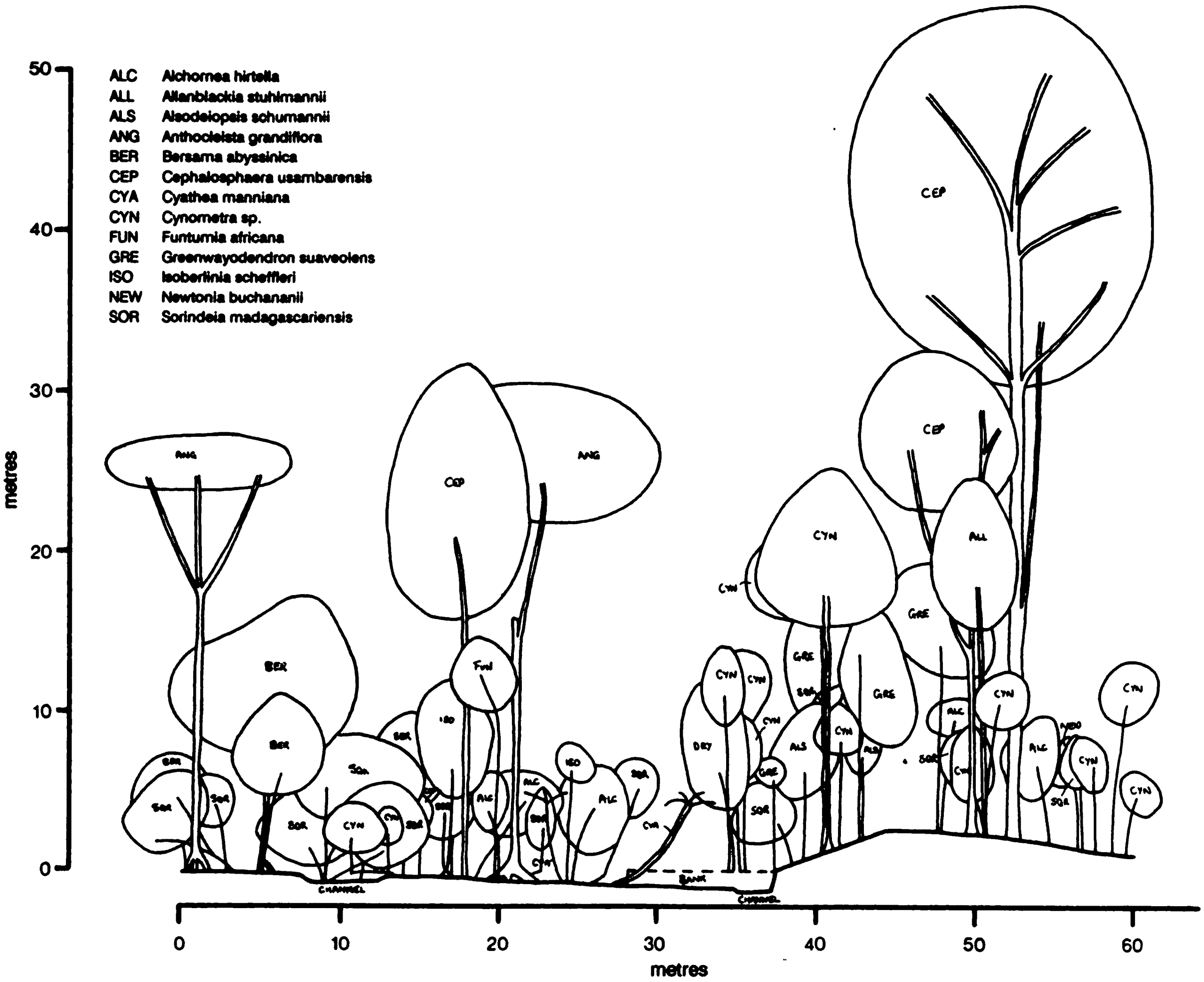

Figure 25.7 Profile diagram of submontane valley forest at Kwamsambia. Altitude 920 m. Profile width 7.5 m.

3. Comparison of lowland and submontane forests

3.1 Number of species

Each profile plot was extended at one end to make a larger sample area of total length 150 m and area 1,125 m^2. The numbers of tree species (>4.8 cm dbh) in the extended plots were determined.

Dealing only with plants identified to the species level, 37 species of trees were present in the three lowland forest plots considered together (between 22 and 24 in each of the individual plots) and 42 species of tree were present in the three submontane forest plots considered together (between 24 and 30 in each of the individual plots). The lowland and submontane forest appear to have similar numbers of species per unit area.

The numbers of species encountered as each plot was increased in size are plotted on Fig. 25.8 This again suggests that all six areas of forest are similar in floristic diversity. In this case all taxa were included, even if not identified to the species level. Curves are still rising as the ends of the sample areas are reached, showing that enlargement of the plots would substantially increase the total numbers of species. Sample sizes are however too small to estimate by extrapolation the total numbers of species the various forests contain, though it may be noted that a greater number of submontane than lowland forest tree species are known from the East Usambaras (Chapter 23).

It is concluded that these lowland and submontane forests are similar in floristic diversity as measured by the numbers of tree species in the sample plots.

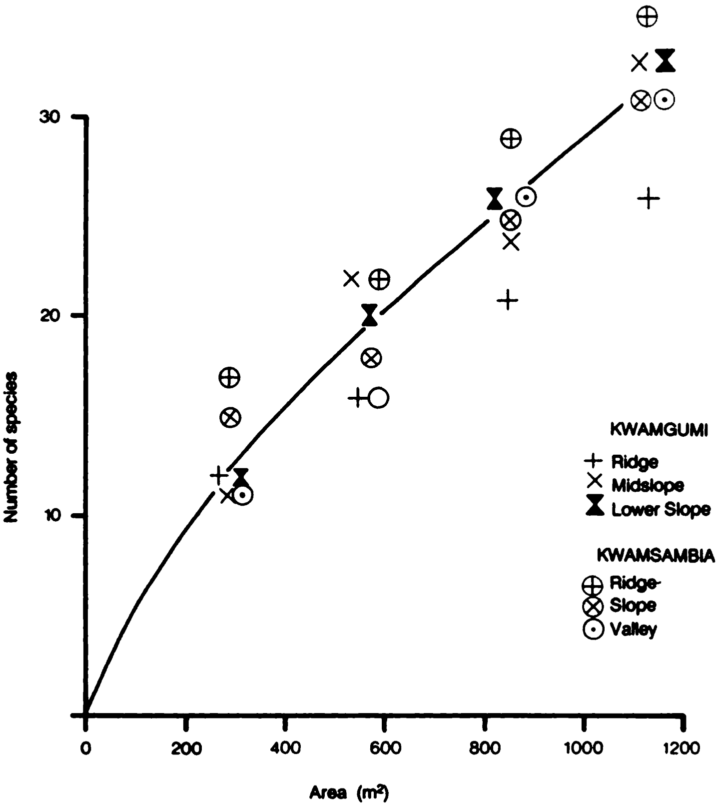

Figure 25.8 Numbers of species encountered in the enlarged profile diagram plots at Kwamgumi and Kwamsambia. All lowland and submontane forests display approximately the same species/area relationship, regardless of catenary position.

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3.2 Floristic similarity of lowland and submontane forests

This analysis uses the expanded 1,125 m^2 areas.

Considering all three plots recorded in each forest type together, only 9% of the species identified to the species level are common to both lowland and submontane forests, demonstrating their floristic distinctiveness. If comparisons are made between the six individual sample areas, then the percentage of species shared between any one of the lowland forests and any one of the submontane forests ranges between 2 and 10%, much lower than between the three individual lowland forest areas (31–41%) and between the three individual submontane forest areas (31–47%).

There is therefore little floristic similarity between the lowland and submontane forests examined.

3.3 Numbers of endemics

Trees identified to species level in the expanded 1125 m^2 plots were assigned to four endemic categories (Chapter 17), defined as follows:

- **Endemic category 1** found only on the East Usambaras.
- **Endemic category 2** found on the East Usambaras and at one or a few similarly restricted localities in eastern Tanzania or occasionally eastern Kenya, Mozambique or Malawi.
- **Endemic category 3** more widely distributed in East African coastal forests. Not in the Guineo-Congolian forests of Central and West Africa (Zaire etc.).
- **Endemic category 4** widely distributed in African tropical forests, usually also in Central or West Africa.

There are a few unclassified species, including those which have been introduced.

Results are shown on Table 25.1 and reveal important differences between the lowland and submontane forests, though not between the three sample areas within each of them.

Table 25.1 Percentages of species identified to species level belonging to various endemic categories in lowland and submontane forests.

	Lowland Forest (Kwamgumi)				Submontane Forest (Kwamsambia)			
ENDEMIC CATEGORY	Total	Ridge Forest	Mid-Slope Forest	Lower Slope Forest	Total	Ridge Forest	Slope Forest	Valley Forest
1. East Usambara endemics	8	14	8	4	10	10	16	13
2. East Usambara near-endemics	5	5	4	9	26	27	36	25
3. East African coastal forest species	24	23	21	30	5	7	8	4
4. Widely distributed African species	62	59	67	57	60	57	40	58

Discussion is limited here to a comparison of the lowland and submontane forests, all plots from each forest type being considered together.

Only low percentages of species (5% in lowland forest; 2% in submontane forest) are known only from the East Usambaras. The number of near-endemics (endemic category 2) is much lower in lowland forest (8%) than in submontane forest (33%). The number of widely distributed East Coast species (endemic category 3) is much higher in lowland forest (24%) than in submontane forest (5%). The number of widely distributed African species is about the same in both cases (62 and 60%). These

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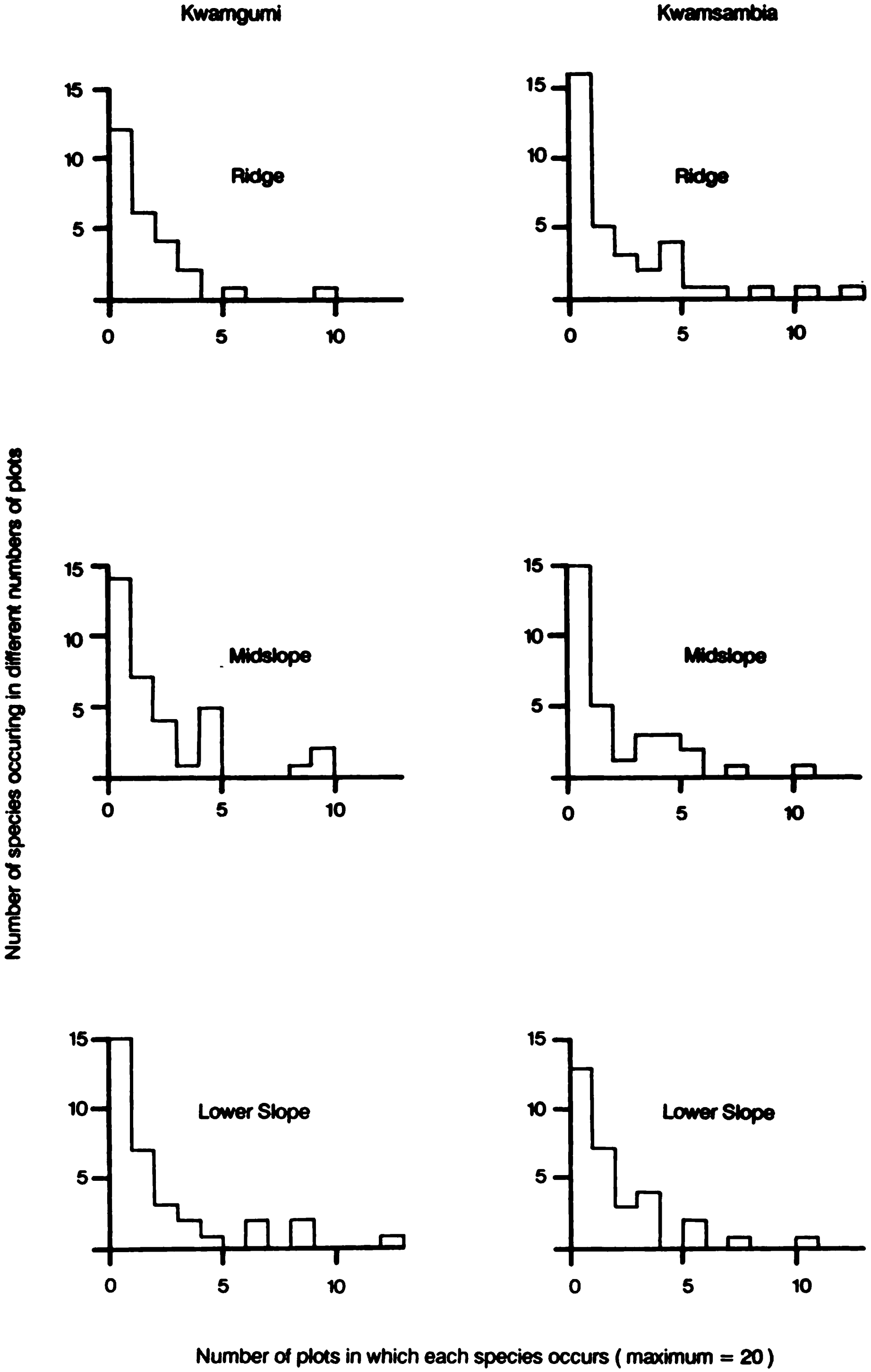

Figure 25.9 The number of plots (out of 20) in which different numbers of species occur, for each of the six sites. Most species are found in only one or a few plots.

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results are similar to those found in an analysis of the variable-area tree plots (Chapter 22) and an analysis of the distribution patterns of the entire forest tree flora (Chapter 23). For an attempted explanation and a discussion of conservation implications, see Chapter 23.

3.4 Rarity and abundance of individual species

The frequencies of occurrence of species in twenty individual 56.25 m^2 plots, together constituting the total 1,125 m^2 sample areas, are shown on Fig. 25.9. All forests show the same pattern of species abundance. A few species are common and many others occur only in one or a few of the individual small plots,

It is concluded that large areas of forest are required to maintain viable populations of the majority of species. Given our lack of knowledge of forest dynamics and of the life-history strategies of nearly all species, it is impossible to estimate with any precision the actual areas required to conserve individual species.

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26. Herb Communities on the Forest Floor

by Peter Linder

The herbaceous vegetation of the forest was investigated along altitudinal gradients in Kwamsambia and Mtai Forest Reserves, and submontane forest around Amani. Four herbaceous communities can be recognized, occupying distinct habitats partly related to altitude. A community which is common on the Amani plateau appears to be the richest floristically and to have the largest number of endemic species. Within each community there are successional pathways associated with treefalls.

1. Introduction

The structure and composition of the herb communities on the floor of tropical rain forests are largely unknown. The factors controlling the structure and composition of these communities are even less understood. And yet a significant proportion of the total floristic diversity of these forests occurs in the understory. This study attempts to determine whether distinct herb communities can be recognized and whether there is any pattern in the distribution of these communities.

2. Methods

The bulk of the field work was done between the end of July and the middle of August 1986. Initially, five samples were placed along an altitudinal transect in Kwamsambia Forest Reserve, partly to collect data and partly to test the methods. Later a much more detailed survey was carried out along an altitudinal transect up the eastern slopes of Mt Mtai above Marimba. This was followed by further sampling in submontane forest on the plateau in Amani-Sigi and Amani-West Forest Reserves.

Three different methods of selecting samples were used, depending on time and transport considerations:

- Five samples (nos. 1 – 5) were recorded along an altitudinal gradient in Kwamsambia Forest Reserve. These were taken at 100 m altitudinal intervals along a path which started near a stream and then ascended the sides of a valley. The transect line is the lower part of the transect line used for the variable-area tree survey in Kwamsambia (Chapter 22).
- Fifteen samples (nos. 8 – 22) were recorded on the eastern slopes of Mt Mtai between 300 and 1,050 m. Care was taken to cover the whole altitudinal range. This is the same transect line used for the variable-area tree survey on Mtai (Chapter 22).

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- Eleven samples (nos. 6–7 and 23–31) were recorded in Amani-Sigi and Amani West Forest Reserves, between 750 and 1,000 m. In this case, little attention was paid to altitude.

Each sample was positioned so as to capture as much of the local variation in vegetation composition as possible. Where feasible, tree-falls, boulders, and closed forest were included in one sample. Sample area is about 30 x 30 m. In practice, all herbs were recorded in an ever-increasing area, until no more new species were noted. Within the sample, between four and eight plots, each measuring 2 x 2 m, were placed subjectively. While each plot was placed in an homogeneous area, between them they record the total structural and floristic variation within the sample. For these plots, for each species, the maximum height and total projected cover were recorded. In addition, crude environmental data were recorded, such as tree canopy height and cover, rock cover, litter cover and slope, and notes were made on the successional status of the forest.

The definition of 'herb' in these forests causes difficulties. Where possible, all plants less than 1.5 m tall were recorded as 'herbs'. 'Tree herbs' growing taller, such as *Dracaena* spp., were also recorded.

Species were identified, where possible, from the Flora of Tropical East Africa (FTEA, 1952 *et seq.*). Species, for which the material was inadequate or which had not yet been revised in FTEA, were identified by the staff of the East African Herbarium at Nairobi, where voucher specimens are housed.

For those species for which published distribution records were available, distributions were plotted and are indicated in Table 26.1. However, due to the use of Flora Zambesiaca and Flora of West Tropical Africa for the determination of distribution ranges of taxa not yet dealt with in the FTEA, the presented data are biased against East African endemic species and the results cannot therefore be analysed statistically.

The sample data were analysed in a phytosociological table, using the methods of the Braun-Blanquet school, as described by Mueller-Dombois and Ellenberg (1974). The data from the 2 x 2 m plots were analysed by inspection.

3. Results and discussion

The variation in the composition and the structure of the herbs of the forest floor is complex. Species appear to be distributed individualistically along altitudinal, successional, edaphic and moisture gradients. Species associations are consequently serendipitous, and borders between communities vague, unless there are abrupt changes in one or more environmental parameters. To allow for these factors, I have not attempted to erect a hierarchical vegetation classification, but rather describe vegetational 'noda', with intermediate forms. Local variation and successional changes are described separately, and are only related to the vegetational 'noda' or communities when it could be empirically demonstrated to be correct.

3.1. Herb communities

The results of the phytosociological analysis of the stands are presented in Table 26.1. The major environmental parameters at each stand are shown in Table 26.1 (Part one). Four major communities can be recognized.

Community 1: *Psychotria faucicola – Erythrococca usambarica* community
(Samples 22, 19, 11, 10, 17, 15, 16, 1, 2, 3, 4, 5, 14)

This occurs on the escarpment slopes, between 400 m and 800 m. On Mt Mtai it is only found above 550 m, while at Kwamsambia it descends to 400 m. It is usually associated with *Olyra latifolia, Piper capens, Marantochloa leucantha, Pollia condensata, Aframomum* sp. and *Rauvolfia mannii*, but these species also occur outside this community. Many of these species are linked to forest disturbance and their frequent appearance here may be related to the increased occurrence of treefalls and rockslides on the steep slopes. On average, there are 15.4 species per stand, and 42% of the stands have at least one species recorded from that stand only.

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This community is quite variable. On Mt Mtai there is a fairly distinct form between 600 m and 700 m, characterized by *Psychotria pandurata, Adhatoda engleriana* and *Nervilia ?umbrosa*. Of the three species, only *Nervilia ?umbrosa* has been recorded from the Kwamsambia transect, from 600 m. *Geophila repens* is found on Mt Mtai between 500 m and 600 m, but also occurs occasionally on the plateau at Amani. The transect at Kwamsambia differs from Mt Mtai in the presence of *Corymborkis corymbis*, which is associated with *Orobanche* sp. and *Gonatopus boivinii*. This association occurs between 500 m and 800 m, and *Corymborkis corymbis* also occurs in the neighbouring Amani-Sigi Forest, at 900 m. Below 400 m in Kwamsambia Forest *Pentas micrantha* occurs and further study of this very poorly sampled area may reveal more species restricted to this area.

This community shows clear altitudinal gradation and on the Kwamsambia transect the upper end clearly grades into the *Memecylon cogniauxii* – *Commelina* sp. community (see below). Linking taxa include *Corymborkis corymbis, Calvoa orientalis* and *Leptapis cochleata. Flagellaria guineensis*, which occurs in the lower half of Community 1, provides a link to Community 4.

This community appears to have very few endemic species or species restricted to the Eastern Arc mountains of East Africa. The majority of the species are widespread in tropical Africa. Species towards the base of the altitudinal range generally have widespread distributions: *Olyra latifolia* is recorded by Chapman & White (1970) as being common in lowland forest in Malawi, and it is widespread in Guineo-Congolian forests, while *Flagellaria guineensis* is similarly a widespread lowland species. Both these species link Communities 1 and 4.

Community 2: *Memecylon cogniauxii* – *Commelina* sp. community
(Samples 24, 6, 7, 27, 28, 29, 31, 23, 30, 26)

This is the community commonly found on the 'plateau' of the East Usambara mountains, being recorded from all stands in Amani-Sigi and Amani West Forests, between 750 m and 1,000 m, excluding sharp, exposed ridges. There are numerous associated species, e.g. *Isoglossa lactea, Blotiella stipitata, Aframomum* sp.2, *Bolbitis gemmifera* and *Asplenium holstii*. The latter species is also frequently recorded from the lower slopes of Mt Mtai, mostly along streams. The community is absent from Mt Mtai; stands 14 and 13, which are from suitable altitudes on Mtai, have none of the characteristic species.

On average there are 19.1 species per stand and 60% of the stands have at least one species only recorded from that stand. This community is relatively rich in endemic species (e.g. *Memecylonsemsei, P. brevicaulis, Psychotria pandurata, P. peteri*), as well as species restricted to the Eastern Arc mountains. Of the remaining species, some have ranges extending to southern Africa, but very few are widespread in tropical Africa. This floristic component can be regarded as more temperate than the Guineo-Congolian element from the slopes of the mountain, and as such reflect the patterns observed for the tree flora.

This community includes a large amount of variation, allowing the recognition of two 'sub-communities':

- ***Memecylon erythranthrum*** **–** ***Psychotria peteri*** **–** ***Psychotria brevicaulis*** **subcommunity:** This occurs on the drained hillslopes, ridges and valleys of the plateau region. Although there is substantial variation among the samples, no smaller subdivisions can be justified from the data.
- ***Begonia oxyloba*** **–** ***Marattia fraxinea*** **subcommunity:** This is found along streams and their associated marshy banks on the plateau. There are numerous further species that occur in one or more of the stream samples. Some, like *Clidemia hirta. Achyrospermum carvalhi, 'Amaranth 2' and Elatostema orientale*, are taxa characteristic of disturbed areas – most streamsides appear to be more or less disturbed. Other species, such as *Whitfieldia elongata, Sclerochiton boivinii, Hypolytrum testui, Trichomanes rigidum* and two species of ferns, are found in other communities, which include streamside samples at lower altitudes (e.g. *Whitfieldia elongata* in samples 21, 22 and 19), or which probably receive more moisture from

mist and cloud condensation on high ridges. It is curious that this subcommunity as a whole shows so few affinities to the low-altitude streamside stands on Mt Mtai. Unfortunately, neither high-altitude streamside samples from Mt Mtai nor low-altitude streamside samples from Kwamsambia are available for comparison.

Community 3: *Parapentas silvatica* – *Hymenophyllum* spp. community
(Samples 25, 12)

This is found on sharp ridges at about 1,000 m, where there is presumably more exposure and mist condensation. The two samples of this community are very different, and both have long lists of species only recorded from that one sample. The sample on Mt Mtai is from elfin forest, dominated by *Agauria salicifolia*, and is particularly rich in ferns. The sample from Amani-Sigi is from a lower altitude, in high *Ocotea usambarensis* forest with a much poorer herb flora.

Lowerdown on the ridge of Mt Mtai, sample 13 is intermediate between Communities 1 and 3. It is situated at 900 m. It shares *Memecylon semsei* with sample 25 and *Hymenophyllum* sp. 2 with the summit of Mt Mtai. With Community 1 it shares *Psychotria faucicola*, *Aframomum sp.* and *Rauvolfia mannii*, but it lacks many of the other associated species. Then, it also has its own set of characteristic species, such as 'Acanth 875'. This could be due to Communities 1 and 3 extending into the habitat normally occupied by Community 2, which is absent here.

The small number of named species for which distributions are known from this community makes it difficult to assess its phytogeographical relationships, but it does not appear to be as high in endemics as Community 2.

Community 4: *Araceae* 5 – *Araceae* 2 – *Asplenium buettneri* community
(Samples 9, 18, 8, 20, 21).

This community is known from between 300 m and 600 m on the lower slopes of Mt Mtai and is usually found on steep, rocky slopes with shallow soils. This type of habitat was absent from the base of the Kwamsambia transect and consequently this community does not occur there. The community penetrates into the lower half of the *Psychotria faucicola* community on Mt Mtai, on shallow soils on flat-topped boulders, while Community 1 occurs on the deeper soils on the forest floor.

There appear to be very few endemic species in this community. However, most of the typical Araceae were sterile and could not be confidently named. These could constitute an endemic element.

The variation in this community allows the recognition of two subcommunities:

- ***Sansevieria kirkii* subcommunity:** This occurs on very steep slopes, where the soil is too shallow for the development of forest. Most of the usual forest herbs are absent from this association.
- ***Phymatodes scolopendria* subcommunity:** This occurs along streams and mostly includes *Whitfieldia elongata* and *Asplenium holstii*. *Dorstenia* spp. and *Peperomia fernandopiana* occur in some stands. On vertical boulder and cliff faces *Saintpaulia* spp. are found.

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Table 26.1 Presence/absence data for herb species in each sample. The samples are grouped into herb communities. Distribution beyond the East Usambaras is indicated as follows:
WAT - West Tropical Africa; PAN - Pantropical; END - Endemic; TAF - Tropical Africa;
EAF - East Africa; EAR - Eastern Arc; TSA - Tropical and Southern Africa;
ESA - East and Southern Africa; USA - Usambaras; OTR - Palaeotropics;
INT - Introduced; UBI - Ubiquitous.

Part 1: Environmental parameters at each sample site.

Sample Number	Altitude (m)	Aspect	Locality	Geography	Slope	Vegetation	Substrate
9	475	ENE	Mtai	Scarp slope	v. steep	Woodland	Bedrock/shallow soil
18	600	E	Mtai	Scarp slope	v. steep	Open woodland	Bedrock & shallow soil
8	375	E	Mtai	Scarp slope	steep	Forest	Boulders & shallow soil
20	300	SE	Mtai	Scarp base	vertical	Riverine forest	Cliff-face
21	400	NE	Mtai	Scarp slope	moderate	Riverine forest	Bedrock & shallow soil
22	525	E	Mtai	Scarp slope	steep	Riverine forest	Bedrock & shallow soil
19	510	N	Mtai	Scarp slope	moderate	Forest & streamside	Deep soil & boulders
11	575	SSE	Mtai	Scarp slope	steep	Forest	No surface rock
10	575	ENE	Mtai	Scarp slope	steep	Forest (disturbed)	No surface rock
17	600	N	Mtai	Scarp slope	moderate	Forest (dark)	No surface rock
15	710	NE	Mtai	Scarp slope	moderate	Forest (dark)	No surface rock
16	710	N	Mtai	Scarp slope	steep	Forest (dark)	No surface rock
1	370	SE	Kwamsambia	Scarp slope	gentle	Forest (undisturbed)	No surface rock
2	470	SE	Kwamsambia	Scarp slope	moderate	Forest (dark)	No surface rock
3	560	ENE	Kwamsambia	Scarp slope	moderate	Forest & treefall	Bedrock outcrops
14	810	ENE	Mtai	Scarp slope	moderate	Forest (dark)	No surface rock
24	875	W	Amani-Sigi	Plateau Hillside	steep	Forest & treefall	Deep soil & boulders
6	900	WSW	Amani-West	Plateau Hillside	moderate	Forest	No surface rock
7	900	ENE	Amani-West	Plateau Hillside	steep	Forest	No surface rock
27	960	WSW	Amani-West	Plateau Hillside	gentle	Forest	No surface rock
28	900	NW	Amani-West	Plateau Hillside	moderate	Forest	No surface rock
29	900	E	Amani-West	Plateau Hillside	moderate	Forest	No surface rock
31	990	-	Amani-West	Ridge top	gentle	Forest	No surface rock
23	750	ESE	Amani-East	Plateau Hillside	moderate	Forest	Rocks & boulders
30	880	ENE	Amani-West	Plateau Hillside	gentle to flat	Forest	Rocks & boulders
26	850	NNE	Amani-Sigi	Plateau Hillside	v. gentle	Forest	Boulders
13	910	ENE	Mtai	Scarp slopes	v. steep	Forest	Cliff-face & deep soil
25	975	-	Amani-Sigi	Ridgetop	v. steep	Forest	No surface rock
12	1045	-	Mtai	Ridgetop	v. steep	Elfin forest	No surface rock

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Part 2: Occurrence of species in each sample.

Species	Dist	Sample Number																														
		9	18	8	20	21	22	19	11	10	17	15	16	1	2	3	4	5	14	24	6	7	27	28	29	31	23	30	26	13	25	12
Cyclosorus quadrangularis	EAF	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	●	·	·	·	·	●	·	·	●	·	·	·	·	·	·
Chlorophytum filipendulum		·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	·	·	·	●	·	·	·	·	·	·	·	·	·	·	·
Calvoa orientalis	WAT	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	·	·	●	●	·	·	·	·	●	·	●	●	●	●
Psychotria tanganyikensis	EAR	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	●	·	●	·	·	·	·	·	·	·	●	●	●	·
Chassalia sp.		·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	·	·	·	·	·	·	·	·	·	·	·	·
Memecylon cogniauxii	EAR	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	●	●	●	●	●	·	●	●	·	●	·
Commelina sp.		·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	●	●	●	●	·	●	●	●	·	·	·
Isoglossa lactea	EAR	·	·	·	·	·	·	●	·	·	·	·	·	·	·	·	·	·	·	●	·	·	●	●	●	●	●	●	·	·	·	·
Biotiella stipitata	EAR	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	●	·	●	·	·	·	·	·	●	·
Asplenium holstii	EAF	·	·	·	●	·	●	·	·	●	●	·	·	·	·	·	·	·	·	●	·	·	●	●	·	·	●	·	●	·	·	·
Aframomum 2		·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	●	·	●	·	●	·	·	·
Bolbitis gemmifera	END	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	●	●	●	●	·	·	●	·	·	·	·
Memecylon erythranthrum	ESA	·	·	·	·	·	·	·	·	·	·	●	·	·	·	·	·	·	·	●	·	●	●	·	●	●	·	·	·	·	·	·
Psychotria peteri	USA	·	·	·	·	·	·	·	·	·	·	·	●	·	·	·	·	·	·	·	●	●	●	●	●	●	·	·	·	·	·	·
Psychotria brevicaulis	END	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	·	·	●	●	●	·	·	·	·	·	·
Dorstenia 4		·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	·	·	·	·	·	·	·	·	·	·	·
Micrococca holstii	USA	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	·	·	·	·	·	·	·	·	·	·
Psychotria triclada	USA	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	·	·	·	·	·	·	·	·	·
Biotiella hiemonymii	END	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	·	·	·	·	·	·	·	·
Asplenium macrophlebium	EAF	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	·	·	·	·	·	·	·	·
Tectaria gemmifera		·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	·	·	·	·	·	·	·	·
Cyclosorus usambarensis	END	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	●	·	·	●	·	·	·	·
Clidemia hirta	INT	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	·	●	·	●	●	·	·	·
Sclerochiton boivinii	USA	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	·	·	·	·	●	·	·	·
Begonia oxyloba	TAF	·	·	·	·	·	●	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	●	·	·	·
Marattia fraxinea	ESA	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	·	●	●	●	·	·	·
Achyrospermum carvalhi	EAF	·	·	·	·	·	·	·	·	●	·	·	●	·	·	·	·	·	·	·	·	·	·	●	·	·	●	●	·	·	·	·
Whitfieldia elongata	TAF	·	·	·	·	●	●	●	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	·	·	·	·
Amaranth 2		·	·	·	·	·	·	●	·	·	·	·	●	·	·		·	·	·	·	·	·	·	·	·	·	·	●	●	·	·	·
Asplenium A		·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	·	·	·
Bolbitis ?		·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	·	·	·
Asplenium inaequilaterale	TSA	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	·	·	·
Elatostema orientale	EAF	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	·	·	·	●	·	·	·	·
Asplenium sandersonii	TSA	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	·	·
Hypolytrum testui	WTA	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	●	·	●	·
Fern 3		·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	●	·	●	·

Species	Dist	Sample Number																														
		9	18	8	20	21	22	19	11	10	17	15	16	1	2	3	4	5	14	24	8	7	27	28	29	31	23	30	26	13	25	12
Culcasia 'scandens'	WAT	*	.	*	.	.	.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	.
Oplismenus hirtellus	PAN	*	*	*	.	.	.	*	*	*	*	*	*	*	*	*	.	*	.	*	.	.	*	*	*	.	*	.	*	*	.	*
Dracaena deremensis	END	*	.	*	.	.	*	.	.	.	*	.	.	*	.	.	*	*	.	*	*	*	*	*	*	*	.	*	.	.	.	.
Dracaena laxissima	TAF	.	*	.	.	.	.	*	.	.	*	.	*	.	*	*	*	*	.	*	.	*	.	.	*	.	*	*	*	*	*	*
Costus sp.		.	.	.	*	*	*	*	.	.	.	.	*	*	*	*	.	*	*	*	*	.	.	.	.	.	*	*	*	.	.	.
Olyra latifolia	PAN	*	.	*	.	.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	.		*	.	.	*	.	.	.	.	.
Flagellaria guineensis	TAF	*	.	*	.	.	.	*	*	*	*	.	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Araceae 5		*	*	*	*	*	*	*	*	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Araceae 2		.	*	*	.	*	*	*	.	.	*	*	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.
Asplenium buettneri	TAF	*	*	*	.	*	*	*	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Araceae 1		*	.	*	.	.	.	.	*	*	.	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sansevieria kirkii	EAF	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseuderanthemum hildebrandtii	EAF	*	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.
Phymatodes scolopendria	PAN	.	.	.	*	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saintpaulia sp.		.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Peperomia fernandopoiana	WAT	.	.	.	.	*	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dorstenia 2		.	.	.	*	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dorstenia 3		.	.	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Erythrococca usambarica	END	.	.	.	.	.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	.	.	.	*	.	.	*	.	.	.	.	.
Piper capense	TSA	.	.	.	.	.	.	.	*	*	.	.	*	*	*	*	*	*	*	.	.	.	*	*	.	.	.	.	.	.	.	.
Marantochloa leucantha		.	.	.	.	.	*	*	.	*	*	*	*	.	.	*	.	*	.	.	.	.	.	.	.	.	.	*	*	.	.	.
Pollia condensata	TAF	.	.	*	*	.	*	.	.	*	*	*	*	.	*	*	*	*	.	*	.	*	*	*	*	.	.	.	.	.	.	.
Aframomum sp.		.	.	.	.	.	.	.	.	*	.	*	*	.	*	*	.	*	.	.	*	.	.	.	.	.	.	*	*	*	*	*
Rauvolfia mannii	WAT	.	.	.	.	.	.	.	*	.	*	*	.	*	*	.	.	.	*	.	.	*	.	.	.	.	.	.	.	*	.	.
Psychotria faucicola	EAR	.	.	.	.	.	*	*	*	*	*	*	*	*	*	*	*	.	*	.	.	.	.	.	.	.	*	.	.	*	.	.
Cyrtococcum multinode	EAF	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Geophila repens	PAN	.	.	.	.	.	.	*	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.
Dracaena usambarensis	EAF	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Psychotria pandurata	END	.	.	.	.	.	.	.	.	.	*	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Adhatoda engleriana	EAF	.	.	.	.	.	.	.	.	.	.	*	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nervilia ?umbrosa	TAF	.	.	.	.	.	.	.	.	.	.	*	*	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pentas micrantha	ESA	.	.	.	.	.	.	.	.	.	.	.	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Corymborkis corymbis	TSA	.	.	.	.	.	.	.	.	.	.	.	.	.	*	*	*	*	.	*	.	.	.	.	.	.	.	.	.	.	.	.
Gonatopus boivinii		.	.	.	.	.	*	.	.	.	.	*	.	.	.	*	*	*	.	.	.	.	.	.	.	.	.	.	.	*	.	.
Orobanche sp.		.	.	.	.	.	.	.	.	.	.	.	.	.	.	*	.	*	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Leptapis zehlanica	OTR	.	.	.	.	.	.	.	.	.	*	*	*	.	.	*	.	.	*	*	*	*	*	*	*	*	*	*	*	.	*	.

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Species	Dist	Sample Number																														
		9	18	8	20	21	22	19	11	10	17	15	16	1	2	3	4	5	14	24	6	7	27	28	29	31	23	30	26	13	25	12
Vernonia 2		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	*
Streptocarpus caulescens	EAR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	*
Acanth 875		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
Memecylon semsei	END	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	*	*	-
Dicranolepis usambarica	EAR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	*	-	-
Vittaria guineensis	ESA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-
Peperomia rotundifolia		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
Parapentas silvatica	EAR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*
Hymenophyllum sibthorpioides	ESA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*
Asplenium pellucidum	ESA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	*	-	-	-	-	-	-
Pteris usambarensis	END	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-
Trichomanes rigidum	PAN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-
Polystachya pudorina	END	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-
Asplenium christii	ESA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-
Palisota schweinfurthii	TAF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-
Cyperus sp.		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Calanthe sylvatica	TAF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Belvisia sp		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*
Solanum nigram	UBI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	*	-	-	-	-	-	-	-	-
Achyranthes aspera	PAN	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	*	*	-	-	-	-	-
Laportea lanceolata	END	*	-	-	-	-	*	*	-	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-
Piper umbellatumi	TAF	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-
Total species in sample		11	6	10	7	10	17	20	10	16	18	16	20	13	13	18	15	18	12	23	15	13	24	21	19	12	19	21	24	17	20	11
No of spp. with restricted distribution		0	0	0	1	1	0	0	0	1	1	0	0	1	0	0	1	0	1	1	1	1	3	0	0	0	1	1	0	2	3	6

3.2 Patterns of species richness and diversity

The species richness of the samples and the communities shows some distinct patterns, the data for which are summarized in Table 26.2. Although the samples are not of a fixed area, the methods used should give results which can be used in a comparative analysis.

The most species-poor is Community 4, which is also found in the harshest environment. Conversely, the most species-rich is Community 2, found in a mesic habitat on a stable substrate. Communities 1 and 3, found on steep slopes and exposed ridges, have very similar levels of species richness.

There are generally considerable floristic differences between the various samples in each community, suggesting a high level of local variation at a scale of more than 100 m.

Table 26.2 Analysis of the patterns of species richness and diversity of the four herb communities.

Community	1	2	3	4
Total number of samples	12.0	10.0	3.0	6.0
Total number of species recorded	190.0	192.0	50.0	61.0
Average no. of spp. per sample	15.8	19.2	16.7	10.0
No. of samples with at least 1 'endemic' species	6.0	6.0	3.0	2.0
% samples with at least 1 'endemic' species	50.0	60.0	100.0	33.0

3.3 Local variation and structure

There is a large amount of local variation or patchiness in the herb cover on the forest floor. The variation is in both structure and floristic composition. Typically, the patchiness appears to be related to local edaphic variation and to variation in the structure of the tree layers, especially to succession following tree falls. Two typical illustrations of local patchiness are given in Figs. 26.1 & 26.2.

In closed, dark forest the herb cover is very low, ranging from totally absent to 10%. Often tree seedlings account for more cover in the 'herb stratum' than the herbs themselves. Individuals of a species become widely spaced, between 1 m and 4 m apart, although the total herb diversity in such forests is still higher than, or as high as, in disturbed, lighter forests. Within these dark forests there are two patterns: if the bush layer is dense, less than 2 m tall, taller 'herbs' such as *Dracaena laxissima* and *Psychotria peteri* grow into this bush layer and become part of it. If the bush layer is absent or the base of it is more than 2.5 m tall, a distinct herb stratum develops, and taxa like *Dracaena laxissima, Psychotria peteri* and even shrubs like *Memecylon spp.* and *Rinorea ferruginea* stay structurally part of the herb stratum.

Occasionally 'light holes' appear to develop in the canopy. These do not appear to be related to treefalls, or to any other form of disturbance, but are simply gaps in the canopy that allow more light to reach a small patch, usually around 9 m^2, of the forest floor. In these 'light holes' small patches of light-demanding taxa exist – in sample 25, *Hypolytrum testui*; in sample 10, *Oplismenus hirtellus* and *Cyrtococcum multinode*; and in sample 15, *Oplismenus hirtellus*.

Substrate variation can lead to patchiness. Obvious cases are where the soil is very shallow on the tops of some of the huge boulders which occur on and around the scarps of the mountains. Towards the base of the mountain, this is the habitat of Community 4; at higher altitude this is replaced by taxa like *Dorstenia* spp., ferns, *Streptocarpus caulescens* and 'Araceae 2'. In this study only two samples above 850 m contain rock faces or boulder tops (samples 13 and 24), and these two do not have much

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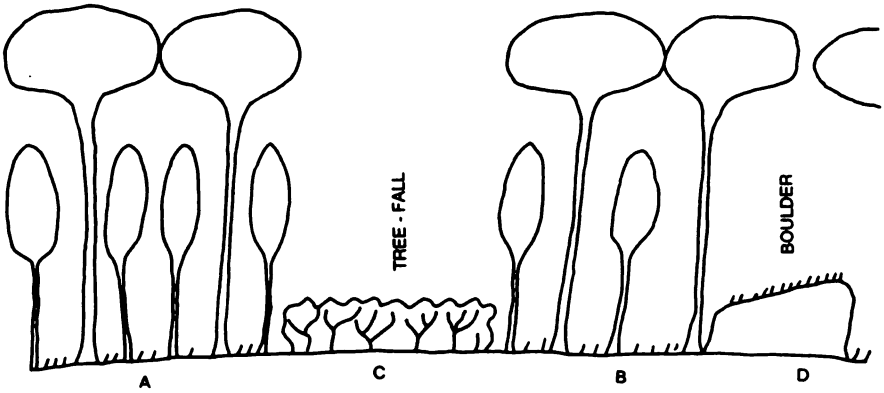

Species	A	C	B	D
Nephrolepis biserrata		6:0.3		
Asplenium christii		1:0.1		
Hypolytrum testui			35:0.6	
Memecylon cogniauxii			10:0.6	
Dracaena laxissima			10:0.8	
Pteris usambarensis			10:0.5	
Calvoa orientalis				20:0.1
Parapentas silvatica				5:0.2
Memecylon semsei				5:1 +
Aframomum 2				1:0.2
Vittaria guineensis				1:0.2
Totals	0:0	6:0.3	50:0.6	15:0.1

Figure 26.1 Sketch illustrating the local patchiness in sample 25 (Amani-Sigi FR, 975 m). Baseline approximately 30 m long. Cover values (first column) as percentages; height (second column) in metres.

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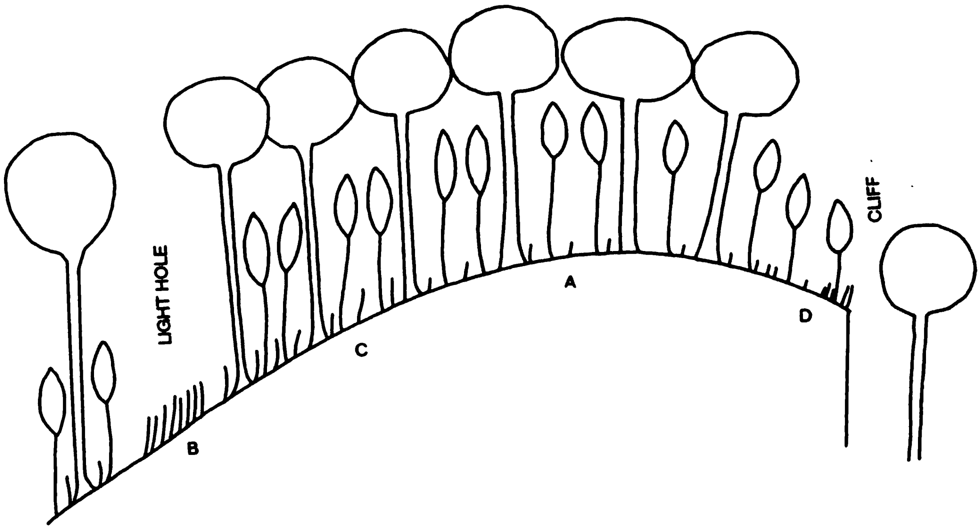

Species	A	B	C	D
Culcasia 'scandens'	3:0.1			
Pollia condensata	1:0.5			
Olyra latifolia	5:1.5			
Acanthaceae 20	5:0.3			
Psychotria brevicaulis	1:0.1	25:0.4		
Bolbitis gemmifera	5:0.2	20:0.2		
Isoglossa lactea	5:0.1	5:0.2	15:0.2	
Commelina sp.	1:0.1		5:0.1	15:0.2
Leptapis cochleata		5:0.4		
Aframomum angustifolium		2:0.1	20:1.7	
Costus sp.			35:1.7	
Laportea lanceolata			15:1.5	
Solanum nigrum			10:1.3	
Dorstenia 4				25:0.3
Aframomum 2				5:0.3
Pteris sp.				5:0.3
Totals	25:0.2	50:0.4	85:1.5	80:0.3

Figure 26.2 Sketch illustrating the local patchiness in sample 24 (Amani-Sigi FR, 875 m). Cover values (first column) as percentages; height (second column) in metres.

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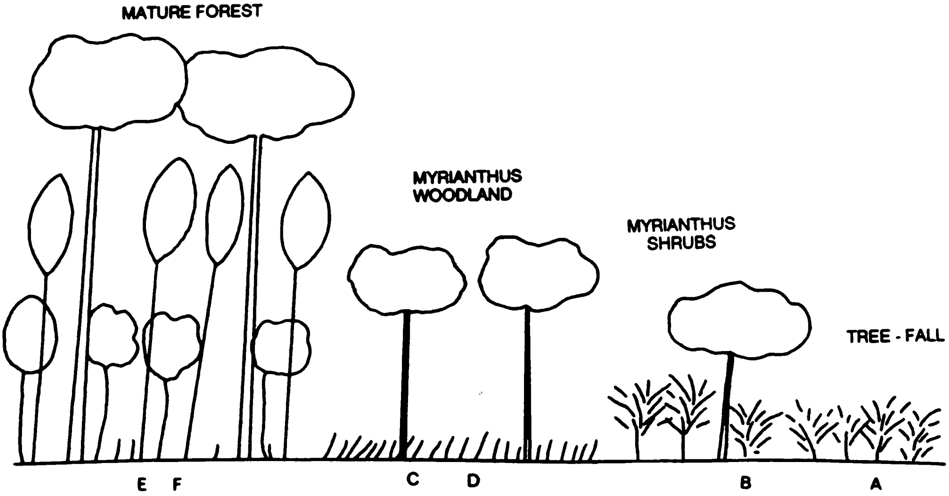

Species	A	B	C	D	E	F
Achrospernum Carvalhi	80:2	5:1.5				
Costus sp.		5:4				
Culcasia 'scandens'		10:0.2	5:0.1	15:0.1	5:0.2	10:0.3
Leptapis cochleata		5:0.3	35:0.2	20:0.3	10:0.3	
Marantochloa purpurea		5:2	5:0.3	10:1		
Piper capense		30:2.5	15:1.5			
Draceana laxissima		10:0.5	5:0.2			
Pollia condensata			1:0.3	8:0.4		
'Fern 4'				5:0.4		
Whitfieldia elongata				10:2		
Psychotria pandurata						5:0.1
Totals	80:2	40:1.5	30:1	30:0.3	15:0.2	15:0.2

Figure 26.3 Schematic diagram showing the treefall succession in sample 16 (Mtai, 710 m). Cover values (first column) as percentages; height (second column) in metres.

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in common. A comparative study of the herb flora of this habitat across the mountain could have interesting results, as there appears to be a steep altitudinal gradient.

On very steep escarpment slopes the substrate appears to be unstable, leading to complex variation in the herb cover, often with small areas of monospecific dominance forming. This is exemplified by patches of *Pollia condensata* on steep rocky slopes where there is a large amount of dead wood.

However, the greatest single cause of patchiness is the post tree-fall succession. Although this complex subject has not been studied in detail, the following pattern has been observed:

- With the destruction of the canopy, tree and bush layers, a dense 'herb-thicket' develops. This is 1.5–2.5 m tall, with cover values of 60–90 %. Several taxa are involved, the composition at any given site probably dependent on the moisture available. In moist localities the thicket is dominated by *Costus sp.*, *Marantochloa prupurea*, *Aframomum sp.*, and *Solanum nigrum*. This is most frequently seen along streams, at all altitudes. Inside forests, in somewhat drier habitats, *Piper capensis*, *Boehmeria platyphylla* and *Isoglossa lactea* dominate. Some treefalls are covered in shrubby 1.5–2 m tall vegetation. The species involved are *Achyranthes aspera* var. *pubsecens*, *Achyrospermum carvalii*, 'Acanth 7', *Pseuderanthemum hildebrandii* and *Adhatoda engleriana*. This is more common on Mt Mtai than around Amani and may be a form of arrested succession.
- In secondary forest, when the forest floor is shaded but the canopy is not dense, such as in *Myrianthus* forest, a dense herb layer develops, with cover values of 40–60%, and with many species being recorded from any 2 x 2 m plot. These usually include 'disturbance relicts' like *Dracaena deremensis*, *Piper capense*, *Costus sp.* and *Olyra latifolia*.
- Scattered stands of *Dracaena deremensis* in mature dark forest may be indicators of old tree-falls.

The inferred process is indicated in Fig. 26.3, giving the best examples of the succession that I have observed.

4. Conclusions

The herbaceous stratum of the forests of the East Usambara mountains is highly complex and rich in species. A preliminary analysis of the distribution patterns of the herbs within the forests suggests the following generalisations:

- Four herbaceous 'communities' can be recognized. These occupy distinct habitats. The richest community floristically appears to be the one that occurs on the plateau of the mountains. This also appears to be the community that is richest in endemic species. The communities of the summit ridges are still very poorly known.
- Within each community there are recognizable successional patches associated with tree-falls, and the occurrence of certain herbs in the understory may indicate old tree-falls. It is possible that further research may indicate that tree-falls may be dated by the herbs in the gaps, and that the succession of the herbs may affect the rate of gap generation of the canopy.
- Distinct azonal communities occur along streams and in special habitats like tops of boulders. These were not studied adequately to separate them from the zonal communities, but they may display altitudinal and habitat replacement similar to that of the zonal communities.
- These very preliminary results indicate that the diversity of the herb flora in these forests may be very high, with a high rate of geographical replacement, especially on the plateau.

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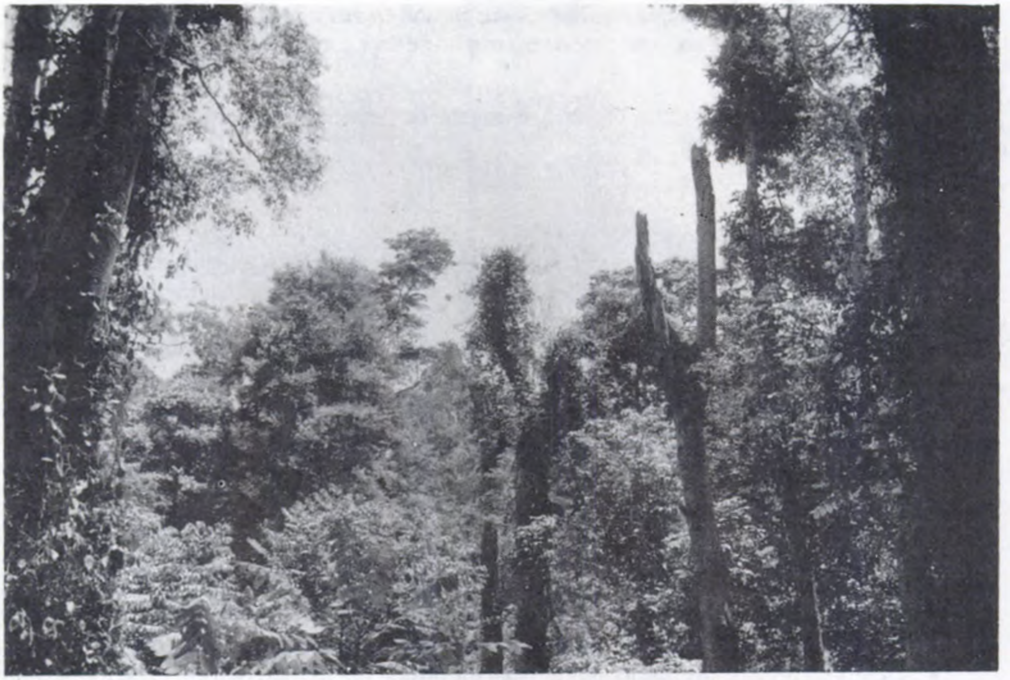

A gap created by felling a large Newtonia in 1978 in Kwamkoro Forest Reserve, 1050 m (Chapter 27, site A). A large gap was created by the tree fall, with many remaining standing trees damaged. The large leafed tree in the left foreground is Polyscias, immediately behind is a Maesopsis; both are pioneer species which have established themselves after the treee fall. March, 1987.

27. The Ecology of *Maesopsis* Invasion and Dynamics of the Evergreen Forest of the East Usambaras, and their Implications for Forest Conservation and Forestry Practices

by Pierre Binggeli

Maesopsis eminii is an introduced tree spreading rapidly in the East Usambara forests. Studies have been made of various stages of its life cycle, especially in relation to its reaction to the formation of gaps in the forest canopy created by tree-falls. Particular aspects investigated were the reproductive biology of _Maesopsis_, gap formation and the distribution of plant species in gaps, and the ecological causes and consequences of the _Maesopsis_ invasion of the forest. It is concluded that _Maesopsis_ could eventually (in 200 years) form a sizeable (perhaps 50%) proportion of the forest canopy, even in unlogged forest. The tree is a threat to the survival of indigenous endemic and near-endemic species and it should be controlled. The effects of _Maesopsis_ in the forest at Kwamkoro, where it was planted in the 1960's and 1970's, is assessed and suggestions are made for the future management of that reserve.

1. *Maesopsis eminii* Engl.

1.1. Vernacular names

Muhumula, Muhumulla (Haya), Msira, Musira, Massira (Kerewe), Msira (Zinsa), Muzizi (Swahili), Musizi (t.n., Luganda), Muguruka (Ki), Muhongera (Lunyoro), Owamdua (=hornbill-tree), Eyamudua (Ashanti), Gotrobo (Ewe), Kwaese (Wassaw), Ndunga.

Sources: Hamilton (1981), Storrs (1979), Taylor (1960) and Watkins (1960).

1.2 Natural range and introductions

Maesopsis is abundant in Uganda and Zaire, occurs in north-west Tanzania, Zambia, Kenya and Angola, and spreads across West Africa to Liberia. In West Africa it is distinguished as subsp. *berchemoides* (Pierre) N. Hallé (Hallé 1962). It has been introduced and is now naturalized in the East Usambaras. It is cultivated in Sumatra, Java and Borneo as an agroforestry tree and was planted in India as a shade tree in coffee plantations (Yap & Wong 1983). Attempts to grow it on Hawaii as a crop tree have been made without success (Whitesell & Walters 1976).

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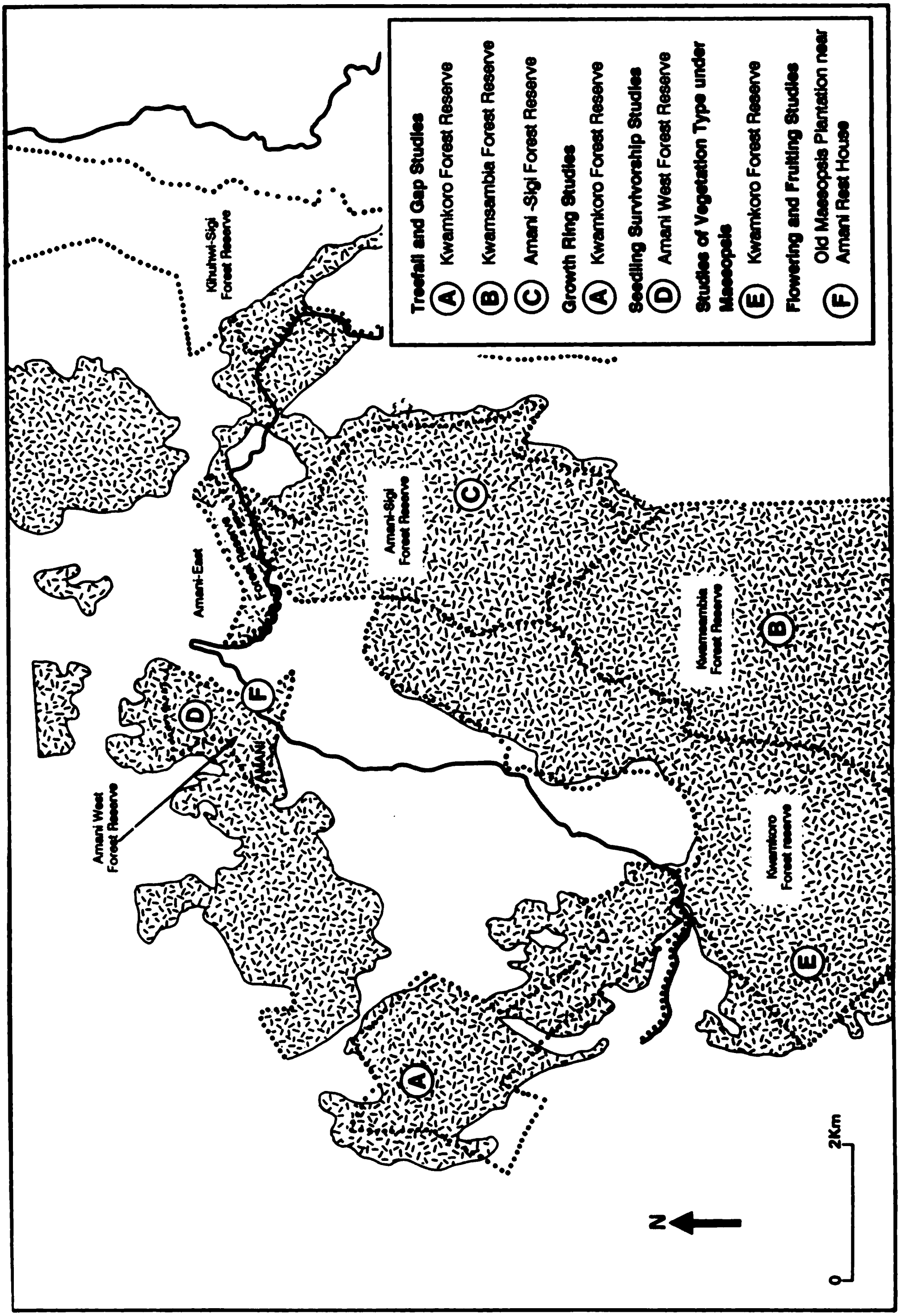

Figure 27.1 Location of sites used in the study of Maesopsis and forest dynamics.

1.3 Botanical description

For a traditional taxonomic description readers are referred to Johnston (1972).

1.3.1 Tree architecture

Maesopsis is a large tree reaching up to 43 m high and a diameter at breast height (DBH) of 100 cm. The trunk is not buttressed, but is cylindrical and straight, free from branches for 10 to 20 m. On young trees the branches are at 45° and on older specimens the branches bend to almost horizontal and curve up away from the trunk. Young trees have a flattened top where the leader is generally at a lower level than the surrounding branches.

The tree is a monkey's nightmare, as it is self-pruning. Branches up to 5 cm at the base die, dry and are naturally shed or broken away by external agencies such as animals, wind and climbers (Kingston 1974). At Amani numerous side branches die during the dry season and are shed during the first storm at the start of the rainy season. When mature, trees lose almost completely their ability to shed branches and they produce a spreading and rounded crown. The number of branch bifurcations is very low and was never observed to be greater than 6 on any specimen. This unusual feature for a dicotyledonous tree species arises because of the self-pruning habit.

The first four leaves of all branches are alternate, then they become subopposite or occasionally opposite. New branches and inflorescences are borne at the base of the leaves and grow slightly upwards and forward at roughly 45°. The process initiating twig or inflorescence formation is not known but during the flowering season an inflorescence is produced at the base of each leaf, with the exception of every third to tenth leaf where a twig is produced instead.

The leaves have a petiole c. 1 cm long and are 9 cm long by 2.75 cm wide. The apex is acuminate and the leaf margins have prominent, fairly widely spaced blunt teeth. Leaves may be shed completely where the dry season is particularly severe, but this is not the case at Amani and Kwamkoro.

1.3.2 Reproductive organs

Flowers are small, yellow-green and are in small axillary cymes up to 5 cm long. The flowers are perfect and have 5 united sepals and 5 small hooded petals, which almost completely cover one stamen each. The ovary is superior and unilocular. Only 1, 2 or rarely 3–5 fruits set per inflorescence. The fruit is ovoid, with one end tapering, and measures 2 to 3 cm in length. It consists of a soft fleshy exocarp surrounding a hard mesocarp and an endocarp. The embryo is enclosed by a thin brown testa. The fruit as it matures turns from green to yellow and finally to purple.

1.3.3 Seedling

Seed germination is epigeal; the slender hypocotyl is about 6 cm long. The cotyledons are thick and do not develop; they are green at first, but later become black and shrivel. The first pair of leaves are borne about 7 cm above the cotyledons and are opposite, while the succeeding leaves are alternate.

1.3.4 Wood: properties, growth and uses

The wood is soft but firm and strong (see Ananthanarayana & Jain 1982 for details) and is used in general carpentry and joinery and for internal building purposes. It is not resistant to fungal decay and termites, but is permeable to preservatives.

The tree plays an important part in the timber economy of the local inhabitants of Bukoba District in north-eastern Tanzania (Watkins 1960) and is widely used all over Central and West Africa (Taylor 1960). In the East Usambaras *Maesopsis* timber is not widely used, probably because better known native hardwoods are still available. The wood is used for cooking, for which branches or poles up to 6 to 10 cm in diameter are preferred. It is not used for charcoal production (in any case it is not a suitable species for charcoal, giving very poor results).

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Maesopsis under full light and high soil moisture can grow up to 3 m a year. The subject has been reviewed by Mugasha (1980, 1981) and will not be dealt with further here.

1.4 Pests and diseases

Browne (1968) has reviewed the subject and found the following pests and diseases of *Maesopsis*:

Seedlings: The aphid *Aulacorthum solani* Kaltenbach infests seedlings in Uganda and Kenya, whereas *Toxoptera citricidus* Kirkaldy is an occasional pest which occurs in Tanzania. The Egyptian cotton-worm *Prodenia littoralis* Boisduval occurs in Tanzania and is a serious pest in Uganda tree nurseries. The fungus *Meliola maesopsidis* Hansf. occurs at Amani and affects shaded seedlings.

Leaves: The larvae of *Charaxes achaemones* Felder and *Rhodogastria atrivena* Hampson are considered as severe potential defoliators in Uganda. Those of *Streblote aculeata* Walker in Kenya, *Drepanoptera albida* Druce, *D. vacuna* Westwood and *Pachypasa subfascia* Walker in Uganda can occasionally be a problem. The larvae of *Eagris decastigma* Mabilla, *Odontogama nigricans* Aurivilliers, *Polyptichus pygarga* Karsh and *Sacada prasinalis* Hampson cause some defoliation in Uganda.

Bark, wood and roots: The larvae of the coleoptera *Monochamus centralis* Duvivier in Uganda and *M. scabiosus* Quedenfeldt in Zaire make shallow galleries and expose the sapwood which leads to stem breakage. The termite *Macrotermes natalensis* Haviland kills young trees and severely damages large ones in Uganda. The fungus *Nectria haematococca* Berk. & Br. causes cankers on the bark and is a severe cause of damage in Uganda (Ofong 1974); it is present in parts of Tanzania.

Seeds: The coleopteran *Araecerus fasciculata* Deg. is commonly found damaging stored seeds (Mugasha 1981).

As Mugasha (1981) points out, the pests and diseases of *Maesopsis* are mild or absent in Tanzania, but reports from Uganda show that the species is potentially liable to severe damage.

1.5 Frost resistance

Siebenlist (1914) reported that in August at an altitude of 1,875 m in the West Usambaras at a temperature below freezing seedlings (one hand high) froze, but survived. Towards mid-September new shoots were produced at the axils of the 'thick and meaty' cotyledons.

2. Reproductive biology of *Maesopsis eminii*.

In order to understand the ecological status of any tree species and its role in forest dynamics, and also for its proper use in forestry, the basic life-history characteristics have to be known. It is the aim of the present section to supply some of this information for *Maesopsis eminii*, using a few simple experiments and observations carried out at Amani in the East Usambaras during the early part of 1987 and data available from the literature.

2.1 Flowering and fruiting

2.1.1 Introduction

Maesopsis produces small yellowish-green flowers, morphologically hermaphrodite, borne on axillary cymes up to 5 cm long. At an early stage fruits are green and after reaching their full size (2–3 cm) they first turn yellow and then purple.

In forestry *Maesopsis* starts to flower 4 to 6 years after planting under favourable conditions (Yap & Wong 1983), but trees arising from natural regeneration were first seen to have fruits at the age of 10 years in Uganda (Karani 1968). The first crop of fruits does not seem to contain fertile seeds, as most of them drop prematurely whilst they are still green.

Several conflicting reports on the phenology of flowering and fruiting have been published both from natural populations and from plantations. Karani (1968) in Uganda noticed a long flowering period

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which starts at about the end of December and can in some areas last until the first week of June. Flowering and fruiting were found to overlap, and by the end of March young fruits were already formed. Although some ripe fruits were seen in April and May, it was not until June and July that ripe fruits were plentiful. In the Entebbe area, black fruits started falling about the third week of April and continued to do so until the second week of December. There seemed to be a second flowering as some green fruits were observed in mid-December. He observed no differences in the mode of flowering between low and high altitude trees.

In Ghana trees are bare from January to mid-April and flowering starts with the first flush of new leaves at the start of the rainy season and lasts until July. Fruits ripen in November and December (Taylor 1960). On the other hand, in Zambia Storrs (1979) has observed flowers during the dry seasons, i.e. in January, February and September, but he believes that flowering in Zambia occurs also at other times.

Outside its natural range, in India, two flowering periods occur in February – March and August – September, and ripe fruits can be collected two months later (Yap & Wong 1983). In Tanzania, at Lushoto, Amani and Kwamkoro, Mugasha (1981) states that there are two flowering periods (March to April and November) and two fruiting seasons (June to July and January) per year. He concludes that flowering takes place during the rainy seasons, while fruit maturing is independent of rainfall.

Phenological data from Kwamkoro collected over 4 years indicate that seeds fall from June to September and that some trees also produce ripe fruits in December (Shoo pers. comm.). Moreau (1935) noted that *Maesopsis* provided abundant fruit for only six weeks of the year. Parry (1953) noted that fruits ripened in August at Amani. Fruit collection for sowing is done from July to October (Wanyancha 1977), also suggesting a main flowering and fruiting period during the first half of the year.

Towards the end of January 1987 profuse flowering was observed on all large trees in the Amani and Kwamkoro area and the following observations were made to obtain estimates of flower production, fertilisation, fruit production and abortion.

2.1.2 Methods

Because of the self-pruning habit of *Maesopsis*, only two leaning mature individuals had low enough branches to carry out quantitative recordings. The trees were situated in the German plantation originally planted in 1913 near the Amani Rest House (Fig. 27.1, site F). On each tree five branchlets were tagged and a weekly count of flower buds, flowers and fruits on each inflorescence was obtained. Because of the small size of the flowers it was not possible to record them individually and the flowering intensity was estimated as the number of flower buds disappearing per week. It is a slight overestimate as some buds never reach anthesis, but instead abort; however it is believed to be a reliable measure of flowering and its intensity did not seem to vary throughout the whole flowering period.

2.1.3 Results and discussion

Flowering: Peak flowering time occurred on both trees during the first week of February and decreased steadily to stop by mid-March on tree 1 and it was then very light on tree 2 (Table 27.1).

Table 27.1 Flowering intensity on two trees at Amani, expressed as number of flower buds disappearing per week.

Period starting on the (day/month/1987)	2/2	11/2	19/2	24/2	3/3	10/3	17/3	22/3
tree 1	269	265	131	114	86	40	7	1
tree 2	381	301	174	126	93	42	16	52

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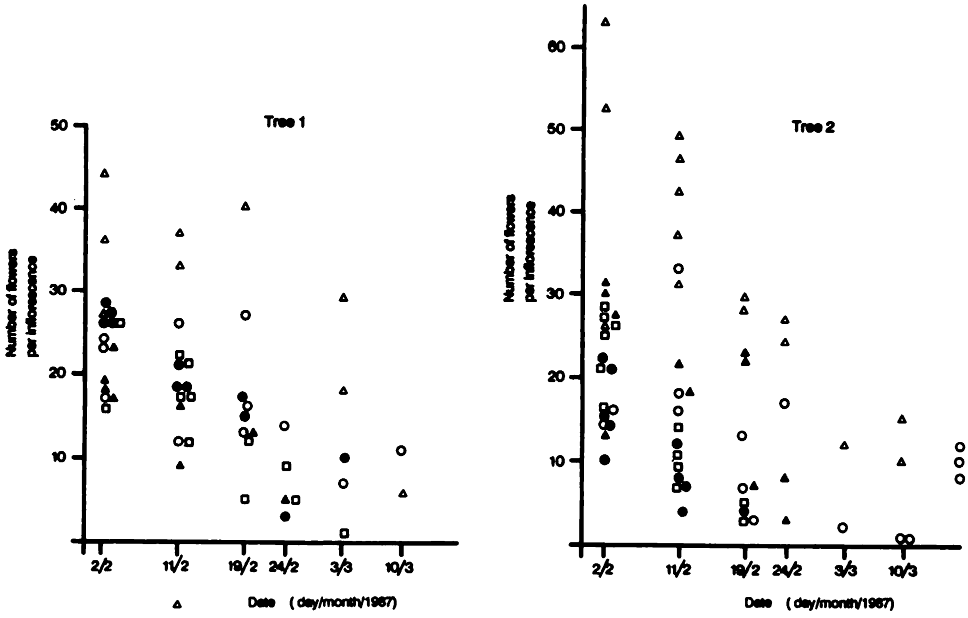

Figure 27.2 Number of flower buds per inflorescence on two Maesopsis trees, initiated at different times. The various symbols refer to different branchlets.

Table 27.2 Fruit set on two trees at Amani.

Period starting on the (day/month/1987)	26/1*	26/1	2/2	11/2	19/2	24/2	3/3	10/3	17/3
tree 1	2	13	20	5	4	1	5	1	1
tree 2	4	21	8	6	1	2	3	0	0

**Already present at the start of the period of observation.*

Table 27.3 Fruit abortion of Maesopsis at Amani.

	Fruits set before 2/2/87			Fruits set after 2/2/87		
	fruits	number of aborted fruits	%	fruits	number of aborted fruits	%
tree 1	32	10	31.2	18	8	44.4
tree 2	24	10	41.7	20	11	55.0

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It was estimated that the initiation of the first inflorescences occurred in December and that flowering started in early January. Inflorescences are initiated at the same time as vegetative growth and the size of the inflorescence decreased with the time of initiation (Fig. 27.2). The number of flower buds per inflorescence varied from 1 to a maximum of 78. High number of buds (30) per inflorescence only occurred on the main axis of the branch.

Sex expression and gender: Hallé (1962) thought that the flowers of *Maesopsis* are protogynous, an unusual character for the Rhamnaceae which are reported to be protandrous (Johnson 1972). Only 2 to 3.5% of the flowers set fruits and the functional status of the remaining flowers is unclear; an estimate of gender can therefore not be given.

Pollination: Mugasha (1981) suggested that *Maesopsis* is insect pollinated because of its flower structure. Although most Rhamnaceae have a thin extrastaminal disk and often fragrant flowers (Johnson 1972), the former character has never been recorded in floras and the latter is not a noticeable feature of the flowers at Amani. Furthermore at no time during the study have any insects been observed on or near the flowers during the days. No observations were carried out at night, dawn or dusk. The flowers were also very dry and only a few of them were embedded in a yellowish liquid.

Herbivory: On both trees very low levels of herbivory were observed and altogether only 17 buds or flowers out of 2,029 buds had been grazed. A small green caterpillar with a black dorsal line was recorded on an inflorescence and it was believed to be responsible for this herbivory and the white threads repeatedly produced on some inflorescences.

Fruit production: Some fruits had already set by the time the observations started and the data for January are an underestimate since some fruits must have been aborted prior to recording. However Table 27.2 shows that the peak for fruit set was during the last week of January and the first week of February, which coincides with the peak in flowering. Only 1 to 3 flowers, and occasionally 4 or 5, set fruit per inflorescence. A total of only 3.4% of the flower buds of tree 1 produced fruits and only 2% on tree 2, with a variation between branchlets from 0.6 to 6.8%. 42% and 30% of the inflorescences produced fruits on trees 1 and 2 respectively.

Fruit abortion: On the 22nd March fruit abortion was high reaching 36.0% on tree 1 and 47.7% on tree 2 (Table 27.3). Fruits set before the 2nd February had a higher abortion rate than those produced after that date.

Fruit predation: During February and March green fruits are taken by small mammals, probably squirrels. At this stage in the development of the fruit the mesocarp is still either soft or thin, and rodents seek the fleshy mesocarp, as observed from the discarded fruits on the ground.

A lepidopteran larva may attack seeds prior to ripening. Leuchars (1957) observed them in Entebbe and, although the damage was not extensive, he considered it as a potential danger to future forest seed supplies.

The blue monkey *Cercopithecus mitis* Wolff eats the exocarp of yellow fruits in great quantities and discards the stone and its seed.

Fruit losses: Two agents may cause minor losses to the fruit crop. Firstly during windy days, particularly before rains, *Maesopsis* sways a lot and mechanical friction of the spreading branches detaches the unripe fruit and produces a shower of green fruits under mature trees. Secondly monkeys, especially the black and white colobus, break off fruits when jumping from tree to tree.

Fruit dispersal: Hornbills occur in the Amani region in great numbers during July and August, and are believed to be the main dispersers of *Maesopsis* fruits (Moreau 1935, 1936; Moreau & Moreau 1941). In Ghana another bird, the plantain eater, also disperses the fruits (Taylor 1960). Just 20 years after the introduction of the species to Amani, Moreau (1935) observed that "*Bycanistes cristatus* (= *B. brevis*) swallow the fruit of *Maesopsis* and the tree is being disseminated over a radius of several miles from Amani by the birds. Actually, although the plantation is a small one it apparently provides

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ample food for about 50 of the great hornbills for 6 weeks in the year." The common occurrence of seedlings far away from the seed parents in the natural forest of Amani-Sigi indicates that dispersal is very efficient and occurs rather evenly throughout the natural forest. Still, a great quantity of fruits fall below the parent trees. Taylor (1960) made similar observations in Ghana.

Two species of hornbills, the Trumpeter *Bycanistes bucinator* and the Silver-Cheeked *B. brevis*, occur in the East Usambara region (Rodgers & Homewood 1982), but little is known of their differences in behaviour and ecological requirements. According to Stuart (1983) the Silver-cheeked Hornbill does not occur below 600 m whereas the Trumpeter Hornbill is very common in the lowlands and rare in submontane forest. *Bycanistes brevis* is much larger (female weight 1,057 g) than *B. bucinator* (male weight 941 g; female 667 g) (Moreau 1944) and the small size of the latter may affect its feeding and dispersal abilities, and might consequently be the cause of the low occurrence of *Maesopsis* in the lowland forest. It was observed that the dry season (January – March) resident hornbill population was low and it is likely that some of the birds come to the East Usambaras during the *Maesopsis* fruiting season in about August from other mountains to feed. They are likely to disperse the species to other Eastern Arc mountains and there natural forests will be invaded just as the East Usambaras have been and still are being invaded.

The fruit bat (*Eidolon helvum*) is very common in the East Usambaras and is known to be able to carry large fruits (Osmaston 1965) and is a potential disperser of *Maesopsis*.

Leaf fall: Two or three weeks after fruit set the accompanying leaf was shed. At the end of the dry season branches on most trees were almost completely bare, with leaves confined to the ends of the branches and branchlets, where flowering was still taking place. It is an unusual feature for a tree to drop its leaves when there is a heavy demand on resources for fruit production. However it has been found that fruits of some temperate zone trees photosynthesize up to 65% of their energetic and carbon requirements, such as in the Norway maple (Bazzaz *et al.* 1979).

Conclusion: This study has shown that, contrary to the opinion of Mugasha (1981), flowering takes place in January and February during the dry season. Secondly, very few flowers set fruit, a common feature of the Rhamnaceae, also found in *Scutia myrtina* (Burm. f.) Kunz and *Ziziphus pubescens* Oliv. (Johnston 1972). By March abortions reach up to 50% of fruit set, but the causes were not found. Further work is clearly necessary to determine the sex expression of individual flowers and inflorescences. The causes of fruit abortions and an estimate of the functional gender of individual trees should also be obtained.

2.2 Seed biology

Few observations were made and information has been obtained almost solely from the literature.

2.2.1 Seed weight and storage

In Uganda a collection of seeds gave an average of 593 seeds per kilogramme (fruits minus exocarp), ranging from 518 seeds kg^{-1} (collected 7 – 10 August) to 783 seeds kg^{-1} (collected 16 – 21 July) (Leuchars 1957). At Amani Wanyancha (1977) found from 550 to 1,000 seeds kg^{-1} with the exocarp removed.

Seeds may be stored for 5 months (Watkins 1960), but the success of storage depends on the seed source. Even when stored at low temperature seeds lose their viability quickly after 3 months to reach only 10% after half a year (Yap 1983).

2.2.2 Seed germination

In Uganda the germination of seeds in forest soil in boxes started 33 to 65 days from sowing and was completed within 79 to 179 days (Leuchars 1957). Watkins (1960) gives a similar germination period of 5 to 12 weeks with a peak between 7 and 9 weeks. Table 27.4 shows that germination of unripe fruits is nil whereas it varies from 28% to 92% for fleshy fruits and is about 45% in some old fallen fruits.

Table 27.4 Percentage germination of fruits at different phenological stages.
Sources: a. Yap & Wong (1983) from India; b. Leuchars (1957) from Uganda.

	old fallen fruit	naked fruit in June	freshly fallen fruits		fruits collected from tree		
			immature	ripe	immature	ripe	July
	a	b	a	a	a	a	b
% germination	45.0	28.0	0	50.5	0	57.2	<92.0
% moisture content	13.4		27.6	16.7	47.0	13.7	

Germination is much more likely if the seeds are buried in the soil or immersed in thick damp leaf litter rather than lying on the soil surface, exposed to greater dessication. At Amani the germination of 120 old fallen fruits, collected on the ground in Amani West Forest Reserve in mid-February and buried in the soil (3 cm deep) had reached 52% by the 22nd March, whereas only 5% of 120 fruits laid on the ground had germinated. Both plots had been irregularly watered. Even after heavy rains during April and May, very few of the seeds lying on the surface of the soil had germinated, probably because intermittent heavy showers do not produce a sufficiently continuous moist environment.

2.3 Survivorship, growth and causes of death of *Maesopsis* seedlings under contrasting environments

2.3.1 Introduction

When seed production is not limiting, seedling survivorship is the key stage in the life history of tree species, because in most years all recruitment will die within 12 months. In January 1987 *Maesopsis* seedlings (<1 year old) were observed in large numbers on the forest floor in Amani West Forest Reserve, reaching up to 805 individuals per square metre, whereas saplings (>1 year old) were very much rarer and confined to gaps. *Maesopsis* is known to require plenty of light and damp conditions to thrive (Mugasha 1981). An experiment was set up to investigate seedling growth and mortality under different light and water regimes. Because of its basic ecological requirements, it was hypothesized that under shade *Maesopsis* seedlings would have low survivorship and in the open the lack of water would cause high mortality.

2.3.2 Materials and methods

Near Forest House No. 1 of the Medical Research Centre in Amani West Forest Reserve (Fig. 27.1 site D), where unlignified *Maesopsis* seedlings are numerous, three sites with different light levels were selected as follows:

Site D1: Shade – Mature forest with a high proportion of large *Maesopsis* in the canopy and low light intensity below. The soil was organic and littered with leaves, twigs and small branches.

Site D2: Gap – Low shade was cast over most of the old gap by the crown of a large *Maesopsis*. Situated on the site of a fallen crown, the organic content was high and the plots were covered with leaves.

Site D3: Open – In an orchard at the edge of the forest with humus-poor soil. Some grass was present and the ground had a light carpet of leaves.

At each site, two plots were demarcated, one of which (the 'Wet Plot') was watered regularly until the onset of the rainy season (15 litres of water every 3–5 days). The plots were divided into squares

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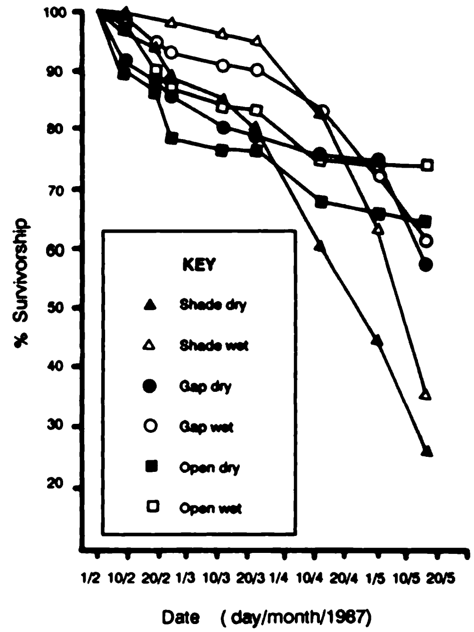

Figure 27.3 Survivorship of Maesopsis seedlings at three sites near Amani, with one wet and one dry plot at each site.

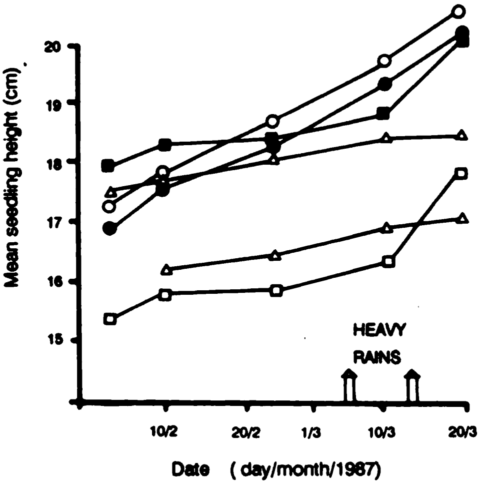

Figure 27.4 Mean height in centimetres of Maesopsis seedlings at three sites near Amani, with one wet and one dry plot at each site.

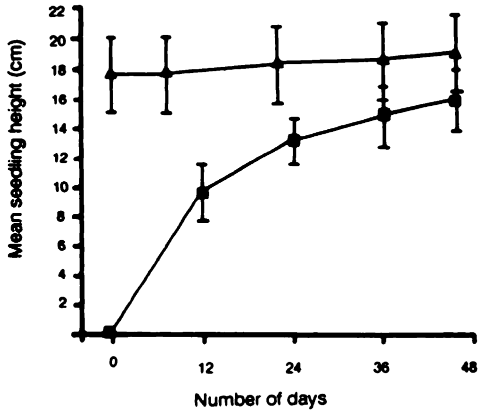

Figure 27.5 Height (mean and standard deviation) of Maesopsis seedlings at the Dry Shade site.

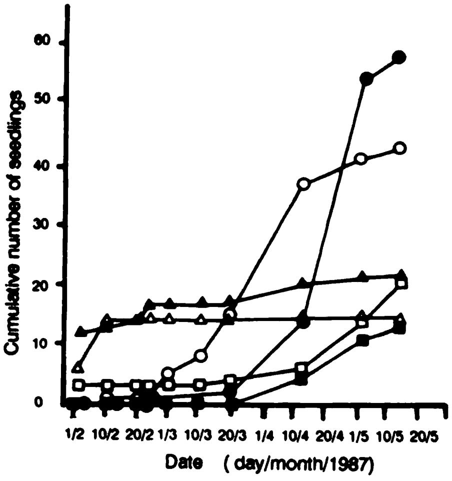

Figure 27.6 Cumulative germination of Maesopsis seedlings at three sites near Amani, with one wet and one dry plot at each site.

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(10 x 10 cm) so that individual seedlings could be relocated. They contained between 70 and 102 seedlings at the start of the experiment. Seedling mortality and recruitment was recorded weekly and growth every two weeks until April and three more times until mid-May. Seedling height was measured to the nearest half-centimetre.

2.3.3 Results

Seedling survivorship was high on all sites after 47 days, ranging from 77.5% to 90% (Fig. 27.3). Up to mid-March survivorship was lowest in the Open and highest in the Shade and at all sites seedlings from the Wet Plot suffered lower mortality. With the onset of the rainy season in April, survivorship in the Shade dropped quickly to reach only 27% in the Dry and 35% in the Wet plots by mid-May. In the Gap survivorship decreased steadily, whereas in the Open very few deaths were recorded even by the end of the period of observation.

Seedling height increased little in all the plots but particularly so in the Shade and in the Open; however in the latter site growth increased rapidly soon after the start of the rains (Fig. 27.4). In the Gap site, where both light and soil moisture were available, growth rates were somewhat higher and more steady.

Fig. 27.5 shows seedling height was 9.2 ± 1.9 cm twelve days after germination and 13 ± 1.8 cm after 24 days. Thereafter, growth slowed down and almost ceased as the food reserves in the cotyledons became exhausted.

Seed germination in the Shade was still taking place at the start of the observation, but ceased by mid-February. In the Gap germination was observed by early March in the Wet plot and by the end of March in the Dry plot and was levelling off by the end of May. In the Open seed germination only started in April and was still taking place by mid-May (Fig. 27.6).

Seedlings suffered no damage from grazing and only a little from branch falls prior to seedling lignification. Damage from branch-fall was greatest in the shade, where litter was more abundant and rooting not fully satisfactory. On the 22nd March, soon after the rains started, only seedlings in the Open had lignified.

A great number of the seedlings suffered from black spots, believed to be *Meliola maesopsidis* Hansf. which Browne (1968) describes as "black patches of mildew on the leaves of *Maesopsis eminii* ". The black patches, when few on a leaf, led to the appearance of holes in the leaf tissue and, when numerous, resulted in eventual shedding of the leaf. Seedlings failing to produce new leaves would ultimately die from this disease. The fungus was observed to be more common under water stress than under watered conditions and seedling death from this cause was thus higher where growth was minimum. On all plots the average height of seedlings at the time of death was 2 to 4 cm below that of the average height of the population.

Although growth did not increase under watered conditions, seedlings looked healthier than in the Dry Plots, where they were drooping their leaves, though the latter recovered quickly after the rare light shower. Nevertheless in the Open the amount of water supplied to the Wet Plot was inadequate to prevent a rate of seedling mortality nearly as high as that in the Dry Plot.

2.3.4 Discussion

Contrary to the hypothesis (see Section 2.3.1), survivorship was highest under the Shade, lowest in the Open and no mass death was observed during the dry season. During the rainy season the pattern changed; instead, high mortality was observed in the Shade and high survivorship in the Open. Watering at the three sites slightly increased survivorship; seedlings looked stronger and it seemed to induce seed germination in the Gap. The onset of the rains triggered seed germination in the Gap and in the Open, with a small delay in the latter site.

Nightingale and Steele (1963) recommended that under nursery practice seedlings should be kept under shade for 2–3 weeks and that thereafter shade should be gradually reduced. During the dry

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season canopy trees grow little and loose a large quantity of their leaves, somewhat increasing the amount of light reaching the ground. With the advent of the rainy season and of the new flush of growth, light levels will drop and seedlings will die in the shade. Nevertheless the ability of seedlings to survive low light intensity for a few months and also the delayed germination of some of the profuse seed crop allows the species to fill gaps whenever they are produced. Linked with its very fast growth under full light conditions and plenty of water, *Maesopsis* will be extremely competitive in comparison with other species in gaps.

Seedlings of *Maesopsis* at Amani do not suffer from grazing and have been observed to be unpalatable to goats. However, bush bucks (*Tragelaphus scriptus* Pallas) caused serious damage to saplings at Kwamkoro in 1965 and 1966 three months after planting (Anon. 1966). Browne (1968) reports several aphids and larval pests of *Maesopsis* seedlings, none of them seemingly present at Amani. Indeed the only disease of *Maesopsis* seedlings seen at Amani is the fungus *Meliola maesopsidis*, which reduces seedling performance and survival under conditions of stress. The fungus is locally common in Nigeria, where it is considered to be of little importance as a pest (Brown 1968).

Competition with other plants was not examined, but it is known that *Maesopsis* seedlings and saplings are intolerant of competition (Mugasha 1981). They can for example be swamped by climbers, which not only block out light but which can also break branches and stems through their weight.

3. Treefalls, gaps and niche partitioning and their impact on forest dynamics

3.1 Introduction

Tropical forests are dynamic systems which, to a large extent, are regulated by disturbance (Pickett & White 1985). Disturbances can be caused by various 'external' agents such as hurricanes, wind, fire and landslides, varying in intensity from region to region. In most cases disturbance is caused by treefalls, either due to uprooting or stem breakage, and as a consequence gaps are produced in the forest canopy. A gap has been defined as a vertical hole in the forest vegetation, extending through all levels of vegetation to within an average of 2 m from the ground at the time of its formation. Gap formation, forest regeneration and forest maturation are nowadays believed to be essential processes in tropical forest dynamics (e.g. Brockaw 1985, Hartshorn 1980, Pickett 1983). Within a gap various species with different niche requirements will become established and will compete with suppressed saplings and regeneration from broken trees until one or a few survivors fill the gap. The establishment and growth of saplings will depend on numerous factors (e.g. seed production, dispersal and viability, light, humidity, soil substrate, herbaceous competition etc.) but rarely have any of them been quantified and differences observed, which has led some biologists (e.g. Ricklefs 1977) to wonder why there are so many different tree species in tropical forests.

Although research on forest dynamics was urged by Phillipps and Shoo (1976) in the Amani-Longuza region, no work in this field has ever been carried out in the East Usambaras. More recently, some European forest advisers have failed to consider understanding the natural processes leading to the establishment and growth of desirable tree species, before drawing management plans for the natural forests. It is vital that forest ecology be recognised as central to modern forestry. To remedy slightly the ignorance of forest ecology, data were gathered during a short research period, in order to obtain a preliminary picture of gap formation and niche partitioning. Recent forestry practices, recent climatic changes, the future of the natural forest, the potential recovery of degraded forests and recommendations for further research are then discussed in the light of these results.

3.2 Site descriptions and methods

The work was carried out at three sites (Fig. 27.1, sites A – C):

Site A: Kwamkoro Forest Reserve. A large degraded natural forest at an altitude of 1,050 m. The site is north-east facing, gently-sloping near a small river.

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Site B: Kwamsambia Forest Reserve. A natural forest at 920–980 m altitude, situated on a north-west facing steep slope (near the site of the three submontane forest profile diagrams described in Chapter 25).

Site C: Amani-Sigi Forest Reserve. The site spread over several hectares of natural forest on the north-west side of the mountain at altitudes between 900 and 1,050 m above sea level.

At Kwamsambia all treefalls were recorded where the angle of fall could be determined and where the nature of the tree fall (stem broken/uprooted) could be seen. Dead standing trees were also recorded.

At Amani-Sigi tree falls were recorded during a walk up a slope. The orientation of the slope and of the fallen trees was recorded and slope steepness was estimated. DBH of logs was measured or estimated when too rotten.

At Kwamkoro, at a site where very heavy, apparently natural, disturbance had occurred over the past 50 years, all treefalls and standing trees (15 cm DBH) were located and mapped over an area of 63 x 80 m. The site was chosen because of its very heavy disturbance, because it was possible to locate a great number of treefalls and because old gaps could be aged with reasonable accuracy. Pit-sawing took place in the general vicinity in 1978, 1969 and possibly earlier, but apart from one small area there was no evidence of past human interference in the plot.

At Kwamkoro, old treefalls were identified using indirect evidence. These included a combination of the following clues: stilt roots, small organic ridges which accumulated from decayed logs, indicator species of old gaps (e.g. *Dracaena*) and *Maesopsis* alignments. These clues were found to be reliable evidence of old treefalls. Several gaps were carefully observed, with mapping of the locations of common species so as to determine in which parts of the gaps they tend to become established. This provides a rough idea of some of their niche requirements.

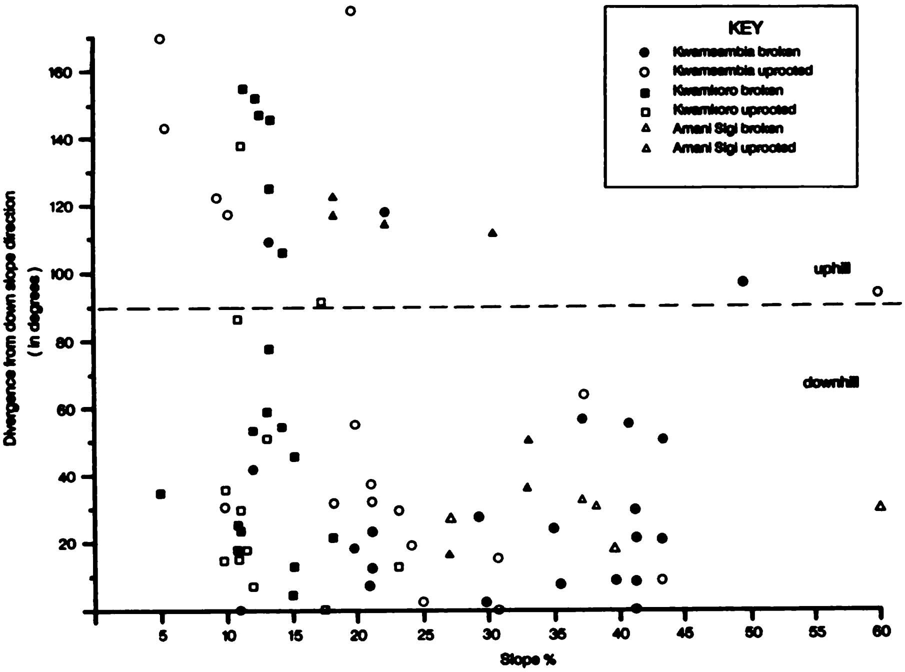

Figure 27.7 Angle of slope and direction of treefalls in submontane forest. The direction of fall is given in deviation from the down slope.

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3.3 Results

Figure 27.7 shows that most trees fall downhill and, as the steepness of the slope increases above 20 to 25% the number of trees falling uphill becomes very low. Most of these individuals falling uphill were growing in clumps of big trees and were therefore leaning that way. As slope steepness increases, tree crowns become asymmetrical and grow much bigger downhill because of reduced canopy competition and greater light. During the rainy season, when the new flush of growth occurs and the crowns are heavier, the centre of gravity is pushed further downhill and the tree may fall. Gusts of wind will of course increase the likelihood of a fall, but in the East Usambaras big storms very rarely occur and are probably not responsible for large disturbances, as they are in other parts of the world. With the exception of flat ridges the forest terrain is dominated by hill-slopes. This feature means that disturbance will almost always be directional, tending to occur in vertical bands, which in the case of multiple treefalls, could involve the whole hillside (100 – 150 m). The forest structure will often consist of bands of trees of similar ages.

The number of trees dying in situ is low (6.9%) and most deaths occur as treefalls (Table 27.5). Trunk breakages (52%) are more common than up-rooted trees (35%). There is some variation between the three sampling sites. At Amani-Sigi there are fewer treefalls but more dead standing trees and branch falls than at the other two sites. This might be related to the fact that Amani-Sigi is also far less disturbed than Kwamsambia and Kwamkoro. Large disturbances are uncommon, not just because of the rarity of storms, but because there is a relative scarcity of large lianes.

Table 27.5 Types of deaths and of treefalls in the natural forest. Note that trees may belong to more than one category and therefore the vertical columns do not necessarily add up to the totals below.

	Kwamkoro		Kwamsambia		Amani-Sigi		Total	
	no.	%	no.	%	no.	%	no.	%
Trunk breakage	20	51.3	25	59.5	6	35.3	52	55.1
Uprooting	13	33.3	16	38.1	6	35.3	35	35.3
Died standing	5	12.8	0	0	2	11.8	7	7.1
Branch fall	3	7.7	1	2.4	3	17.6	7	7.1
Total no. of trees	39		42		17		98	

The pattern of treefalls in the very disturbed area of Kwamkoro Forest Reserve is shown in Fig. 27.8. When compared to the degree of rottenness of a 9-year old cut tree, all fallen logs seemed to be older. The completely rotten logs were the remains of treefalls estimated to be at least 50 years old. By examination of the forest structure and of rotten branches it was estimated that about 50% of the forest canopy had been destroyed by treefalls within half a century or so. It was also noticeable that some areas were repeatedly disturbed by treefalls whereas others were not. It looks as if the forest is a mosaic of very disturbed patches, where trees are regularly damaged or killed, and areas of regular growth. The consequence of this pattern will be the clumping of older trees. This particular plot had a gentle slope of 10 – 15% and treefall direction was almost random. However as the gradient increases, treefalls become unidirectional and it is likely that the distribution pattern of larger trees will be different.

The environment within gaps is very variable, helping to create conditions suitable for different species to become established. Most environmental variables are very difficult to measure, but a few, such as soil substrate related to seedling establishment, are easy to differentiate into niche groups. In gaps, niche groups can be divided into the crown debris, bare humus soil, bare mineral soil and rotting logs. In Table 27.6 the commonest species are ascribed to these niche groups. The rotting log is used

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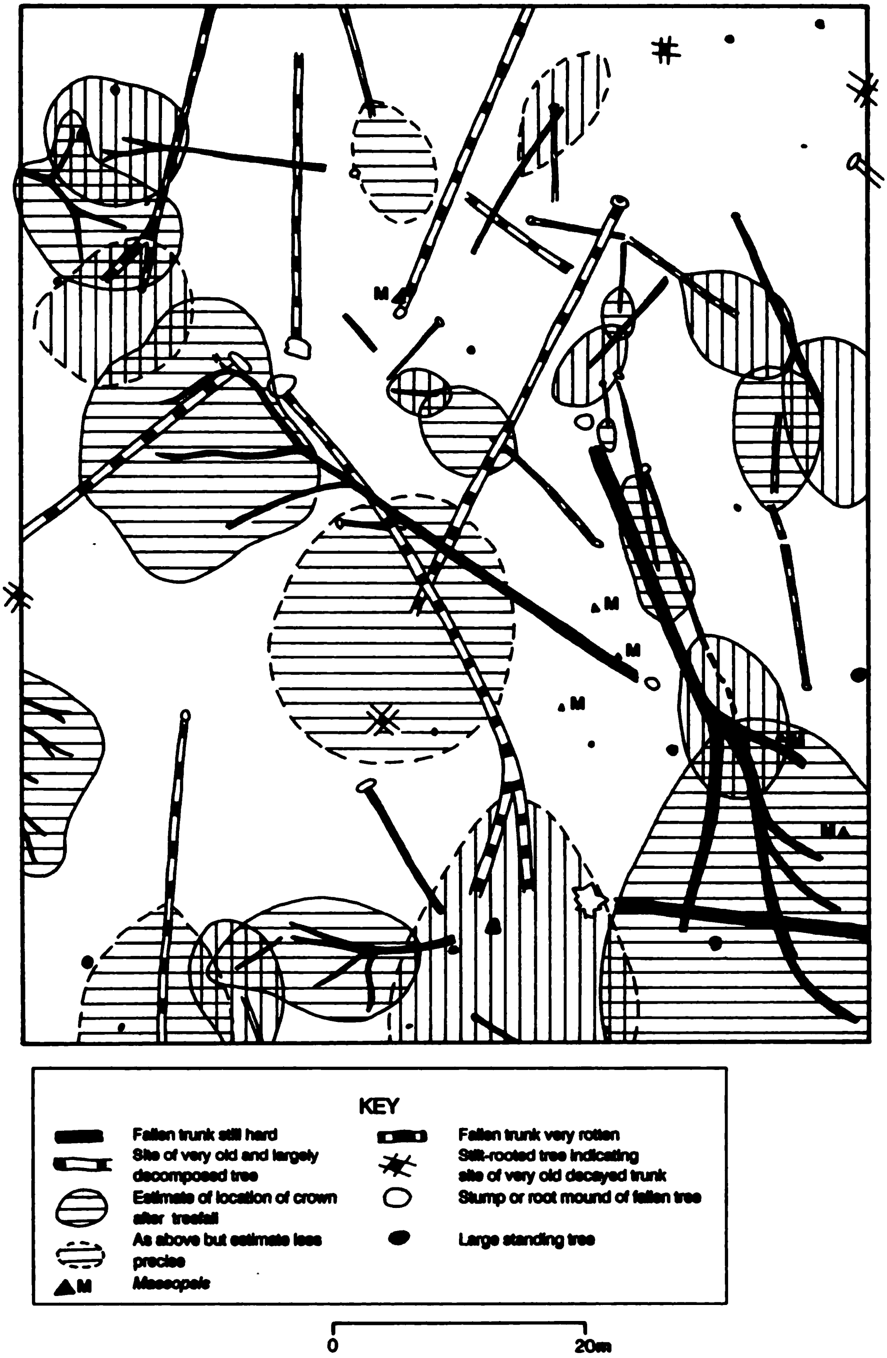

Figure 27.8 Pattern of natural treefalls in a very disturbed area of Kwamkoro Forest Reserve.

by six species, both pioneer and primary species. However the former group, including *Anthocleista*, *Polyscias* and *Myrianthus*, become established before the log has shrunk and produce stilt roots, whereas in the latter group (*Newtonia* and *Allanblackia*) seedlings will grow only when the wood is well rotted.

Anthocleista is the only species which seems to get established solely on logs whereas the others will also favour either the bare humus or the debris zone. *Trema* favours exclusively bare mineral soil and is one of only two species exploiting this niche group, the other being *Macaranga*. This is not surprising, as bare mineral soil is rather scarce in the natural forest. Some species like *Sorindeia*, *Morinda*, *Xymalos*, *Maesopsis*, *Harungana* and *Alchornea* seem to get established solely on bare humus soil, whereas most species which can grow in the debris zone will also grow in the bare humus zone. In general most species are not specific to one of the niche groups but to two (and for *Macaranga* three), suggesting that factors such as availability and dispersal pattern of seeds are more important for the establishment of particular species than soil substrate. Apart from the information shown on Table 27.6, there is a great lack of data on regeneration of primary forest trees.

Table 27.6 Establishment preferences of trees among different niche groups in gaps.
*xx = common; x = occurs; * = pioneer species.*

Species	log	mineral soil	humus soil	crown debris	regrowth from broken tree
Anthocleista gran. *	xx				
Polyscias fulva *	xx			xx	
Myrianthus holstii	xx		xx	x	x
Ficus sp.	x		x		
Newtonia buchananii	x		xx		x
Allanblackia stuhl.	x		x		
Trema orientalis *		xx			
Macaranga capensis *		x	xx	x	
Harungana madag. *			xx		
Alchornea hirtella			xx		
Maesopsis eminii *			xx	xx	
Morinda astero. *			xx		x
Sorindeia madag.			xx		x
Xymalos monospora *			xx		x
Canthium sp.*			x		
Greenwayodendron ss.			x		
Isoberlinia schef.			x		
Englerodendron usa.			xx	x	x
Mesogyne insignis			xx	x	x
Tabaernaemontana sp.*			xx	xx	
Rawsonia lucida			x	x	
Uvariodendron sp.			x	x	
Anisophyllea obtus.			x	x	
Alsodeiopsis schum.			x	xx	x

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During treefalls numerous trees of different species get broken, survive and subsequently grow again (Table 27.6), but it was not possible to assess their success in filling gaps.

3.4 Discussion

It has been shown that the dynamics of the submontane evergreen forest on the East Usambaras is determined largely by treefalls and that slope causes treefalls to become predominantly unidirectional in steep areas. Four broad categories of niches in relation to establishment of species in gaps have been described and several species have been ascribed to them, although they show some niche overlap. This research has raised numerous questions.

We still have no indications of how most of the tree species, including all the endemic and near-endemic species, regenerate and subsequently survive in the forest.

Why have so many trees died recently in so short a period of time at the site studied at Kwamkoro? Two possible explanations may be suggested:

- In Section 3.3 an area of forest is described in which most of the large trees have fallen within about 50 years, producing numerous, large, overlapping gaps and with the few remaining large trees clumped. Lundgren (1978), in a similar forest type on the nearby West Usambaras, observed the opposite; his plot had no gaps and the large trees seemed to be randomly distributed. From numerous casual observations, such stand structures seem to occur in the East Usambaras as well, and it could be suggested that patches of forest up to several hectares in size go through death-regeneration, building-up and mature phases. So the forests might not just be a mosaic of patches of forest of different ages (Whitmore 1975; Brockaw 1985), but this mosaic might itself possess a higher level of pattern. There might, for example, be waves marked by a high frequency of gap formation passing through the forest. Hubbell and Foster (1986) pointed out that the existence of the gap-disturbed regime does not imply that it is identical from one area to the next.
- On the other hand, the widespread forest instability observed might be caused by climatic change, perhaps the result of large-scale forest clearance, which has been taking place since early this century. There do seem to have been climatic changes on the East Usambaras during the last 10–25 years, quite likely related partly to forest clearance (Chapters 12–14), but many of the tree deaths at Kwamkoro do seem older than this and the question of causality is difficult to resolve. It is likely that the reproductive behaviour, growth rates and general health of canopy trees have been affected as a result of recent climatic change.

[Editors' note: Binggeli's second suggestion for the recent large number of tree falls on the East Usambaras – climatic change – receives support from observations in Mazumbai Forest, West Usambaras, where many large trees are also dying. As much as 20% of the forest is estimated to be at risk from large tree deaths (Hall 1985).]

It can be suggested that large-scale phases of death-regeneration are common features of the forest and that this phenomenon is likely to increase dramatically over the next few decades, because climatic change is affecting the upper part of the mountain range.

This widespread disturbance will undoubtedly favour the spread of pioneer species in the forest. It also means that a change in the dispersal regime may drive some endemic species to extinction. Judging by observations, the number of pioneer species seems to be greater in younger than older gaps, although this might be due not just to a more open forest, but also to a greater seed source, with the massive invasion of logged areas by pioneers. If the climate continues to become warmer, as it appears to have become recently (Chapters 13–14), then tree species at present confined to high altitudes could become 'squeezed out' as vegetation zones are shifted altitudinally upwards.

One particular aspect of the forest regeneration has been taken into consideration by foresters over the past year, following the widespread concern about the mechanised logging practices. Forestry advisers recommended that more large specimens of commercial species be left as seed producers,

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presumably to encourage natural regeneration. In the light of our near complete ignorance of the autecology of most tree species, including virtually all commercial species, and our poor understanding of forest processes, and given the observed spread of various pioneers and climbers into the logged areas leading to the creation of a typical secondary forest, it is naive to believe that these large remnant trees will produce large seed crops and that recruitment of these desirable species will take place underneath.

3.6 Future research

Further research on forest disturbance is clearly needed. Proper sampling design is also important, as the kind of stands selected may have important effects on the eventual conclusions of a study (Lorimer 1985). Lorimer suggested the use of randomly located plots of about 0.5 ha and non-destructive sampling, where all species are tallied and identified, and past disturbance assessed from external physical evidence, as was used at the Kwamkoro site. However in the East Usambaras indirect evidence for disturbance can in some areas be very difficult to observe and even in an area with clear pit and mound topography, stilt roots, pioneer alignments and indicator species of old gaps, it does take a long time to learn all the detective skills. Furthermore the skills needed in the death-regeneration, building-up and mature phases are quite different. It is therefore suggested that initially areas typifying these three phases should be sampled and skills acquired. Later random plots in the forest could be looked at to answer questions as to whether disturbances are patchy in occurrence, affecting only small areas at a time, or whether they affect large areas of the forest.

Such accurate reconstructions of disturbance history are labour-intensive and lack almost entirely a time dimension, which prevents us making reasonable estimates of forest turnover rates. To do so, randomly located permanent plots (0.5 ha) will have to be set up and surveyed at regular intervals over several decades. Such a study should take into account the possibility that trees which differ, in either size or species, may have different turnover rates. In general, forest profiles show that trees are divided into emergent and canopy trees (Chapter 25; Lundgren 1978) and it has also been observed that large treefalls destroy canopy trees but often have no effect on the larger trees, although multiple large treefalls do occur. Thus it can be suggested that emergent trees have a much longer turnover rate than canopy individuals.

4. The ecology of the *Maesopsis* invasion of the East Usambaras

4.1 Introduction

With large-scale use of transport and the desire to improve natural environments, man has over the past two centuries introduced numerous species to foreign parts. Some of these species have become successful at invading unoccupied niches or displacing local species to eventually become pests. This is a common phenomenon all over the world. Well documented instances have been reported in Europe for species such as *Acer pseudoplatanus* and *Rhododendron ponticum*. In the East Usambaras several species have established themselves including *Lantana camara*, *Maesopsis eminii*, *Millettia dura* and *Rubus rosifolius*.

Since the introduction of *Maesopsis* by the Germans around 1913 and more acutely since large scale planting in the 1960's and 70's, *Maesopsis* has spread greatly in the forests. It is highly successful in establishing itself after heavy logging. *Maesopsis* has also been invading the natural forest and many people are concerned about its potential threat to the mature forest and its endemic flora.

The aim of the present study was to investigate the following points:

- How extensive is the *Maesopsis* invasion of the natural forest?
- What biological characteristics of *Maesopsis* favour its success? This includes an attempt to describe most of its life-history characteristics.
- Which species, if any, are displaced by the invasion of *Maesopsis*? What impact does it have on the species composition and dynamics of the forest?

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- How should *Maesopsis* be managed in future to ensure that the natural forest retains its present characteristics?

4.2 Status and ecology of *Maesopsis* in its natural range

Maesopsis occurs from north-west Tanzania to Liberia and is generally described as a pioneer species (Eggeling 1947). Taylor (1940) noted that the species occurs in gaps, in which growth is rapid, and although much natural regeneration takes place below the parent tree, seedlings die rapidly unless overhead light is available. In Uganda *Maesopsis* is a common tree after heavy felling in Mabira Forest, but elsewhere (Thomas 1945), for example Budongo Forest, other species such as *Trema* are more common (Hamilton pers. comm.). On the Sesse Islands of Lake Victoria *Maesopsis* is dominant in hill-top forests (Thomas 1941). Grassland on the hill slopes is slowly invaded by forest trees, which establish themselves around the bases of anthills, where the soil is barer and richer than in the surrounding grassland. *Maesopsis* eventually becomes the dominant species, but only after initial establishment of *Volkensia duemneri*, followed by *Harungana madagascarensis*. Only then, can *Maesopsis* seedlings establish themselves and displace the former two species to the edge of the ring.

4.3 Reproductive biology and life-history characteristics of Maesopsis

A summary of the results of the experimental work is given below. For details readers are referred to Section 2 of this chapter.

Maesopsis flowers readily from the age of 4 to 10 years old, and produces a prolific number of seeds yearly, with a main crop during the June to September period in the Amani-Kwamkoro region. Fruits are readily dispersed by hornbills throughout the East Usambaras although large quantities are eaten on the trees by monkeys and dropped very locally. Seedling establishment is favoured by a double strategy. Firstly, seeds can germinate over a long period of time (up to 200 days) and germination seems to be triggered by water availability and not light. Secondly, seedlings can survive in a suppressed state on the forest floor for several months. Because *Maesopsis* needs light to grow, this double strategy will ensure that seeds will germinate or seedlings will grow as soon as appropriate conditions occur at almost any time between seed crops.

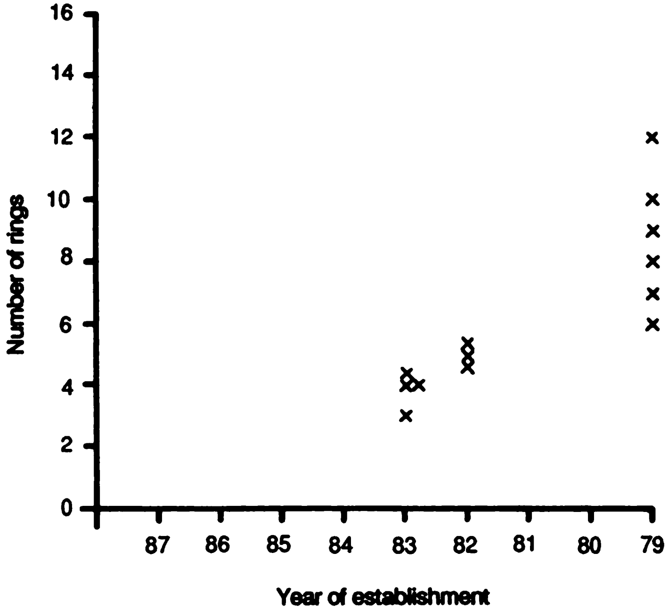

Figure 27.9 Relationship between number of tree rings and age of Maesopsis.

4.4 Site description and methods

Maesopsis produces growth rings and, in order to determine whether or not they are annual, treefalls of known age were visited. Two treefalls from 1983, two from 1982 and one from 1978 were located in Kwamkoro Forest Reserve (Site A in Fig. 27.1) and all *Maesopsis* individuals present in the tree fall areas were cut and their growth rings counted. Fig. 27.9 shows that about one ring is produced each year, although there is variation and it is sometimes difficult to distinguish rings. Consequently, when dating a tree fall by *Maesopsis* tree rings, it is necessary to obtain ring counts from more than one tree and to take the average as an age estimate. Bryant (1968) has shown that growth rings are also annual on *Pterocarpus angolensis* on the West Usambaras and I have observed probably more or less annual rings on several other tree species in the East Usambara forests. Subsequent work carried out on two 17-year-old individuals of the Kwamkoro plantations showed that tree rings were difficult to detect in older wood, being hidden by material of apparently secondary deposition (Taylor pers. comm.). These observations do not invalidate the dating technique when applied to trees younger than 15 years old in gaps. In further work stains should be used to help detect rings.

Fieldwork was carried out at the following two sites (sites A and B on Fig. 27.1):

Site A in Kwamkoro Forest Reserve was in a forest where pit-sawing was carried out in 1978, 1969 and possibly earlier. The gap was formed by the felling of a *Newtonia* in 1978. (Fig. 27.10). This partially exploited mature forest was dominated by *Newtonia buchananii*, *Strombosia scheffleri*, *Allanblackia stuhlmannii*, *Chrysophyllum* spp., *Anisophyllea obtusifolia*, *Aningeria aldofi-friedericii*, *Cynometra* sp. and *Parinari excelsa*, with a few *Maesopsis* scattered throughout. The *Newtonia* had been cut in 1978 and the gap produced was accurately mapped using a 10 x 10m square grid. In each square fallen logs were measured and located, and standing trees were identified, and their diameters and locations mapped.

Site B in Kwamsambia Forest Reserve, was at the northern end of a plot used for describing a profile diagram from undisturbed slope forest (Chapter 25; Fig. 25.6). Three gaps of different ages were located (Fig. 27.11). Gap B1, caused by death of a large *Greenwayodendron*, was situated at the right hand end of the profile shown on Fig. 25.6 and was less than 1 year old. Gap B2, a double treefall caused by the fall of a large *Newtonia*, was estimated to be 11 years old from ring counts of 4 trees. Gap B3 is a very old treefall (ca. 50 years), and was detected through the presence of a slight organic ridge (all that remains of a decayed trunk) and the remains of a root soil mound. The canopy had subsequently closed.

In the previous section, following the most used definition, a gap was described as a vertical hole in the forest vegetation, extending through all levels to within an average of 2 m from the ground at the time of formation, and is called here a vertical gap. Around the vertical gap, there is often an area undisturbed by the treefall, where canopy trees remain undamaged and where there is relatively little undergrowth vegetation, as is typical of the mature forest phase. This area will receive indirect light or direct sunlight for a limited duration and can be called a diagonal gap. The positions of vertical and diagonal gaps were recorded at Site B and other gap features noted, including the disposition of all *Maesopsis* plants. The positions of the debris and bare humus zones were recorded.

The gaps of all treefalls used in Section 3 were examined and the presence or absence of *Maesopsis* recorded to obtain an estimate of its invasion of the natural forest. The state of decay of the trunks was subjectively compared to that of fallen logs of known age and all fallen trunks were ascribed to two classes, young (ca. < 15 yr) and old (ca. > 15 yr). Numerous other gaps were observed, mainly in Amani West Forest Reserve, to confirm the observations made in the above gaps.

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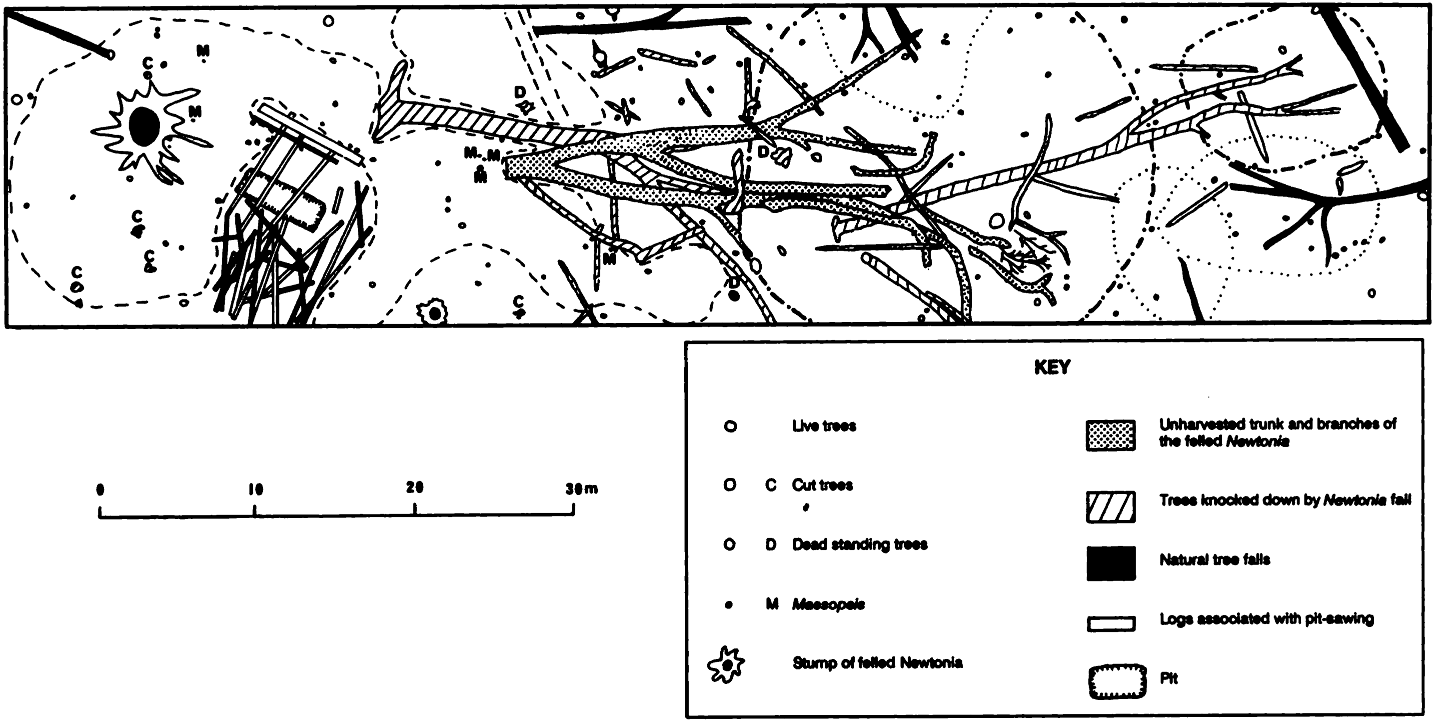

Figure 27.10 Map of a ten-year-old gap in Kwamkoro Forest Reserve around a Newtonia, felled by pit-sawing.

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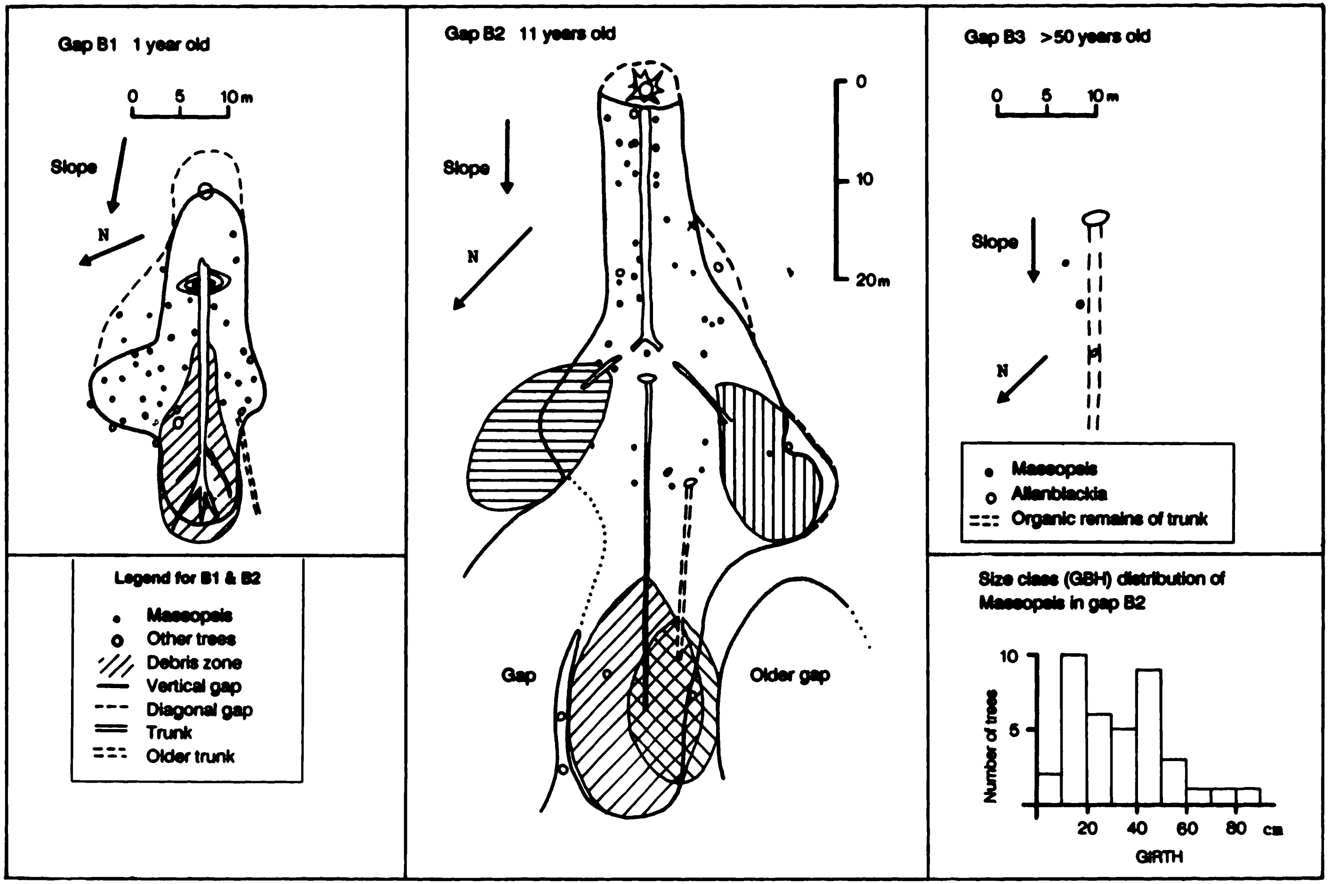

Figure 27.11 Patterns of Maesopsis invasion in three natural gaps of different ages in the Kwamsambia Forest Reserve.

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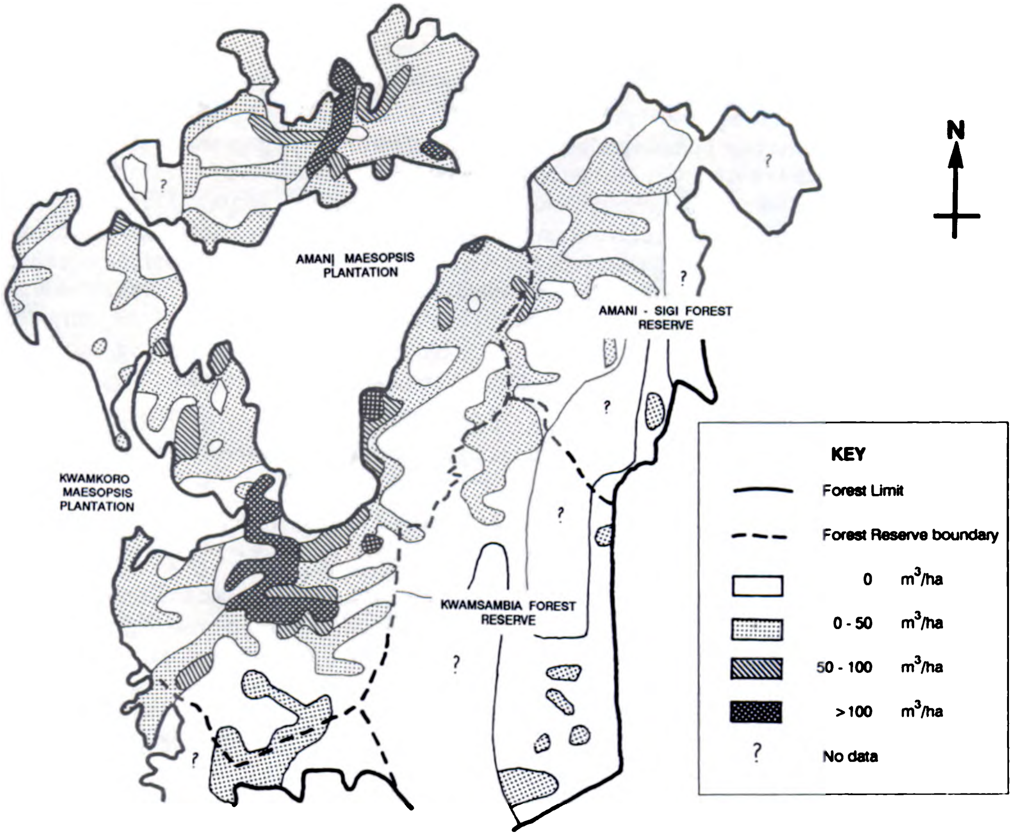

Figure 27.12 Distribution of Maesopsis at the southern end of the main range of the East Usambaras, from 1986/87 inventory.

4.5 Results

Fig. 27.12 shows the extent of the *Maesopsis* in the Amani-Kwamkoro region. The species occurs almost throughout the natural forest. [Editors' note: a map of the distribution of *Maesopsis* in the East Usambaras according to the results of the 1986/87 Forest Division/FINNIDA inventory survey is given in Fig. 24.1]

The Kwamkoro gap (Gap A) is depicted in Fig. 27.10. The gap, produced by pit-sawyers differs from natural gaps in having an increased area of bare soil. Several trees up to 30 cm in diameter were cut down to provide wood to build a sawing platform around the tree above the buttresses and to build structures on to which logs could be rolled for sawing. The logging activity has also increased the amount of bare mineral soil in areas such as the pit and the soil heap. Furthermore, because the area was well cleared of vegetation and heavily trampled, the organic content of the topsoil would have been reduced through erosion, reduction in the quantity of organic matter influx to the soil surface and increased decomposition. Apart from the area where the pit-sawyers worked, the disturbance and the structure of the gap is exactly like the natural fall of a very large tree. The height of the felled tree was over 55 m and possibly as much as 65 m, and during the fall it uprooted three large trees and broke several other large individuals, which are still standing, either dead or nearly so. All the small trees were killed. *Maesopsis* has invaded the area (Fig. 27.10), with 7 individuals established in the bare zone. No

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Maesopsis is present in the debris zone, which has however been invaded by some other light-demanding species such as *Polyscias fulva*.

At Kwamsambia an identical pattern of tree establishment was observed in the 3 gaps of different ages (Fig. 27.11). In the one-year-old gap (Gap B1) 34 *Maesopsis* seedlings (height ranging from 5 to 25 cm) were found in the bare humus zone both in the vertical and diagonal gaps and no seedlings were observed within the debris zone. Gap B2 had an estimated age of 11 years with 36 trees of *Maesopsis* established in the bare humus zone, one individual in the bare mineral zone and one in the debris zone. Along the first fallen trunk (the upper trunk on the figure) the bare area is rather narrow, so that all the trees grow along the log. The largest tree had reached a height of over 10 m and the size class distribution of the *Maesopsis* individuals shows a double peak (Fig. 27.11) with most of the individuals of the small size classes being suppressed either by larger *Maesopsis* or other species. Trees with small girths will eventually die due to lack of light. In Gap B3, which has closed completely, two large *Maesopsis* have reached canopy height; they are likely to be survivors of a larger cohort.

All other treefalls which had *Maesopsis* in the gaps showed the same pattern of establishment, i.e. all the trees were growing on the bare humus zone along the trunk or around the stump. No *Maesopsis* were observed under the forest canopy apart from young seedlings.

Table 27.7 shows that between 40 and 62.5% of recent (<15 yr) gaps have been colonized by Maesopsis, whereas the species established itself in only 2 to 8% of the older gaps.

It is difficult to estimate the minimum gap size necessary for *Maesopsis* to reach the canopy. Firstly, seedlings will need an area of bare humus soil. Secondly, because it is a light-demanding species, the required gap size will vary according to canopy tree height, rates of lateral tree growth and growth recovery of broken trees. Lateral growth rates are unknown, but they might not be of great significance, as is the case in northern American hardwood forests, where the maximum rate of lateral growth is only 26 cm yr^{-1} and normal rates are only 10 cm yr^{-1} (Hibbs 1982). Casual observations did not supply many indications as to the recovery success and impact on establishment of broken trees. So, only big gaps will provide enough bare humus ground and enough light for a long enough period of time for *Maesopsis* to reach canopy height. Only the falls of large trees (60 cm DBH) are believed to produce conditions suitable for successful establishment. At Kwamsambia these treefalls represent 64% of the total number of falls recorded. As big treefalls cause most of the disturbance it can be estimated that they produce 75% of the total disturbance. In two gaps (Gaps B1 and B2) the areas suitable for *Maesopsis* were estimated at 63% and 76% of the total vertical gap area, suggesting that roughly 70% of all large gaps (ca. 300 m^2) are suitable for *Maesopsis* invasion. Using the above figures it is possible to estimate the area which *Maesopsis* could invade, assuming no displacement of mature individuals by primary species, as being as high as 50%. Various turn-over rates have been estimated for tropical rain forest and they range from 100 to 400 years (Brokaw 1985), with 200 years as a likely figure for the Amani type of forest. It may therefore be estimated that in 200 years 50% of the canopy of the 'natural' (unlogged) submontane forest on the East Usambaras will consist of *Maesopsis*.

Human activities have been observed to produce more favourable sites for *Maesopsis* establishment. Local people collect firewood from the forest and the crown areas of fallen trees are systematically removed, increasing the amount of bare humus soil. Under such conditions *Maesopsis* can potentially invade the whole gap.

Data on species displacement are still being analysed and little information is yet available. Nevertheless species listed on Table 27.6 as being capable of establishing themselves in the bare humus zone may potentially be regarded as under threat from the *Maesopsis* invasion.

4.6 Discussion

It is argued above that up to 50% of the forest could be invaded by *Maesopsis*: this could be considered as a very high figure. However, observations carried out in Amani West Forest Reserve near Forest House No. 1 confirm this prediction. *Maesopsis* has been in the area for just over 70 years

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Table 27.7 Number of gaps of different ages and the number colonised by Maesopsis, at three sites in natural forest.

(a) Kwamkoro

Age of gaps	With *Maesopsis*		Lacking *Maesopsis*		Total	
	No	%	No	%	No	%
Old	1	2.9	33	97.1	34	100
Young	2	40.0	3	60.0	5	100
Total	3	7.7	36	92.3	39	100

(b) Kwamsambia

	With *Maesopsis*		Lacking *Maesopsis*		Total	
	No	%	No	%	No	%
Old	1	2.9	33	97.1	34	100
Young	5	62.5	3	37.5	8	100
Total	6	14.3	36	85.7	42	100

(c) Amani-Sigi

	With *Maesopsis*		Lacking *Maesopsis*		Total	
	No	%	No	%	No	%
Old	1	8.3	11	91.7	12	100
Young	2	40.0	3	60.0	5	100
Total	3	17.6	14	82.4	17	100

and some patches of that forest are totally taken over by the species. It was also noted that very little or no regeneration of primary tree species is taking place below mature *Maesopsis*. Typically, invasive animal populations decline after first displaying exponential growth, a course which alien plant populations may also show – a fact which has yet to be demonstrated (Mack 1985). It is possible that after an initial growth, the *Maesopsis* population may eventually change to reach a smaller size.

Several factors single out the *Maesopsis* invasion as exceptional and insidious. Tree species rarely become naturalized in any vegetation type and particularly so in tropical forest (Budowski pers. comm.). Only 2 out of 674 naturalized species in California are trees (Mooney *et al.* 1986) and in Britain the data suggest that naturalized trees only become established if they have been grown in the area for many centuries (Orians 1986). Baker (1986) suggests that in North America disturbance caused by human activities seems to be necessary for plant (trees or other types) invaders (except perhaps for exotic pines – see Chilvers & Burdon 1983). However, in the reduced floral richness of oceanic islands, vigorous spread of exotic trees may occur, such as the invasion of Hawaii's grassland by the guava introduced as a fruit tree. Nevertheless, Baker adds that some ecosystems such as dense forest seem relatively resistant to invasions. *Maesopsis* on the East Usambaras is obviously exceptional: it started invading the forest within twenty years of its introduction earlier this century. The invasion began when human disturbance creating gaps was rather little and is now proceeding within dense forest.

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Although the present research gives the impression that *Maesopsis* is the only threat to the forest, observations have shown that several other species are also invading. For instance *Milletia dura* is commoner than *Maesopsis* in the area of high disturbance at Kwamkoro described in Section 3. At present, no information on its ecology and patterns of invasion is available. Another aggressive species is *Melia azedarach* in the lowland part of Kwamsambia Forest Reserve. *Maesopsis*-rich forest itself contains a large number of alien species, including *Rubus rosifolius* and *Lantana camara*.

The East Usambaras have been subject to a high degree of biological isolation from other mountain ranges for a long time. This has led to the evolution of numerous endemic species in many groups of organisms and, it may be assumed, distinctive genotypes in many species which also occur elsewhere. The mountains may be considered as an ecological island. It can be concluded that some dense forests, particularly those which are isolated and contain a high proportion of endemic species, are very susceptible to plant invasions. Up to now this fact has not been fully appreciated and never considered whenever species have been introduced. This is the reason why all pioneer species and to a lesser extent shade-tolerant species, which are non-native to the East Usambaras and which show any potential for vigorous spread, should not be introduced or, if already present, should be eliminated or at least controlled. The danger of invasions from the Amani Botanical Garden, with 900 species planted, mostly exotic trees, is clear.

5. Kwamkoro's *Maesopsis* plantations and degraded forests: a need for sustainable forestry and sound environmental policies

5.1 Aims and extent of plantations

When large-scale logging started in the early 1960's at Kwamkoro, it was felt that slow growing species of the mature forest should be replaced by quick growing exotics. The Chief Conservator of the time, considering various proposals, decided that exploitation would take place in two ways. Firstly, partial felling of 50 acres (20.2 ha) annually to 50% of the merchantable basal area and secondly clear-felling of 25 acres (10.1 ha) would be carried out. It was felt that clear-felled areas would be invaded by agriculturalists if left alone and so planting of *Maesopsis* was ordered. This species was favoured because its felling cycle was only 40 years instead of 80 years for trees producing harder wood. Gap planting in the partially felled areas by the triplet technique was also requested. In case the silvicultural work lagged behind the sawmiller's, the latter would be requested to replace clear-felling of the 25 acres (10.1 ha) by partial felling. The Chief Conservator also recommended trials of alternatives to *Maesopsis* and that research on natural regeneration techniques should continue (Nightingale & Steele 1963).

By 1968, the emphasis changed and *Maesopsis* was planted with a mixture of the hardwood *Cephalophaera usambarensis*. The idea was that *Maesopsis* would play the role of a nursing tree to the moderate-shade demander *Cephalosphaera*. Ten years and 421 hectares later it was eventually realised that the scheme was a failure and planting was discontinued (Mugasha 1982).

In the early years of planting a precise tending programme was formulated to look after the plantations. During the 1960's this programme was to a large extent followed but in the 1970's these operations became more and more irregular and by the early 1980's, all activities had stopped, including both planting and tending.

With the arrival of substantial Finnish aid to Sikh Saw Mills in the late 1970's, especially the introduction of heavier machinery for logging, the rates of both logging and environmental degradation increased. This short-sighted, destructive use of a scarce natural resource led to an international outcry. Eventually, in December 1986, Sikh Saw Mills stopped logging in the Kwamkoro area. During all the period of felling no silvicultural work was carried out behind the loggers and the degraded forest has been invaded by a mixture of *Maesopsis* and *Trema orientalis* on disturbed soils, along with a carpet of climbers, chiefly *Raphidiocystis chrysocoma*, and also *Cissus oliveri* and *Gerrardanthus lobatus*.

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Shortage of money is blamed for the apparent end to all silvicultural operations in Kwamkoro Forest Reserve and for the lack of control.

5.2 How a sweet dream turned into a nightmare

In the early 1960's *Maesopsis* was considered as the magic answer to the problem of reafforestation after logging. It had all the qualities needed for quick returns and low establishment costs. Unusually fast growth rates could be expected, leading to short felling cycles and allowing tending operations to be reduced to a minimum. The nursery establishment was made simpler because the seeds were produced in large quantities, were easily gathered, and grew without any major problems. Furthermore, *Maesopsis* suffers from virtually no diseases at Kwamkoro (see Sections 1 & 2). It was also thought to be the ideal nurser for *Cephalosphaera*, casting the right amount of shade. Its self-seeding habit seemed to have been thought of as an asset (Willan 1965). However, problems which could arise from all these exceptional characteristics were not considered.

Over the years most of the features which the foresters thought to be most profitable turned out to be detrimental. The prolific seeding habit of *Maesopsis*, its efficient dispersal by hornbills, its very high germination rate and its fast growth rates give *Maesopsis* the potential to invade up to 50% of the surface area of the natural forest, and in doing so to lead to the probable extinction of some rare and unique species (Sections 2 & 4). Macfadyen (Chapter 31) has shown that *Maesopsis*-rich forest, unlike natural forest, does not allow the build up of organic matter after it has been lost following felling or in natural gaps. Putz (1983) has shown in Panama that pioneers will preferentially invade mineral soils and that primary species such as *Cephalosphaera* (Mugasha 1978) need organic damp soils to get established. This suggests that primary species will not regenerate under *Maesopsis* plantations.

Observations were made in a pure *Maesopsis* plantation planted in 1975 at Kwamkoro (Fig. 27.1, Site E) in order to find out whether primary species are becoming established. With the exception of a few *Newtonia* saplings (< 1m tall) all species observed were light-demanders, which are found in gaps (Table 27.8). The *Maesopsis* canopy was about 20 m, with individual crowns being damaged through wind knock because of an overly high tree density. Below 5 to 10 m the usual light-

Table 27.8 Vegetation type growing under a Maesopsis plantation.

Canopy, (18-20 m tall)	Tree layer under canopy, (to 10 m tall)	Shrub layer (2-3 m tall)	Bottom layer, (up to 50 cm)
Maesopsis eminii	*Harungana madagascariensis* (very common)	*Costus*	*Pollia*
	Albizia gummifera	*Fleurya*	*Oplismenus*
	Maesopsis eminii (few)	*Clidemia*	*Rubus rosifolius*
	Polyscias fulva	*Aframomum*	*Newtonia*
	Macaranga capensis	*Newtonia*	*Alsodeiopsis schumannii*
	Anthocleista grandiflora	*Tabernaemontana*	*Albizia gummifera*
	Myrianthus holstii		
	Sorindeia madagascariensis		
	Allanblackia stuhlmannii		

[Editors' note: this is fairly typical. For example, another logged site in Kwamkoro with 20-35 m tall *Maesopsis* contained scattered individuals of trees left during logging (*Englerodendron, Maranthes, Newtonia, Odyendea*), which were not regenerating. Trees which had regenerated were nearly all light-demanding pioneers (*Cylicomorpha, Harungana, Macaranga, Polyscias, Tabernaemontana*). Like other *Maesopsis* sites, the upper humus-rich topsoil found in natural forest was lacking and instead reddish inorganic mineral soil was often visible on the forest floor under an incomplete thin covering of litter.]

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demanding species found in gaps were recorded (Table 27.8). Very few *Maesopsis* seedlings (< 1yr) and no saplings were observed.

In conclusion, at the end of the rotation (40 years), *Maesopsis* will not regenerate to any great extent after logging, primary species will be virtually absent and the plantation will become a typical secondary forest. Clear-felling of the whole area as an alternative will cause the usual problem of soil erosion and some new planting scheme will have to be designed and implemented. The introduction and use of *Maesopsis* to the East Usambaras was ill-conceived and based on little forestry and ecological data.

The wood of *Maesopsis* is considered by locals as useless for charcoal-making, house-building and other carpentry uses, and it is only valued for kindling fires. It has thus very little use and its economic prospects are not great, if one also considers the current glut of softwood in Tanzania.

5.3 What to do with *Maesopsis* and its plantations

We have seen above that *Maesopsis*, apart from its failure to fulfill its silvicultural role, has become a pest. As in all such cases, the best option is to eradicate the pest, or if this is not feasible, to reduce its harmful effects to tolerable levels. It is therefore suggested that *Maesopsis* in the Kwamkoro plantations should be cut as soon as possible. Mechanical logging is a possibility if carried out properly, a condition which includes restriction of all vehicles to the existing tracks, with no new roads to be built. However the use of local skills and workers would be far more desirable as it would provide badly needed employment to a large number of people. It would also be less destructive of the forest environment and remove fuel costs and the burden of maintenance of large machinery. The local population should also be encouraged to cut *Maesopsis* for fuelwood wherever it occurs. If the control of *Maesopsis* is to be achieved, it means the eradication of all seed-producing trees, which will include the felling of the German plantation at Amani as well. The badly infested forest around the Amani Forest House No. 1 is due to that small seed source alone and the extent of the invasion of the forest was noticed by Willan (1965) before any of the recently planted trees could produce any seeds. Control of *Maesopsis* also requires that trees in the mature forests will have to be killed, and the best approach would be to ring-bark them. Felling requires too much labour, is time-consuming, and the fallen trees would create gaps where *Maesopsis* would readily grow again, as shown in Section 4. Naturally, *Maesopsis* will sprout and grow again but in most cases it is believed that its growth will be limited because of low light intensity. Other species will either grow from a suppressed state or laterally, thereby reducing the light intensity. Many of the *Maesopsis* sprouts should die before reaching the canopy.

Biological control should also be considered for use in conjunction with ring-barking. *Maesopsis* pests are almost entirely absent from the East Usambaras; their potential should be investigated in Bukoba District and in Uganda. It is suggested that biological control would be most effective using pests affecting seed survival and fruit production. Before the introduction of any pests their specificity should be determined as it is known that pests such as those attacking roots may cause severe damage to more than one tree species, particularly in tree nurseries.

5.4 Long-term sustainable forestry

The future of the *Maesopsis* plantations and of the degraded forest lies in the growth of local hardwoods on a sustainable forestry basis. Hardwoods will soon become a very scarce resource worldwide. Planting the logged *Maesopsis* plantations with hardwoods under the shade of short-lived native pioneer species is proposed, as suggested by Mugasha (1978).

Cephalosphaera usambarensis has been shown to be a successful species when tended properly. However this should not be the only species planted, because, as is well known in the tropics, single-species plantations are very susceptible to pests and diseases. Mugasha (1978) emphasized this point in the case of *Cephalosphaera* plantations on the East Usambaras. This species is susceptible to fungal attack when grown in pure stands. Other species which have been suggested, such as *Newtonia*, *Beilschmiedia*, and *Allanblackia*, all occur with *Cephalosphaera* in the natural forest. The first two species should be easy to grow, whereas major problems have been encountered with the third

(Mugasha 1981). Nonetheless, to increase species diversity and to reduce threats from pests and diseases, other species should be considered and could, for example, include *Parinari excelsa*, *Cynometra* spp., *Anisophyllea obtusifolia*, *Drypetes gerrardii*, *Greenwayodendron suaveolens* and *Aningeria adolfi-fiedericii*.

In order to establish and grow successfully some of these species, basic knowledge of their ecologies will have to be obtained. Such suggestions have been made repeatedly. Maliondo (1979), for instance, asked to "study the ecology of recruitment of *Allanblackia stuhlmanni* from flowering to establishment of seedlings, see what happens to the seedlings and how to obtain and germinate the seeds". However, little research in any of these areas has been carried out.

In order to be successful, research on nursery practices and planting of particular species is needed and ways to regenerate the forest using the potential of natural regeneration will have to be found. Experiments will have to be set up to answer specific questions and will have to be cost-effective as research budgets are certain to remain rather limited for some time. As Mugasha (1981) pointed out, most of the experiments set up in the 1960's or the 70's had either too small a sample size or no replication to supply accurate and reliable data on which successful management plans could be drawn. Even so, if the right questions had been asked and the proper experiments started in the late 1950's, a problem such as the invasion of *Maesopsis* might not have arisen.

5.5 Nursing species

Above, it has been argued that local hardwoods have to be cultivated at Kwamkoro. In most cases these hardwoods need some shade in the early stages of their lives and nursing species are therefore necessary. *Maesopsis* does not fulfill that purpose as it suppresses the species it should encourage. Other non-native, light-demanding species, which could replace *Maesopsis* as a nurser, are also invading the forest at a lesser speed, but in due course they could become just as detrimental to the mature forest (see Section 4). There is therefore a need to keep such exotics out of the East Usambaras and emphasis should be placed on the use of native species.

The ideal nursing species should be easily raised in nurseries or by direct sowing, be fast growing, not invasive, and should also be short-lived so that the species will die naturally, reducing the costs of tending work. Maliondo (1979) suggested that *Antiaris* and, rather strangely, *Grevillea robusta*, *Podocarpus*, *Ocotea* and *Prunus africana* should be used as nursers. Table 27.9 gives lists of species

Table 27.9 Native and exotic pioneer species present in the East Usambaras uplands.
** = suggested nursing species.*

Native	Exotic
Alangium chinense	*Albizia chinensis*
Anthocleista grandiflora	*Maesopsis eminii*
Antiaris toxicaria	*Millettia dura*
Bridelia micrantha	
Cylimorpha parviflora	
Harungana madagascariensis	
**Macaranga capensis*	
Maesa lanceolata	
**Polyscia fulva*	
Sapium ellipticum	
**Trema orientalis*	

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which could and which must not be used as nursing trees. It is suggested that *Macaranga capensis, Polyscias fulva* and *Trema orientalis* are potentially the best species for this purpose.

It is suggested here that only native species should be grown in the higher altitude forest reserves, but this does not preclude the planting of some exotics for agroforestry purposes. Care should be taken to ensure that any exotics introduced will not be invasive into the natural forests - preferably they should be species which are propagated solely by cuttings.

The susceptibility of ecosystems to invasions and the ecological attributes of invading species have recently been described in Groves and Burdon (1986), who provide further insights to assess the potential impact of exotic species.

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Dedication

This work is dedicated to my grandmother, Mme Berthe Guillod-Blanchard, who died during the trip. This research would not have been possible without the help and support she provided over the years. Her constant small financial and material contributions allowed me to obtain a somewhat erratic education, and the supply of food, shelter and small jobs got me through several winters of unemployment. Because of her constant interest in trees and forests, she would have gladly joined this research but for her old age, and her teaching and gardening commitments; instead she was eagerly waiting for a first-hand report of the action.

Acknowledgements

Travelling expenses were paid by the British Ecological Society, IUCN paid for all expenses during my stay in Tanzania, The Northern Bank provided a substantial loan, the Biology Department of the University of Ulster supplied some of the field equipment.

C.K. Ruffo and Alan Hamilton provided their expertise in tree identification in the field. The fieldwork was greatly eased by Ruffo and Abdallah's commitment and interest. Mteru's urge to chop everything down helped the party's progress through gaps and thickets. The Tanzanian people made my stay most enjoyable.

Alan Hamilton, Amyan Macfadyen and Brian Rushton provided essential intellectual stimulation and comments on the manuscript and greatly improved my appalling writing, while housing was supplied by Janet Kay and Brian Rippey who also provided word-processing facilities and advice during the last stage of the write-up.

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28. A Preliminary Study of the Undergrowth of Primary and Secondary Submontane Rainforests in the East Usambara Mountains, with Notes on Epiphytes

by T. Pocs

The undergrowth of submontane forest varies with human disturbance. Some species, many of which are endemic, are restricted to undisturbed forest, some seem indifferent to disturbance, while others prefer disturbed forest. The latter include many introduced species. Epiphytes are much rarer in disturbed than undisturbed forest; those that do occur are chiefly heliophytic bryophytes found on the lower parts of *Maesopsis* trunks. These same species occur at canopy level in undisturbed forest. Epiphytes in natural forest have declined in luxuriance since 1970, probably because of a drying in climate.

1. Undergrowth

The aim of this study was to establish the main characteristics of the shrub and herb layers of primary undisturbed submontane rainforest on the East Usambaras and to investigate how these characteristics differ in degraded forest, especially forest rich in *Maesopsis eminii*. Special attention was paid to species thought to be endangered by forest degradation and to species indicative of human impact.

Field work was carried out during February 1987. I was accompanied by Dr. S. Mahunka and Prof. A. Zicsi, who carried out investigations on the soil fauna at the same sites (Chapter 32), and by Mr. I. Mwasha, who kindly assisted my fieldwork. Ferns were identified by R. Schippers (TENGERU), Rubiaceae by A. Borhidi (Vacratot), some other woody species by S. Iversen (Uppsala) and the remaining specimens by myself. Identifications are awaited for some species.

Sites were selected for study with the assistance of A.C. Hamilton. Three of the plots (no. 1 – 3) were placed in apparently undisturbed primary submontane rainforest close to the plots used for examining profile diagrams (Chapter 25; locality shown on Fig. 10.1). Two other plots (no. 4 & 5) were also placed in undisturbed forest nearby. The remaining 7 plots (no. 6 – 12) were in forest clearly disturbed by man. They are arranged from left to right in Table 28.1 in order of increasing disturbance, with disturbance at a very high level in plots 10 to 12. *Maesopsis* is increasingly abundant in the forest canopy with greater disturbance and is more or less completely dominant in plots 10 to 12.

At each site the covers of species were noted in a 20 m^2 plot. All species occurring in more than one plot or with an individual cover value higher than 2% are listed in Table 28.1. Species are grouped in this table according to the heights of dominant shrubs and herbs. These layers are then further subdivided into climbers, tree seedlings etc. and within each category species are arranged according to their tolerance to disturbance, starting at the top with species which occur only in intact forest and

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seem to be intolerant of any disturbance, continuing with indifferent and more tolerant species and ending with those growing only or predominantly in disturbed forest.

The first group, occurring only in undisturbed forest, consists mostly of species endemic to the East Usambaras or occurring only on a few neighbouring mountains. Species include *Impatiens engleri*, *Renealmia engleri* and species of *Memecylon*, *Pavetta* and *Psychotria*. These species are highly endangered. Some undergrowth species, like *Blotiella hieronymi* and *Culcasia falcifolia*, seem to be indifferent to disturbance. Other species are only present or at least are only common in disturbed forest. These include *Aframomum usambarense*, *Clidemia hirta*, *Maesopsis eminii* (seedlings and shrub-sized trees), *Olyra latifolia* (at this altitude), *Rubus rosifolius* and *Whitfieldia elongata*. Although a limited number of endemics occur in this last group (e.g. *Aframomum usambarense*), the majority of species are introduced and naturalized (like *Maesopsis*, *Rubus rosifolius* and *Clidemia*) and have fitted themselves into the new environment and spread with surprising speed. For example, *Clidemia* is very common in seedling form on the forest floor in Kwamsambia Forest Reserve 50 m from the end of a Sikh Saw Mills logging track only constructed a few months ago. In some long disturbed places, for example below Amani Forest Houses, *Clidemia* can constitute 85% of the shrub layer, suppressing anything else (plot 9).

Floristic change is accompanied by drastic change in life-strategies and life-forms. *Maesopsis*-dominated secondary forest has a much more open canopy allowing much more insolation to reach the ground. There is more light and it is hotter near ground level. Larger forbs like *Aframomum* and *Costus* appear and climbers become much more abundant in terms of numbers of species, biomass and coverage. The five left-hand (undisturbed) plots on Table 28.1 contain a total of only four species of climbers compared with fifteen species in the right-hand, *Maesopsis*-dominated plots.

Concerning the regeneration of canopy trees, no great differences are apparent from the table, except for the quite high abundance of *Maesopsis* seedlings and *Newtonia* saplings in some of the disturbed plots. *Cephalosphaera* saplings are present in many of the disturbed forest plots.

[Editors' note: The less disturbed plots (e.g. no. 1–5) have similarities with Linder's *Memecylon cogniauxii-Commelina* sp. community (plots between nos. 24 and 31 inclusive on Table 26.1). There are however notable differences between the two surveys, some of which is attributed to differences in method.]

2. Epiphytes

It is striking that foliicolous epiphytes (mostly liverworts and lichens) are completely absent from the disturbed stands. This is obviously related to the hotter and drier microclimate found in *Maesopsis*-dominated forest. Epiphytic filmy ferns are also absent from disturbed forest. Rates of endemism are exceptionally high among foliicolous bryophytes and filmy ferns and destruction of primary forest could endanger many species. During the last twenty years about 25 new taxa of foliicolous bryophytes have been described from the Usambara Mountains.

Among other epiphytes, most of the sciophytic macro- and micro-epiphytes, which are common in undisturbed submontane rainforest, are missing from the *Maesopsis*-dominated or influence stands. Instead, the lower parts of the *Maesopsis* trunks bear another type of epiphytic community, consisting of heliophytic species of bryophytes (species of *Acrojeunea*, *Diplasiolejeunea*, *Frullania*, *Leucolejeunea* and *Schiffneriolejeunea*). This community is common only at canopy level in primary forest. Elsewhere, it can be found on the lower parts of the trunks of trees growing in the open, such as on the royal palms, mangoes and jacaranda trees at Amani.

I was shocked to witness the disappearance of the giant specimens of the epiphytic fern *Vittaria zosterifolia*, which used to be found in the Amani area. *Vittaria zosterifolia* is an interesting fern, capable of almost indefinite growth during rainy seasons. During dry seasons, the greater part of the ribbon-like fronds die back, so the lengths of the leaves seem to be a good indication of average wetness in

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rainforest habitats. In 1970 I could observe many specimens on trees in the Amani Botanical Garden and in the neighbouring primary rainforests with leaves longer than 2 m. Nowadays, these individuals, if they can be found at all, bear leaves only 20–30 cm long, with bigger specimens (but still only 50-60 cm long) only found on trees bending over the cataracts of Sigi River. I should blame this on a more general climatic change than the local microclimatic changes induced by spreading *Maesopsis*.

Epiphytes in submontane forest on the East Usambaras have previously been described by Johansson (1974).

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Table 28.1 *Species occurring in the shrub layer and herb layer in the forest*

	1	2	3	4	5	6	7	8	9	10	11	12
FOREST RESERVE	Kwamkoro-Kwamsambia border					Amani West					Kwamkoro	
Altitude a.s.l. in metres	960	960	920	940	960	960	960	950	950	960	960	950
Position s:slope, r:ridge, u:upper	r	m.	v.	l.	u.	plateau		l.	l.		moderate slope	
m:middle, l:lower, vb:valley bottom	top	s.	b.	s.	s.			s.	s.	-	-	-
Direction of slope	-	E	-	W	W	-	-	SW	SW	E	E	E
Inclination of slope in degrees	-	20	-	15	25	-	-	1-4	1-4	3	2	3
SHRUB LAYER												
Coverage in %	20	25	70	25	30	50	60	65	90	80	60	60
Height in m	3.5	2.5	3	2.5	1.5	2.5	2.5	2.5	1.5	3.5	2.5	1.5
Shrubs, woody herbs and forbs												
Cassipourea sp.	-	10	*	-	-	-	-	-	-	-	-	-
Oxyanthus speciosus	3	-	-	3	-	-	-	-	-	-	-	-
Pavetta spp.	1	-	-	-	1	1	12	-	-	-	-	-
Psychotria cf. *schliebenii*	-	1	-	-	*	-	-	2	-	-	-	-
Psychotria usambarensis	-	-	2	*	-	-	*	*	-	-	-	-
Chazaliella abrupta	-	-	-	4	-	2	-	2	-	-	-	-
Memecylon amaniensis	*	*	-	-	-	-	-	-	-	-	-	-
Memecylon cogniauxii	-	-	-	-	2	2	10	-	-	-	-	-
Memecylon schliebenii	-	-	-	-	2	-	-	-	-	-	-	-
Tabernaemontana pachysiphon	-	-	-	-	*	2	5	1	-	-	*	-
Culcasia falcifolia (as hemi-epiphyte on trunks)	*	*	1	1	1	3	8	*	-	-	1	-
Leptaulus holstii	8	3		3	2	5	-	-	-	-	1	-
Dracaena afromontana	-	-	15	-	-	4	-	-	-	1	-	-
Acalypha sp.	-	-	5	-	-	-	-	5	-	-	-	-
Clidemia hirta	-	-	*	*	*	4	-	20	85	35	10	15
Aframomum usambarense	-	-	-	-	-	6	-	-	-	-	5	30
Costus sarmentosus	-	-	-	-	-	-	-	-	-	10	10	-
Whitfieldia elongata	-	-	-	-	-	-	1	*	-	10	*	*
Vernonia sp.	-	-	-	-	-	-	-	30	-	-	-	-

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	1	2	3	4	5	6	7	8	9	10	11	12
FOREST RESERVE	Kwamkoro-Kwamsambia border					Amani West				Kwamkoro		
Achyrospermum carvalhi	-	-	-	-	-	-	-	-	-	*	*	-
Psychotria tanganyikensis	-	-	-	-	-	-	-	-	-	4	2	-
Rutidea orientalis	-	-	-	-	-	-	-	-	-	-	15	5
Shrub-size regeneration of canopy trees												
Cynometra sp.	*	*	-	-	-	-	6	-	-	-	-	-
Entandophragma excelsum	-	*	3	1	1	-	*	-	*	-	-	-
Uvariodendron spp.	-	*	-	1	4	6	8	-	-	2	-	-
Newtonia buchananii	-	-	*	-	-	4	2	-	-	*	2	2
Cephalosphaera usambarensis	-	-	8	-	-	-	4	-	2	8	*	2
Anisophyllea obtusifolia	-	-	-	-	-	6	1	2	-	2	-	-
Maesopsis eminii	-	-	-	-	-	1	-	-	2	3	2	-
Climbers												
cf. Dalbergia lactea	-	*	*	2	6	-	-	-	-	-	-	-
Landolphia spp.	*	-	-	-	-	-	-	-	*	*	-	-
Adenia rumicifolia	-	-	*	-	-	-	-	*	-	*	-	-
Combretum sp. *aff. C. illairii*	-	-	-	2	-	-	-	-	-	1	-	-
cf. Leptoderris harmsiana	-	-	-	-	-	*	-	*	-	-	-	-
Momordica spp.	-	-	-	-	-	-	-	*	*	*	-	-
Acacia pentagona	-	-	-	-	-	-	-	-	*	-	2	*
Rubus pinnatus	-	-	-	-	-	-	-	-	-	-	5	5
Rubus rosifolius	-	-	-	-	-	-	-	-	-	-	15	-
Dioscorea sansibariensis	-	-	-	-	-	-	-	-	-	5	-	3
HERB LAYER												
Coverage in %	35	30	70	35	30	30	25	25	10	5	10	8
Height in cm	30	40	50	40	35	30	40	30	50	40	40	40
Renealmia engleri	2	*	3	1	2	-	-	-	-	-	-	-
Stanfieldiella imperforata	-	-	3	2	-	-	10	-	-	-	-	-
Solenodesmium rigidum	-	1	-	1	-	-	-	-	-	-	-	-
Impatiens engleri	-	-	40	-	-	-	-	-	-	-	-	-
Leptaspis cochleata	-	*	*	5	-	4	*	1	-	-	-	-

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	1	2	3	4	5	6	7	8	9	10	11	12
FOREST RESERVE	Kwamkoro-Kwamsambia border					Amani West				Kwamkoro		
Asplenium christii	*	*	-	-	*	-	-	*	-	-	-	-
Pollia condensata	-	-	1	-	-	-	-	-	-	-	-	*
Culcasia falcifolia (on ground)	30	16	20	4	15	15	15	10	2	2	5	2
Asplenium paucijugum	-	*	1	-	-	-	-	*	-	-	-	-
Pteris burtoni	-	*	-	20	4	-	6	2	-	-	-	-
Bolbitis auriculata	-	-	-	3	4	-	-	1	2	-	-	-
Blotiella hieronymi	12	-	-	2	15	2	1	1	-	-	*	5
Chlorophytum sp.	-	-	-	-	2	-	-	1	-	2	-	-
Tectaria gemmifera	-	-	-	-	-	-	-	3	1	-	-	-
Clidemia hirta	-	-	-	-	-	1	*	3	2	1	5	4
Olyra latifolia	-	-	-	-	-	-	-	-	-	-	10	-
Seedlings of canopy trees												
Anisophyllea obtusifolia	2	1	-	-	*	2	-	1	-	*	-	-
Newtonia buchananii	-	*	-	1	*	1	1	-	-	*	-	-
Maesopsis eminii	-	-	-	-	-	*	*	2	4	-	-	-
Litter coverage in %	99	85	60	50	55	70	60	40	40	60	60	60
Litter depth in cm	3	2	0.5	3	4	3	2	2	2	1	6	2

*The size of each sample plot was 20 m^2 (5 x 4). The list contains only those species which occurred in more than one plot or for which the coverage value was higher than 2% (only 5 cases). Cover is given as percentage; * = rare.*

29. Seed Banks in the Forest Soils

by P. Binggeli, C.K. Ruffo, D. Taylor
& A.C. Hamilton

Topsoils were collected from lowland, submontane and *Maesopsis*-rich forests and spread out in a nursery to study germination. Among trees, seedlings of pioneer species were much more abundant than primary forest species. Climbers, forest herbs and forest shrubs were also well represented.

1. Introduction and methods

The objective was to gain some preliminary knowledge about seed banks in the soils of the East Usambara forests. Samples of topsoil and litter were collected from little disturbed lowland and submontane forests in Kwamgumi and Kwamsambia Forest Reserves. Two topsoil samples were collected from each of three sites along catenary series within the lowland and submontane forests; these were the same sites used for the profile diagram plots (Chapter 25) and for examining soil profiles (Chapter 10). There were also two topsoil sites from a *Maesopsis* forest, making a total of 14 topsoil samples. Litter samples for studying seed germination were collected from some of the same sites.

Topsoil was collected from beneath the litter in 2,500 cm^2 square quadrats, 10 cm deep. The area used for litter collection varied between 625 and 10,000 cm^2, according to the depth of the litter. Topsoil and litter samples were transported to Amani and spread out in a nursery bed constructed close to Forest House no.1 of the Amani Medical Research Centre. This bed was made by removal of surface vegetation (*Paspalum* grassland) and topsoil to a depth of about 20 cm, levelling the exposed subsoil and emplacing a timber framework which divided the area into individual experimental plots. A topsoil or litter sample was placed in each plot, most of which were about 3,500 cm^2 in area. Because of differences in degree of compaction of the topsoil, in thicknesses of litter and in sizes of the plots, the results must be treated as semi-quantitative. There were four control plots without topsoil or litter. The beds were covered with nylon netting with a mesh size of 1.5 mm to decrease the numbers of seeds entering the plots from the atmosphere.

The nursery bed was constructed in February 1981 during the dry season and was not watered artificially. The soils were not 'turned'. Observations continued throughout the 'long rains' until 31 May. Seedlings were removed after identification.

2. Distinguishing between seedlings from forest seed banks and contaminants

Seedlings or young plants growing in the nursery plots can have come from forest soils, or have grown from seeds or other plant parts present in the topsoil at the experimental site, or have entered the plots after the establishment of the nursery, for example by penetrating through the meshes of the netting.

Contaminant plants are believed to be numerous in these plots and to have originated in the greater part from seeds in the subsoil. Some contaminant plants, such as *Oxalis* and perhaps *Hydrocotyle*, have grown from deeply buried bulbs or pieces of root. Species which occur in the control plots are good candidates to be regarded as contaminants, as are species which grow in the grassland which grew on the site prior to its preparation as a nursery, and agricultural weeds. The ground used for the nursery has almost certainly been cultivated fairly recently and there are vegetable plots close to the site. Species regarded as contaminants are listed separately on Table 29.1. Most are weeds of cultivated ground or grassland plants; many weeds are known from other studies to have seeds of long viability. Some of the seedlings regarded as contaminants could of course have grown from seeds present in the forest soils.

3. Forest seedbanks

The results are shown on Table 29.1. Results from the litter samples from each of the three localities (lowland, submontane, *Maesopsis* forests) have been summed. The total area of litter collected is 3 m^2 from each of the lowland and submontane forests and 1 m^2 from the *Maesopsis* forest.

3.1. Pioneer trees and shrubs

Seedlings of pioneer trees or shrubs germinated in all topsoil samples. *Trema orientalis* was the most widely found species, occurring in all six lowland forest plots, four of the submontane forest plots and in the lowland litter sample. *Harungana madagascariensis* occurred in all six of the submontane forest plots. *Maesopsis eminii* was found sparingly (one seedling each) in both valley samples from submontane forest, and in large quantities in both topsoil and litter samples from the *Maesopsis* forest. The pioneer shrub *Securinega virosa* was represented by one seedling in a lowland forest sample.

The distribution of these pioneer trees corresponds roughly to their distribution in the forest types. *Trema* is found in both lowland and submontane forests, but is generally commmoner in the former. *Maesopsis* is common in submontane forest, but virtually absent from Kwamgumi lowland forest. *Harungana* is only found in submontane forest. The fact that no *Harungana* seedlings were found in litter is not regarded as especially significant. The occurrence of seeds in litter at any particular time is probably very dependent on very recent events, for example on the timing of seed dispersal from trees close to collection sites.

Despite the relative abundance of seedlings of these pioneer trees in the seedbanks, the profile plots in the lowland and submontane forests (Chapter 25), from within which the samples were collected, do not actually contain any of these species. Indeed *Trema* was not at all common in the vicinity of any of the sample plots.

3.2. Primary forest trees

These are much rarer than seedlings of the pioneer trees and were only encountered in two topsoil samples (a total of only four seedlings, all *Celtis mildbraedii*) and one litter samples (one seedling of *Antiaris toxicaria*), all from lowland forest. *Antiaris* is actually a light-demanding species and its seedlings and young trees are never found under shade in the forest.

3.3. Climbers

These are quite well represented, though less so than the pioneer trees. At least ten species (including two species of *Cissus*) are present. The climbers include both large lianes and smaller types.

3.4. Forest herbs and shrubs

Only *Culcasia* is commonly present in lowland forest. The young plants may be coming from tubers or pieces of root rather than seeds.

The submontane forest plots have a notable abundance of *Clidemia hirta*, an introduced American shrub which grows in open places. This species had a limited distribution on the East Usambaras in 1935 (Moreau 1935) and has since spread very rapidly through the forest. The fruits are dispersed by

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birds (Moreau 1935); they are very small. The forest grass *Leptaspis cochleata* is found in three of the plots, in two in great abundance. This grass can persist under fairly dense shade, but possibly, like *Dracaena*, can only become established under more open conditions.

The *Maesopsis* forest has common *Acalypha* in both topsoil samples, *Dracaena* in one and *Olyra* in another. Surprisingly, there are no *Clidemia* seedlings. *Clidemia* is a common plant in *Maesopsis* forest.

4. Comparison with previous work

The results of this experiment are similar to those reported by workers elsewhere (Cheke *et al.* 1979; Hall & Swaine 1980; Keay 1960; Putz 1983; Uhl & Clark 1983; Whitmore 1983). Soils beneath mature tropical forest characteristically contain large numbers of seeds of pioneer species and few viable seeds of more mature forest. It is thought that the latter may be rare because they germinate rapidly and are not stored in the soil. Earlier studies have also shown that other gap species (herbs, shrubs, climbers), as well as pioneer trees, can be well represented in seed banks from mature forests.

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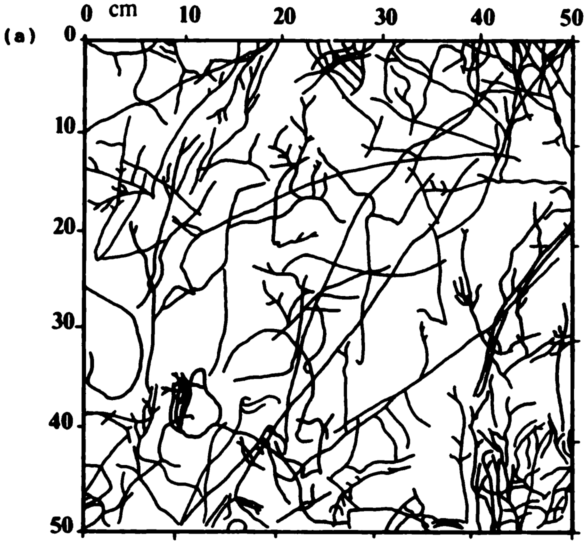
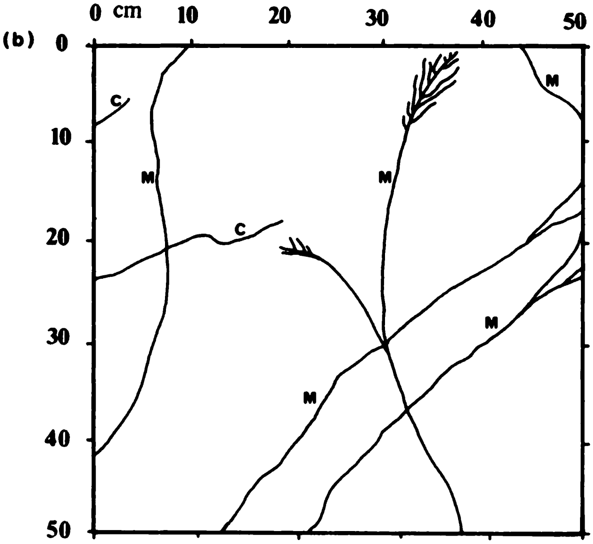
Table 29.1 Numbers of seedlings germinating in seed bank nursery

Origin of soil	Lowland forest (Kwamgumi) Ridge		Mid-slope		Lower		Submontane forest Ridge slope		Slope		Valley		*Maesopsis* plantation (Kwamkoro)		Controls				Litter Low-land	Sub-montane	*Maes-opsis*
Replicates	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	C	D			
1. Seedlings suspected of originating (mainly) from forest soil bank																					
a. Pioneer trees and shrubs																					
Harungana mad.	-	-	-	-	-	-	6	9	5	8	9	11	-	-	-	-	-	-	-	-	-
Maesopsis eminii	-	-	-	-	-	-	-	-	-	-	1	1	36	13	-	-	-	-	-	-	35
Securinega vir.	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trema orientalis	5	3	9	47	12	13	-	1	9	-	3	3	-	-	-	-	-	-	3	-	-
b. Primary forest trees																					
Celtis mildbr.	-	-	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Antiaris toxic.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
c. Climbers																					
Adenia	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Asparagus	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Caesalpinia	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cissus	-	-	3	-	6	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-
Clerodendrum	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cucurbitaceae	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	4	-	-
Ipomoea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Thunbergia	1	1	-	7	1	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-	-
Toddalia	-	-	-	2	2	2	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-
d. Other woody seedlings (uncertain whether trees, shrubs or climbers)																					
	-	-	1	1	-	-	11	-	-	-	2	-	-	-	-	-	-	-	-	-	-
e. Forest herbs and shrubs																					
Acalypha	-	-	-	-	-	1	-	-	-	1	1	1	4	7	-	-	-	-	-	1	-
Acanthaceae	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
Clidemia hirta	-	-	-	-	-	-	22	455	37	27	7	19	-	-	8	-	-	-	1	1	2
Commelinaceae	-	-	-	-	-	1	-	-	219	-	-	-	-	2	-	-	-	-	-	-	-
Culcasia	5	-	1	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dracaena	-	-	-	-	-	-	-	-	1	-	-	-	-	8	-	-	-	-	-	-	-

Origin of soil	Lowland forest (Kwamgumi)						Submontane forest Maesopsis						Controls plantation (Kwamkoro)		Litter						
	Ridge		Mid-slope		Lower		Ridge slope		Slope		Valley								Low-land	Sub-montane	*Maesopsis*
Replicates	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	C	D			
Leptaspsis coc.	-	-	-	-	-	-	4	66	138	1	-	-	-	-	-	-	-	-	-	-	-
Olyra latifolia	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-
Solanum (shrub)	-	-	-	-	-	-	1	2	1	-	-	-	-	1	-	-	-	-	1	1	-
2. Seedlings suspected to be (mainly) contaminants																					
Ageratum conyz.	-	-	-	-	-	-	-	-	-	-	-	-	16	3	3	-	-	-	-	1	2
Aspilia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Bidens pilosa	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	3	-	1	1	-
Compositae(herb)	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Conyza florib.	1	1	4	8	11	1	-	4	-	1	3	-	1	-	-	1	4	1	-	1	5
Crassocephalum	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Cyperaceae	1	-	-	-	-	1	-	2	1	-	2	2	-	5	5	7	2	2	-	3	11
Desmodium (herb)	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-	-	-
Gramineae	3	-	13	11	7	1	-	-	1	-	-	-	5	-	27	3	1	-	-	2	4
Hydrocotyle	14	2	12	12	24	22	-	-	6	4	-	1	21	6	-	9	14	7	36	6	27
Lobelia	1	1	3	2	2	3	-	-	-	1	-	-	1	1	3	4	28	19	1	1	32
Oldenlandia	1	-	1	2	3	1	-	-	-	-	-	-	4	-	19	4	29	1	2	-	3
Oxalis	-	-	-	2	5	-	-	-	1	-	-	-	6	-	1	-	4	-	-	7	13
Phyllanthus (herb)	-	-	-	-	-	-	-	-	-	-	-	7	-	1	-	-	-	-	-	2	-
Senecio	-	-	-	1	12	-	-	-	1	-	-	1	47	-	-	1	-	-	4	1	8
Sonchus	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spathodea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Spermacoce	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
3. Unidentified herbaceous seedlings (mostly very small)																					
	8	7	12	9	2	3	10	36	13	10	14	13	30		41	5	28	2	7	4	15
4. Unidentified	-	-	-	-	-	-	-	-	3	-	4	4	-	-	-	-	-	-	1	1	-



SUBMONTANE FOREST



MAESOPSIS FOREST

Figure 30.1 Density of roots in the upper 5 cm of soil in 50 cm x 50 cm grids in two forest types:
(a) in little disturbed submontane forest (Kwamkoro, 950 m) and
(b) in a Maesopsis plantation (Amani, 910 m).
Root density accurate, but roots not drawn to scale. Minimum root diameter drawn 1 mm.
Roots identified in submontane forest plot include Alchornea hirtella, Cola sp. Maranthes goetzeniana, Myrianthus holstii and Tricalysia anomala. Roots in Maesopsis forest are Maesopsis eminii (M) and Coffea robusta (C). Note the much higher density in the natural forest, which is typical.

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30. Root Distribution in Relation to Vegetation and Soil Type in the Forests of the East Usambaras

by David Taylor

Observations were made on the rooting characteristics of plants in semi-natural forests at Kwamkoro and Kwamgumi and in an old *Maesopsis* plantation near Amani. Results further refute the idea that tropical forest trees are characteristically 'shallow-rooters', supply evidence that some variations in root density may be due to differences in soil fertility, suggest that the *Maesopsis* plantations may have affected soil conditions there, and provide a basis for an hypothesis that could explain, at least in part, some of the success of *Maesopsis* in the natural forest.

1. Aims

The objectives of this short study were to examine variations in root distribution and density in the semi-natural forests of Kwamkoro (submontane forest) and Kwamgumi (lowland forest) and in a *Maesopsis eminii* plantation at Amani, all on the East Usambara mountains. Further, it was hoped to suggest causes for, and effects of, any differences in rooting behaviour and to supply much needed evidence on the rooting strategies adopted by selected submontane tropical forest trees.

2. Introduction

2.1 The '*Maesopsis* problem'

The significance of a relatively large number of endemics and near-endemics in the East African coastal forests, such as those on the East Usambaras, has been stressed elsewhere in this report (Chapter 21). Similarly, the susceptibility of the long isolated forests to invasion has been discussed (Chapter 27). Irrespective of the original vector, it appears that aggressive, introduced species can spread rapidly through the forests, doubtless to the detriment of the indigenous flora. *Maesopsis* is one such - introduced plant which has recently expanded its range to include a large area of 'natural' forest.

The rapid colonisation of large tracts of forest by *Maesopsis* has been achieved through the tree's apparent ability to act to some extent as both a 'pioneer' and a 'primary forest' tree. This is further discussed in Chapter 27. The idea that at least part of the capability of *Maesopsis* to invade and establish itself within the natural forest may be due to the strategy of roots adopted prompted further study.

2.2 The distribution of roots: a changing view

Paradoxically, in view of the lush vegetation they can support, tropical soils are often infertile. In the absence of an external supply of nutrients, other than those dissolved in the through-flow and stem-

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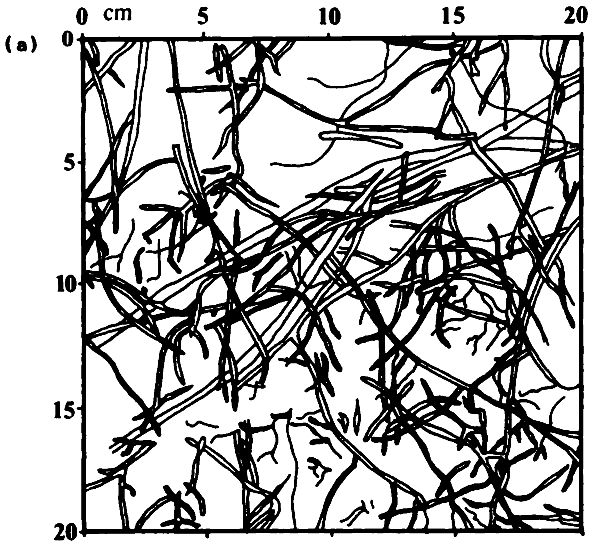
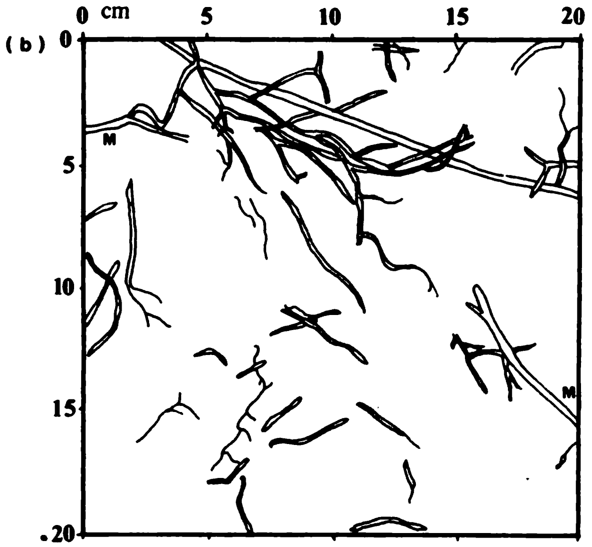


SUBMONTANE FOREST



MAESOPSIS FOREST

Figure 30.2 Scale diagrams of roots in the upper 5 cm of soil in 20 cm x 20 cm grids in two forest types:
(a) in little disturbed submontane forest (Kwamkoro, 950 m) and
(b) in a Maesopsis plantation (Amani, 910 m).
Minimum root diameter drawn 0.75 mm. 'M' indicates Maesopsis eminii root.

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flow water, and with few available sites for cation bonds within the mineral soil itself, nutrients in many tropical soils are likely to be in short supply and to be 'locked up' in the organic matter (Colinveaux 1986).

Due to the high leaching potential of the warm rains, any nutrients released on decay of detritus would quickly be lost from the system, were they not rapidly taken up by the numerous plant (and mycorrhizal) roots which ramify through the surface soil horizons. Thus, under oligotrophic conditions, there would appear to exist an almost 'closed' cycle of nutrients between the decaying detritus and the actively absorbing roots.

Plant ecologists have traditionally generalized about the 'shallow-rootedness' of tropical forest trees (e.g. Chevalier 1916). Unfortunately they were in most cases assuming that all tropical soils could be classified as infertile, with a consequent concentration of available nutrients near the surface, where organic matter is greatest, and based their conclusion on rather limited observations on the apparent rooting depths of, mainly, wind-toppled trees.

Under a regime where nutrients are difficult to obtain and limited to the upper few centimetres of soil, and in an apparently stable forest environmment, generalisations about rooting depth and strategy may seem justified. However, infertile soils are not ubiquitous in the tropics. Soil nutrient content can, under certain circumstances, be boosted through an external source, such as volcanic dust, river-borne sediment or, especially in areas where the onset of soil genesis has been relatively recent, the chemical weathering of rock. Under such circumstances, soil fertility will be higher, with a more even distribution of nutrients throughout the soil and less of a need for their conservative cycling. Even within the 'infertile' regions, temporary eutrophication will occur. During the process of vegetation succession, for example, changes may take place in both the amount of nutrients and their location. Disruption of the cycle between the organic matter and roots can lead to loss of valuable nutrients from the system and a consequent need for their replacement. Thus, cycles of nutrients in tropical forests are not 'closed' but open, the degree of openness being variable (Deshmukh 1986). Finally, the stability of tropical forests is somewhat illusory. Species there are affected by similar environmental stresses to those experienced in more temperate vegetation, such as mass movements of soil, especially on steep slopes, and the exposure of their canopies to strong winds.

Considering the above, over the full range of edaphic conditions tropical trees would not benefit from a total dependence on shallow roots and can be expected to exhibit a degree of variation in root development similar to that found in temperate forests. The ability of some species to exhibit a high level of accommodation in rooting strategy is fully displayed when the rooting systems of different ecotypes of the same equatorial species are compared (Kerfoot 1963); there is a great deal of variety in root depth, not a rigid production of shallow roots independent of environment.

The view that a large part of the rooting behaviour of tropical trees is a consequence of the environment, especially after the initial stages of development, has received support from recent research (Jenik 1971). Thus, we can envisage the root/soil relationship as being dynamic, with changes in the soil nutrient and water regimes being represented locally by a high turnover of roots (Fitter 1976; Reynolds 1975) and regionally by a broad spectrum of root depth.

2.3 The importance of root investigations

Our knowledge of the rooting systems of trees is limited, mainly because of their inaccessibility. Quantitative studies on the below-ground biomass of tropical forest trees suggest that it may form a considerable part of the total, e.g. 20% (Basilevia & Rodin 1968) or 27% (Klinge 1973). However, the importance of root studies lies not only in accurate estimations of phytomass; an understanding of root/soil relationships may provide the key to many problems, especially those which concern plant competition (Scully 1942).

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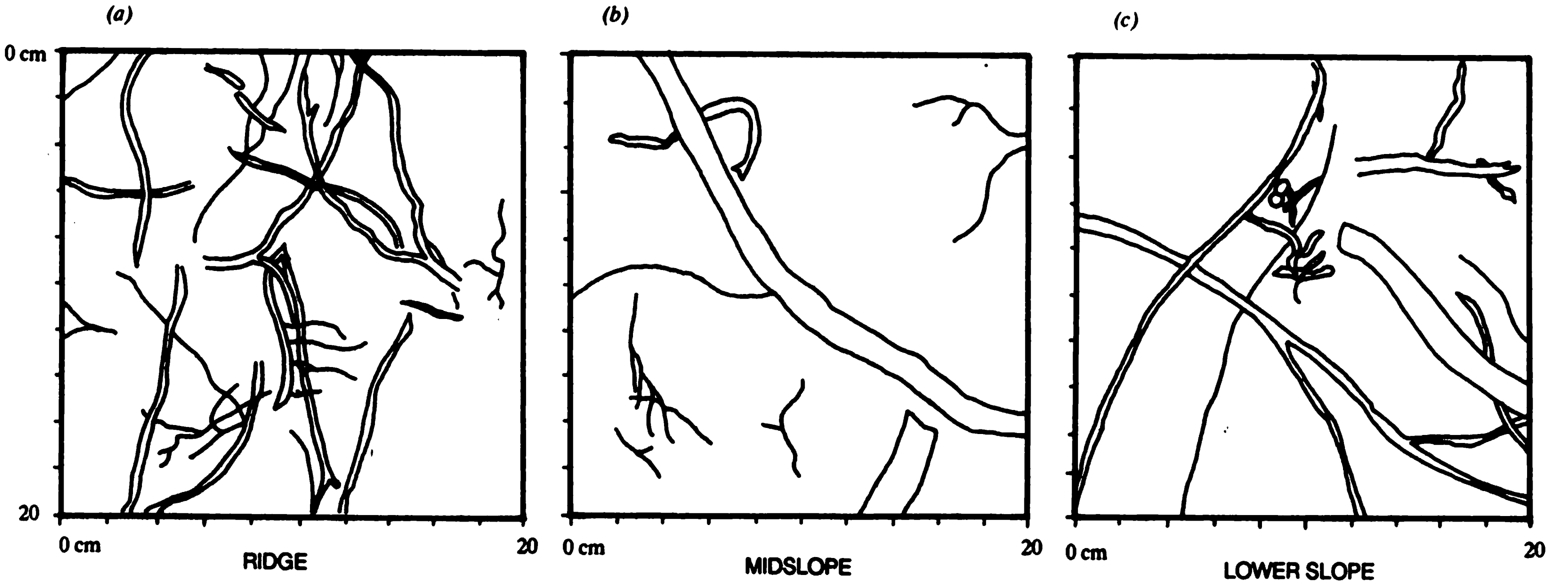

Figure 30.3 Scale diagrams of roots in the upper 5 cm of soil in 20 cm x 20 cm grids in Kwamgumi Forest Reserve (altitude 215 – 230 m), at three positions along the catena: (a) on the ridge (b) on the mid-slope and (c) on the lower slope. Minimum root diameter drawn 0.75 mm.

3. Materials and methods

The survey was completed during the months of April and May 1987 in the East Usambara forests.

3.1 Materials

The patterns of superficial roots were examined in Kwamkoro and Kwamgumi forests and in a *Maesopsis* plantation close to Amani village.

Both Kwamkoro (altitude 920–980 m) and Kwamgumi (altitude 215–260 m) are extensively described elsewhere in this report (especially in Chapter 25). The part of Kwamkoro examined varies from disturbed to more or less natural submontane forest, whilst Kwamgumi forms part of the formerly extensive lowland forest and is more or less undisturbed. The now seemingly abandoned *Maesopsis* plantation forest at Amani (Chapter 27) was planted in 1913. It occurs at a similar altitude (910 m) to Kwamkoro and, apart from experiencing a slightly lower rainfall, is environmentally very similar.

Studies were made of topsoil pH and earthworm numbers in Kwamkoro Forest and the *Maesopsis* plantation, as supplements to Macfadyen's work (Chapter 31).

Finally, the complete rooting systems of a selection of trees in Kwamkoro Forest were investigated to determine whether there were any obvious differences in strategy. The species were chosen to cover a range of 'life strategies', including secondary forest trees (*Harungana madagascariensis, Macaranga capensis & Maesopsis eminii)*, tall primary forest trees (*Allanblackia stuhlmannii, Anisophyllea obtusifolia, Cephalosphaera usambarensis, Newtonia buchananii & Parinari excelsa*) and an understory primary forest tree (*Sorindeia madagascariensis*).

3.2 Methods

As far as possible the standard techniques of root investigation were followed (Bohm 1979). Most recent work on roots (e.g. Jenik 1971) criticises any suggestion of there being a dependable relationship between root diameter and function. I would agree with such criticism and appreciate that the roles of roots (uptake of water and nutrients and anchorage in the soil) are not necessarily dividable, in the field, into morphologically distinguishable parts. However, it is assumed here that the primary function of the finest root fraction is cation uptake from the soil, with in-soil stability being, generally, the responsibility of the thicker, older and more suberized roots.

The methods of assessing root density and abundance used in this study can be further criticised in that they take no account of the dynamics of root development (living and dead roots were not separated and the period of study was short) and tend to favour, in their design, the larger and horizontally displaced roots (see also Price 1965; Russel & Ellis 1968).

3.2.1 Superficial and near-surface root drawings

The litter and upper 5 cm of mineral soil were carefully removed in an area of 'typical' natural forest (i.e. away from obvious signs of disturbance etc.). A grid was then laid out on the forest floor and the angle of slope and aspect of the site noted.

At Kwamkoro and in the *Maesopsis* forest two grid sizes were chosen, 50 x 50 cm and 20 x 20 cm, the grids in the two forests occupying roughly similar positions on slopes of an equal gradient. Illustrations from the larger grid attempted to depict root density (only roots with a diameter of at least 1 mm were considered), whilst those from the 20 x 20 cm grid concentrated upon the sizes of roots (minimum size drawn = 0.75 mm). Where possible, roots were identified. At Kwamgumi only the smaller-sized grid was used and variations of root distribution along the catena were investigated.

3.2.2 Determination of root dry-weight variation with depth

Two soil monoliths were collected, at sites close to the surface root surveys, in both Kwamkoro Forest and the *Maesopsis* plantation. Each of the monoliths measured 25 x 25 cm in plan and 100 cm in depth. The monoliths were subsampled before the roots were extracted by sieving and floatation. The roots

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were then washed, separated into different size-classes and finally dried in an oven at 107°C for 7 days. After drying, the roots were weighed and mean dry weights of roots (mg cm^{-3} of soil) were plotted against depth.

3.2.3 Determination of soil pH and abundance of earthworms

Surface soil samples under the litter were collected from both Kwamkoro Forest and the *Maesopsis* plantation. Soil pH was then estimated using a portable pH probe. Thirty sites were chosen, fifteen in each forest, the sample points being located along transects placed at an angle of 90° to the direction of the valley bottom.

Sample sites for estimating earthworm abundance were 0.5 x 0.5 m quadrats adjacent to those used for measuring soil pH. Earthworms were 'encouraged' to come to the surface by removal of the litter and application of a dilute solution of formalin to the soil surface. The numbers of worms emerging over a 15-minute period were noted.

3.4 Investigation of complete root systems

The complete root systems of a number of selected submontane forest tree species of different sizes were described and drawn. A note was made of the devlopmental stage of the plant, the trunk diameter and, where possible, height and age. Any unusual morphological features were recorded.

The smaller plants were carefully excavated and their root systems drawn. A grid was used to assist with the drawing, great care being taken to ensure that all roots were drawn according to their original positions within the soil body. For sizes too large to excavate, use was made of root systems exposed at the sides of the freshly cut logging tracks, which are abundant in parts of Kwamkoro Forest today.

4. Results

4.1 Superficial and near-superficial root drawings

4.1.1 Kwamkoro

Fig. 30.1 shows that virtually the whole of the area within the 50 x 50 cm plot is covered by a dense mat of both superficial and near-surface roots, while Fig. 30.2 suggests that a large proportion of these roots are of the smallest (and physiologically most active) size class. Almost all the surface roots belonged to forest trees. Trees and shrubs recorded near the plot include (* denotes roots positively identified as occurring within the plot): *Alchornea hirtella**, *Allanblackia stuhlmannii*, *Cola sp.**, *Cynometra* sp., *Maranthes goetzeniana**, *Myrianthus holstii**, *Tricalysia anomala** and *Whitfieldia elongata*.

4.1.2 *Maesopsis* plantation at Amani

Root density in the upper 5 cm of soil is much less here than in Kwamkoro Forest (Figs. 30.1 & 30.2). The majority of the smallest fraction of superficial and surface roots belong to shrubs, including the introduced *Coffea robusta*, which is abundant in the understory. *Maesopsis* roots are relatively easy to identify, being a distinct red colour, and, although present, are rare, tending to be thick and 'woody' in appearance.

Apart from *Maesopsis*, small individuals of *Newtonia buchananii* and *Trema orientalis* were noted within the plantation. However, apart from the planted *Maesopsis* there were no other large trees. Regeneration, even of *Maesopsis* from seed, appears to be hindered beneath the *Maesopsis* canopy. In addition to *Coffea*, shrubs and herbs identified (all with roots in the upper 5cm of soil) were *Culcasia 'scandens'*, *Clidemia hirta* and *Tragia* sp.

4.1.3 Kwamgumi

Three sites were investigated, each at a different position along the catena at altitudes of between 215 and 230 m. The sites are those used for profile diagram plots (Chapter 25). The highest density of

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roots occurred on the ridge, although maximum densities were much less than in submontane forest and did not exceed those of the *Maesopsis* plantation. (Fig. 30.3).

4.2 Determination of root dry weight variation with depth

Fig. 30.4 shows that total mean root weights are generally much greater in submontane forest than in the *Maesopsis* plantation, the lowest sample level (50 – 100 cm) being exceptional.

At both sites, maximum weights cm^{-3} of soil occur in the 3 – 6 cm level for all size classes. Below this peak, root abundance generally declines with increasing depth, anomalous levels being 50 – 100 cm (*Maesopsis* plantation) and 25 – 50 cm (Kwamkoro) where root weight increases.

When only the finest root fraction (diameter 1 cm) is considered, root weights cm^{-3} decrease with increasing depth at both sites. The 0 – 1 cm diameter category is likely to include a high proportion of the physiologically more active roots, that is those whose primary role is active uptake of nutrients and water from the soil. It is significant that they occur mainly in the upper reaches of the soil profile, particularly above 12 cm. Highest nutrient concentrations are thought to occur in the upper ca. 20 cm of soil (Chapter 10).

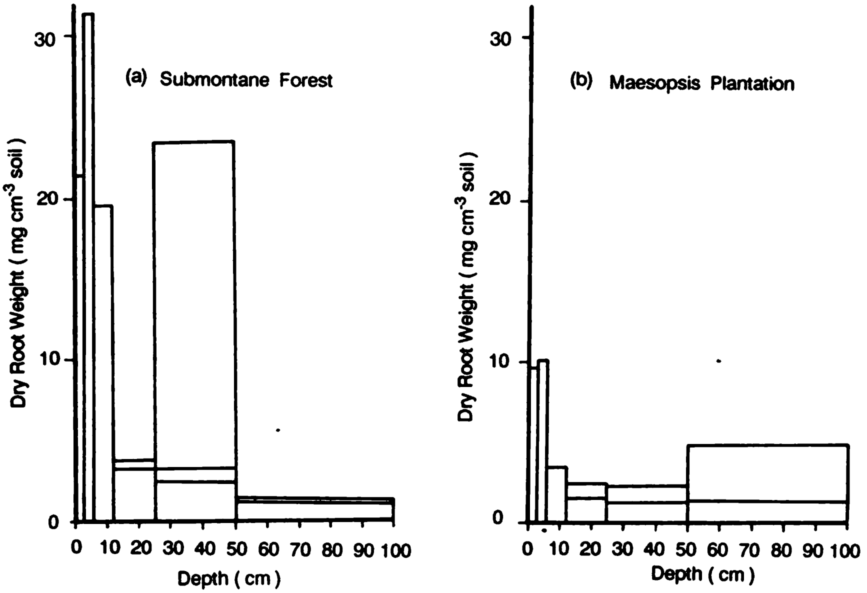

Figure 30.4 Root distribution with depth in in two forest types: (a) submontane forest (Kwamkoro) and (b) Maesopsis plantation (Amani). Note the greater root weights in submontane forest.

4.3 Determination of pH and abundance of earthworms

4.3.1 General description of litter and topsoil

Kwamkoro: There was a general feeling of moistness in this forest. The topsoil was crumbly, perhaps due to the activity of the large and numerous millipedes. The deep litter mainly consisted of decaying leaves, through which ramified many fine roots. It was observed that little rain fell directly onto the forest floor during storms.

The *Maesopsis* plantation: The canopy was more open than in the forest at Kwamkoro and the environment much less humid. Leaf litter was virtually non-existent with small branches making up the

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largest part of the detritus (*Maesopsis* is a self-pruner). Millipedes were not in evidence, the topsoil appeared far more compact and there were noticeably fewer superficial and surface roots than at Kwamkoro. Unlike Kwamkoro, a large part of the rain tended to fall uninterrupted onto the forest floor, leading to much surface run-off. During a particularly heavy storm it was observed that numerous rivulets quickly developed on the floor of the plantation.

4.3.2 pH and earthworm abundance

Results are shown in Table 30.1. Topsoil samples from the *Maesopsis* plantation have a mean pH value noticeably higher (6.2, range 5.8–6.8) than those from natural forest (4.2, range 3.4–5.4). Earthworms are more abundant in the *Maesopsis* plantation (mean number of worms per site = 7.3) than in natural forest (mean = 4.3). The species involved do differ, with more of the large species 'A' in natural forest and the small species 'B' in Maesopsis forest (Table 30.1).

Table 30.1 Numbers of earthworms in 50 cm x 50 cm plots and associated soil pH in Maesopsis plantation (samples 1–15) and submontane forest (samples 16-30). Earthworms are of two types, a large species (type A) and a small species (type B).

***Maesopsis* plantation**

Sample no.	Position on slope	Angle of slope (degrees)	Number of earthworms (type A)	Number of earthworms (type B)	pH
1	upper	28	0	14	6.2
2	"	30	0	4	6.5
3	"	31	0	4	6.4
4	"	27	0	6	5.7
5	"	30	0	1	5.9
6	middle	36	0	8	6.4
7	"	28	0	17	6.2
8	"	26	0	5	5.9
9	"	30	0	15	5.8
10	"	27	0	3	5.8
11	lower	28	0	13	6.6
12	"	29	0	5	6.8
13	"	12	0	5	6.1
14	"	30	0	3	6.6
15	"	32	0	6	5.8
Means		28.3	0.0	7.3	6.2
Submontane forest					
16	top	10	0	0	5.3
17	"	15	7	2	5.0
18	upper	15	0	6	3.6
19	"	19	1	0	3.8
20	"	31	2	2	3.4
21	middle	26	1	3	3.8
22	"	24	0	3	3.9
23	"	24	0	1	3.6
24	"	16	1	3	5.4
25	"	17	0	17	4.9
26	"	13	0	10	4.9
27	lower	29	0	4	4.3
28	"	25	0	1	3.6
29	"	32	0	0	4.1
30	"	24	0	0	3.5
Means		21.3	0.8	3.5	4.21

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4.4 Investigations of complete root systems (Fig. 30.5)

All species examined, including *Maesopsis* in the natural forest, possessed both lateral and deep tap roots. Along with the measurements of root abundance with depth, these results would tend to refute the idea that tropical forest trees are characteristically 'shallow-rooters'. Unfortunately the method of examination made it difficult to quantify accurately the physiologically more active roots, as these, being fragile, would tend to be damaged and subsequently lost when road-cuttings were made or the root system excavated.

4.5 Casual observations on roots

Both *Alchornea hirtella* and *Parinari excelsa* were seen to regenerate by root-suckers. Surface roots of *Alchornea* formed mycorrhizal 'fans' (*sensu* Weaver & Kramer 1932). Sub-surface lateral roots of *Allanblackia stuhlmannii* exhibited apogeotropism. A noticeable feature in Kwamkoro was the great lateral extent of some roots. *Maranthes goetzenii*, for example, had a radius of roots almost equal to the height of the tree (32 m compared to 40 m).

5. Discussion

Although species of trees at the two sites do differ, it is most likely that variations in the rooting density at Kwamkoro and Kwamgumi are related to differences in nutrient availability. In less fertile soils, roots are reported to be more numerous (Huttel 1975; Vitousek & Sandford 1986) and it is, therefore, perhaps not surprising to find that the highest concentration of roots occur in the least fertile, submontane soils (Chapter 10). Differences in fertility could also explain the catenary variation observed at Kwamgumi, where soil on the ridgetop was found to have a higher density of surface roots than the lower parts of the catena.

Variations in overall root density between Kwamkoro and *Maesopsis* forests may, similarly, be due to differences in fertility. This would also explain the pH differences betwen the sites. Before removal of the natural forest and planting of *Maesopsis* at the Amani plantation, the soils would probably have been similar in pH and nutrient status to those of Kwamkoro (which is closely situated at the same altitude and shares the same type of bed rock). The increased pH in the plantation soil could have arisen through the pumping of nutrients to the surface by *Maesopsis* and an increased rate of decomposition of the more nutrient-rich organic matter (Hogberg 1986) in the less humid environment (Birch & Friend 1956).

The dependence of *Maesopsis* within the plantation upon a reservoir of nutrients at depth in the soil could explain the noticeable lack of unsuberized roots of *Maesopsis* near the soil-surface. Instead, the bulk of surface and superficial roots within the plantation belong to the numerous herbaceous and shrubby plants. This is quite unlike the natural forest, where the majority of the surface roots belong to trees.

In the natural forest, opening of the canopy provides conditions favourable for the colonisation by *Maesopsis*. Not only is more light allowed to reach the forest floor, but also accelerated decomposition of litter may occur as a result of the decreased humidity. Opening-up of the forest would cause the normally efficient nutrient cycle between litter and roots to be temporarily interrupted and cause valuable nutrients to be lost to the subsoil. *Maesopsis*, by concentrating, at least in its early stages, on a strategy of deep, vertical and actively absorbing roots, would be less affected by this upset in the nutrient cycle and, indeed, would be able to recover some of the nutrients lost to the subsoil through leaching (Jordan & Herrera 1981). Later, as the deep-seated reservoir of nutrients becomes depleted, *Maesopsis* could gradually become more dependent on its horizontal roots, which would not only compete for nutrients in the surface horizons, but which could also provide sites for root 'sinkers', thus enabling the tree to exploit further areas of subsoil while persisting as a 'primary forest' species.

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Results of seed bank studies (Chapter 29) suggest that viable *Maesopsis* seeds occur in topsoil from a *Maesopsis* plantation. A few small seedlings of *Maesopsis* and *Newtonia* may be seen in the *Maesopsis* plantation whenever the canopy becomes more open. However, nowhere are there the dense carpets of *Maesopsis* seedlings sometimes seen in degraded natural forest. Nor are there seedlings of primary forest trees, apart from the occasional *Newtonia*. *Maesopsis* is somehow preventing other species from regenerating, maybe directly through the production of allopathic compounds or indirectly as a consequence of an alteration in pedological conditions and a less humid micro-climate.

Consequences of a dense *Maesopsis* cover appear to be an increase in the pH of the surface soil horizons, changes in the amount and type of litter and soil fauna, a higher rate of soil erosion and a less humid micro-climate. *Maesopsis* may also exert a strong influence on the vegetation beneath its canopy; conditions there are apparently inimical to the establishment of many species of the natural forest.

The suggestion that *Maesopsis* may owe some of its success in colonizing submontane forest to a rooting system which is more flexible than that of many of the indigenous trees is possible and worth further study.

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Acknowledgements

The following deserve thanks for allowing me the opportunity to visit Tanzania: the Tanzanian Government, my parents, Alan Hamilton (and extended family) and Robert Bensted-Smith and the other staff of IUCN in Nairobi. Further thanks are also due to Mr. C.K. Ruffo and Mr. R. Abdallah for help (and entertainment) in the field, the 'Dutch in Muheza' for food, Dr. Mike Bruen for allowing me a room while staying in Dar es Salaam, Professors Macfadyen and Schmidt and Pierre Binggeli for useful discussions and Mrs. Linda Southall.

Soil profile exposed at the side of logging truck, Kwamkoro Forest Reserve, 950 m. Note the dense root mat in the uppermost soil layer and the deep (red and infertile) subsoil below. July, 1986.

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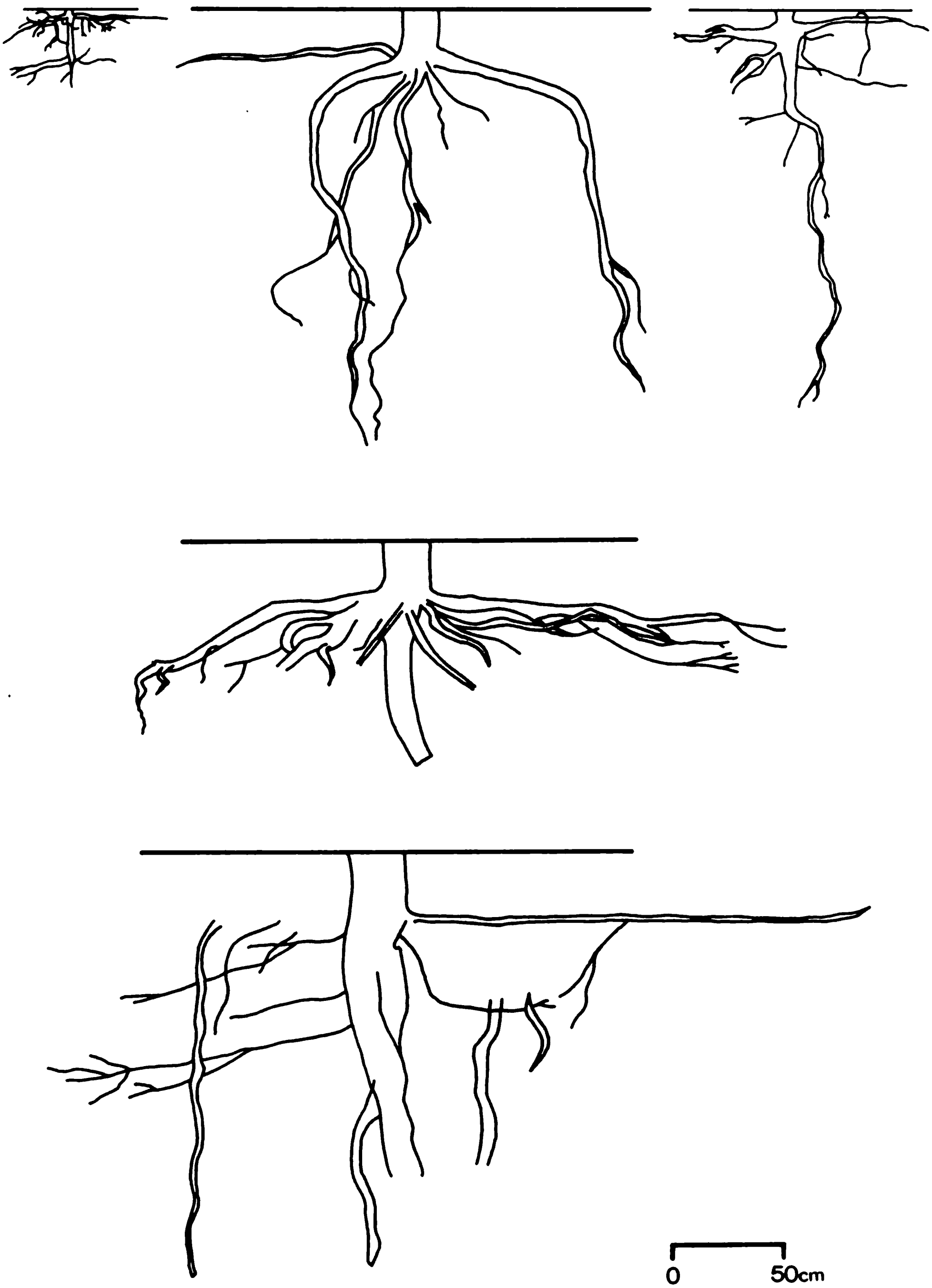

HARUNGANA MADAGASCARIENSIS

Figure 30.5 Root profiles of selected species in submontane forest.

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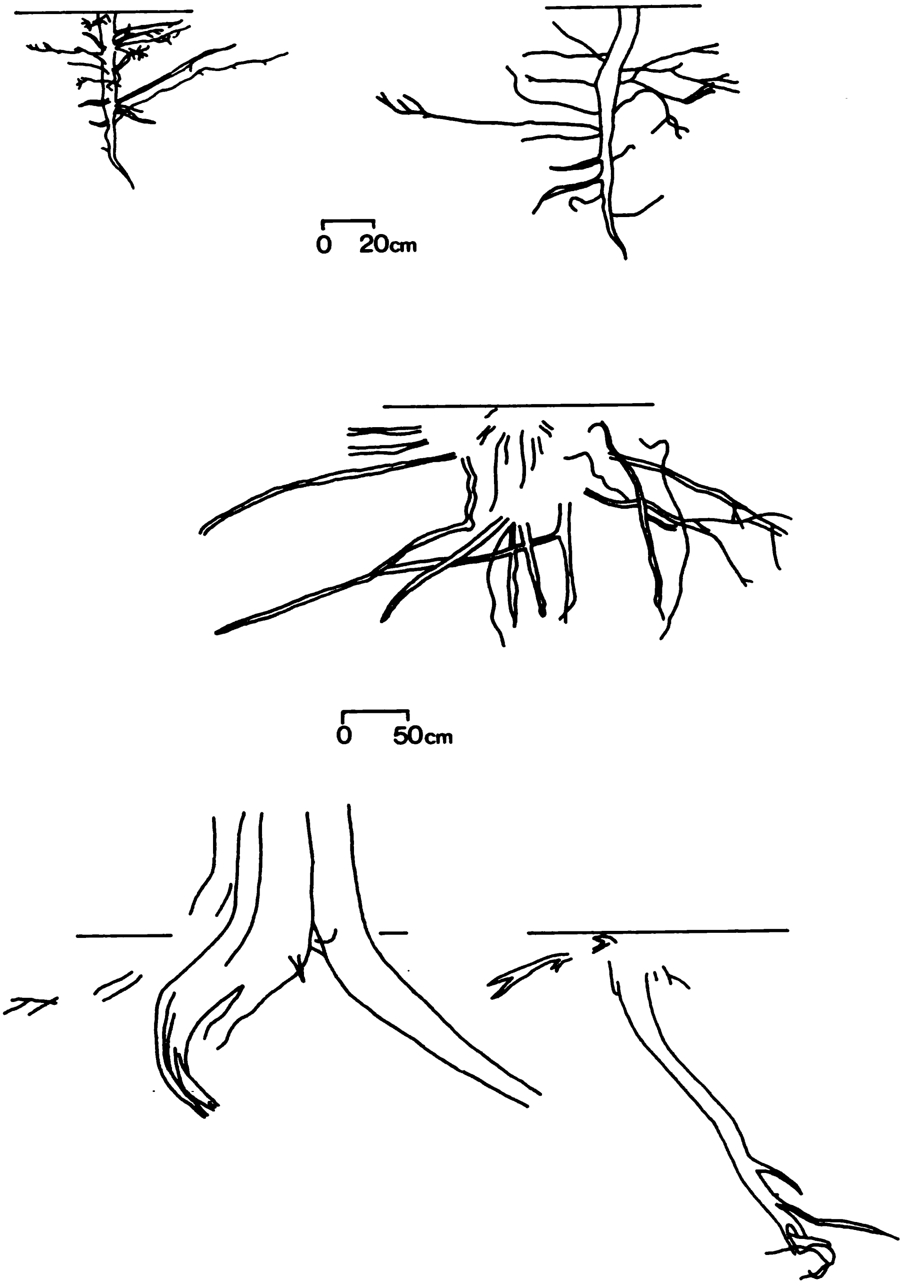
ALLANBLACKIA STUHLMANNII



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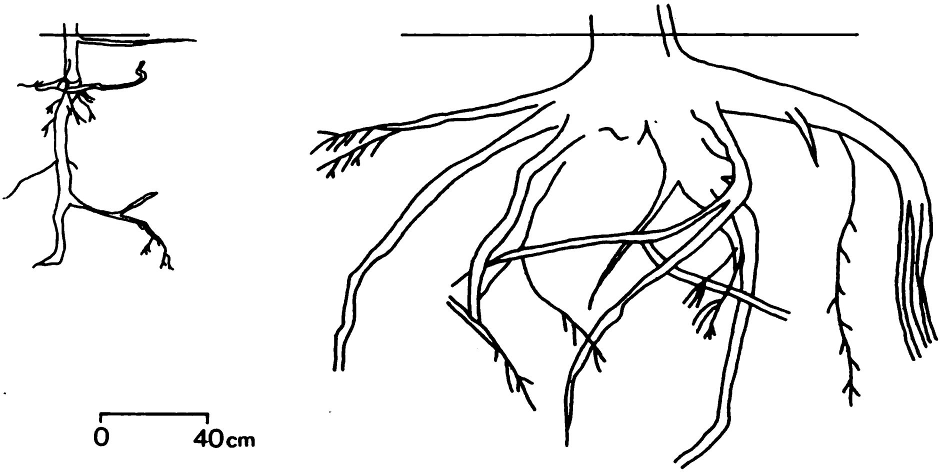
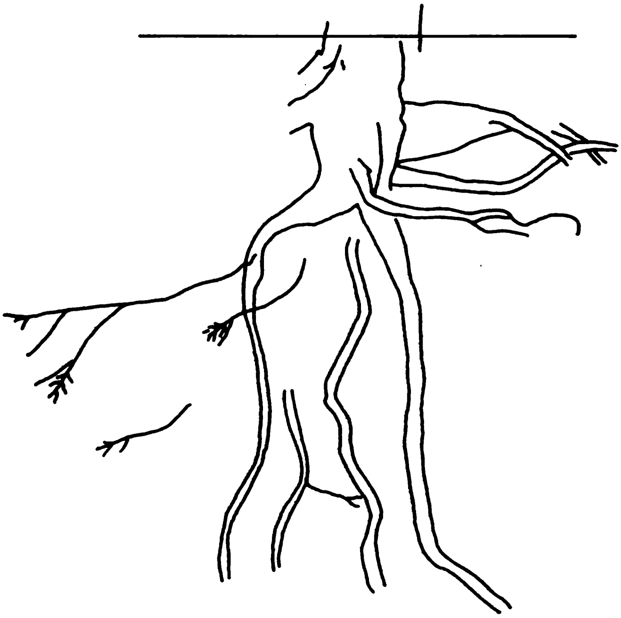
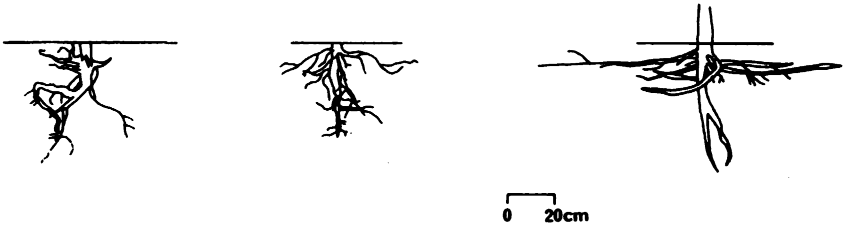
NEWTONIA BUCHANANII

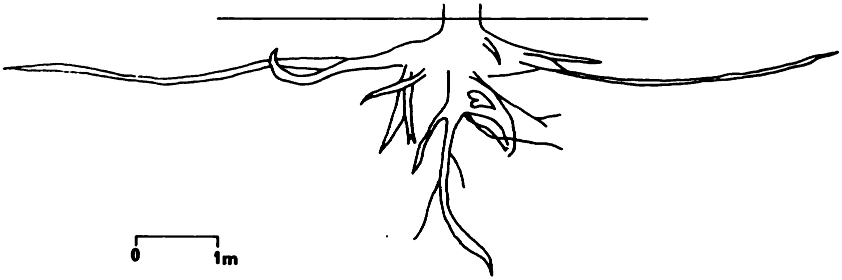


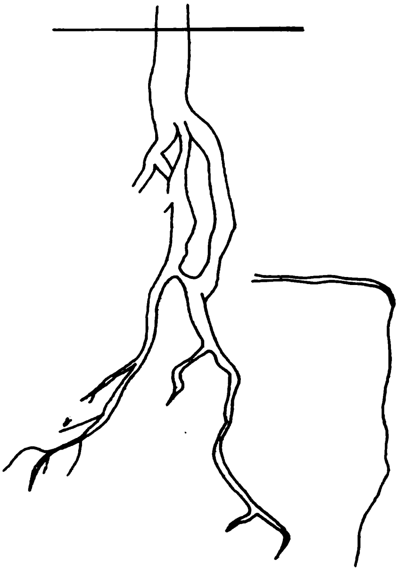


SORINDEIA MADAGASCARIENSIS

MAESOPSIS EMINII







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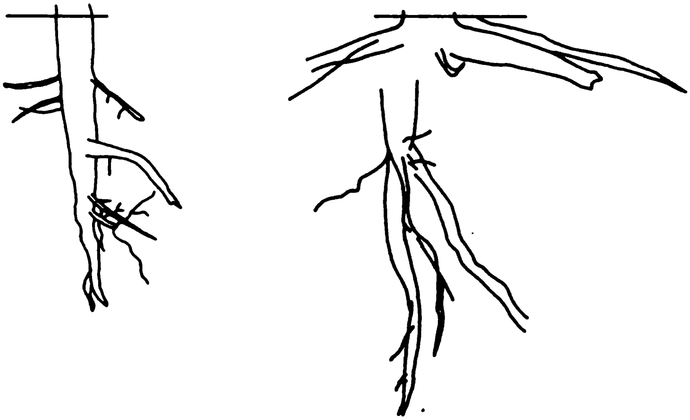
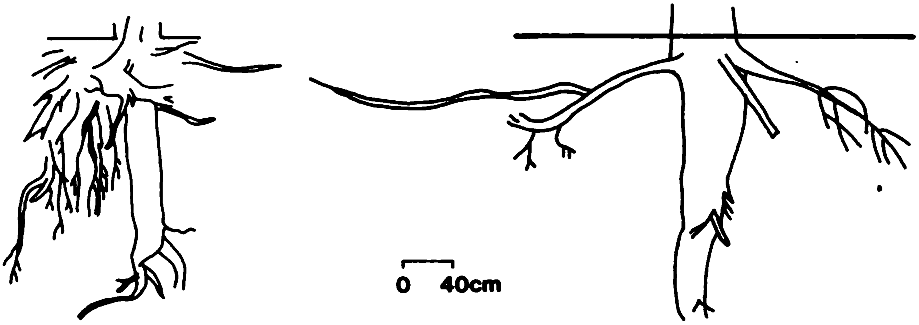
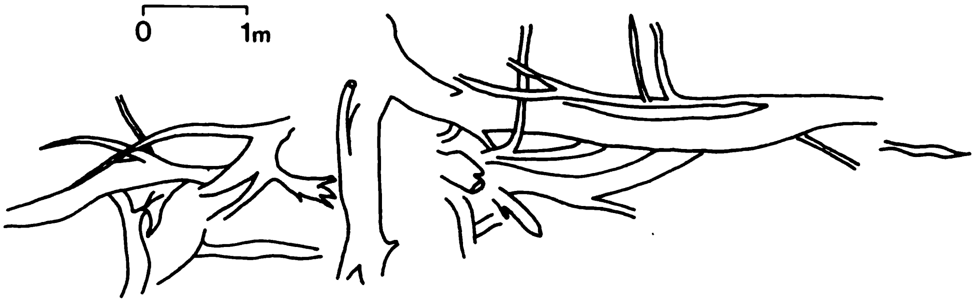
ANISOPHYLLAEA OBTUSIFOLIA



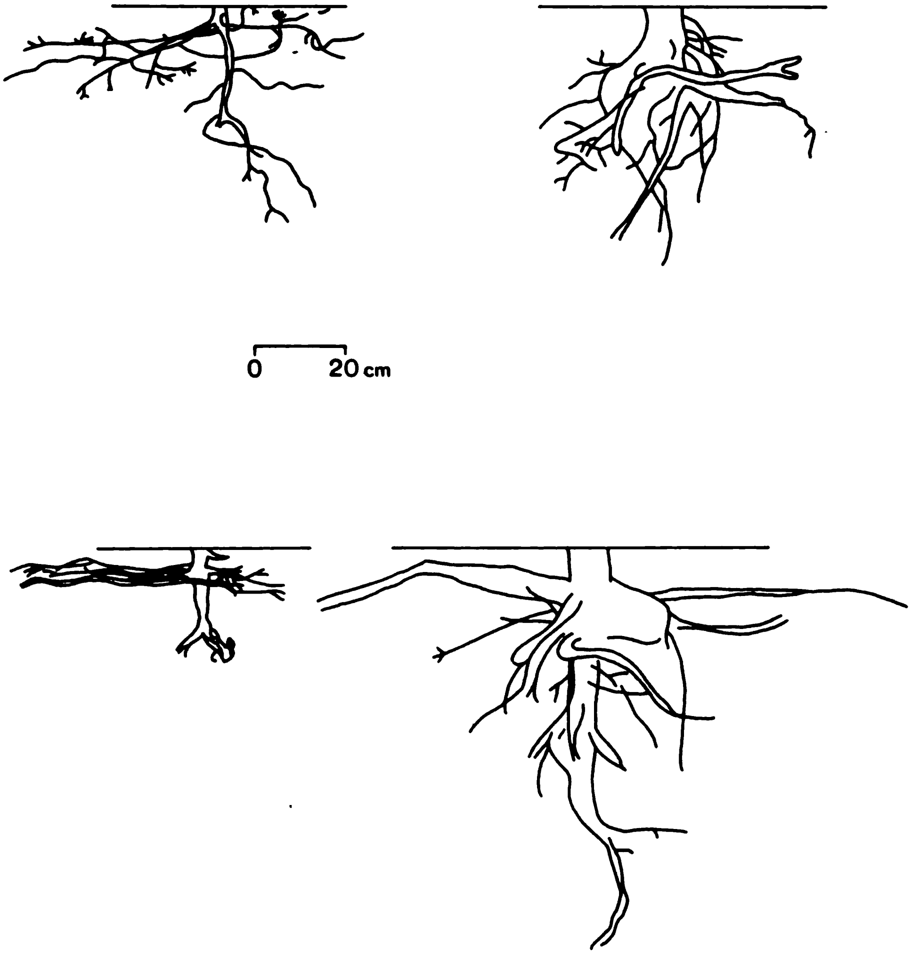
CEPHALOSPHAERA USAMBARENSIS



PARINARI EXCELSA



MACARANGA CAPENSIS



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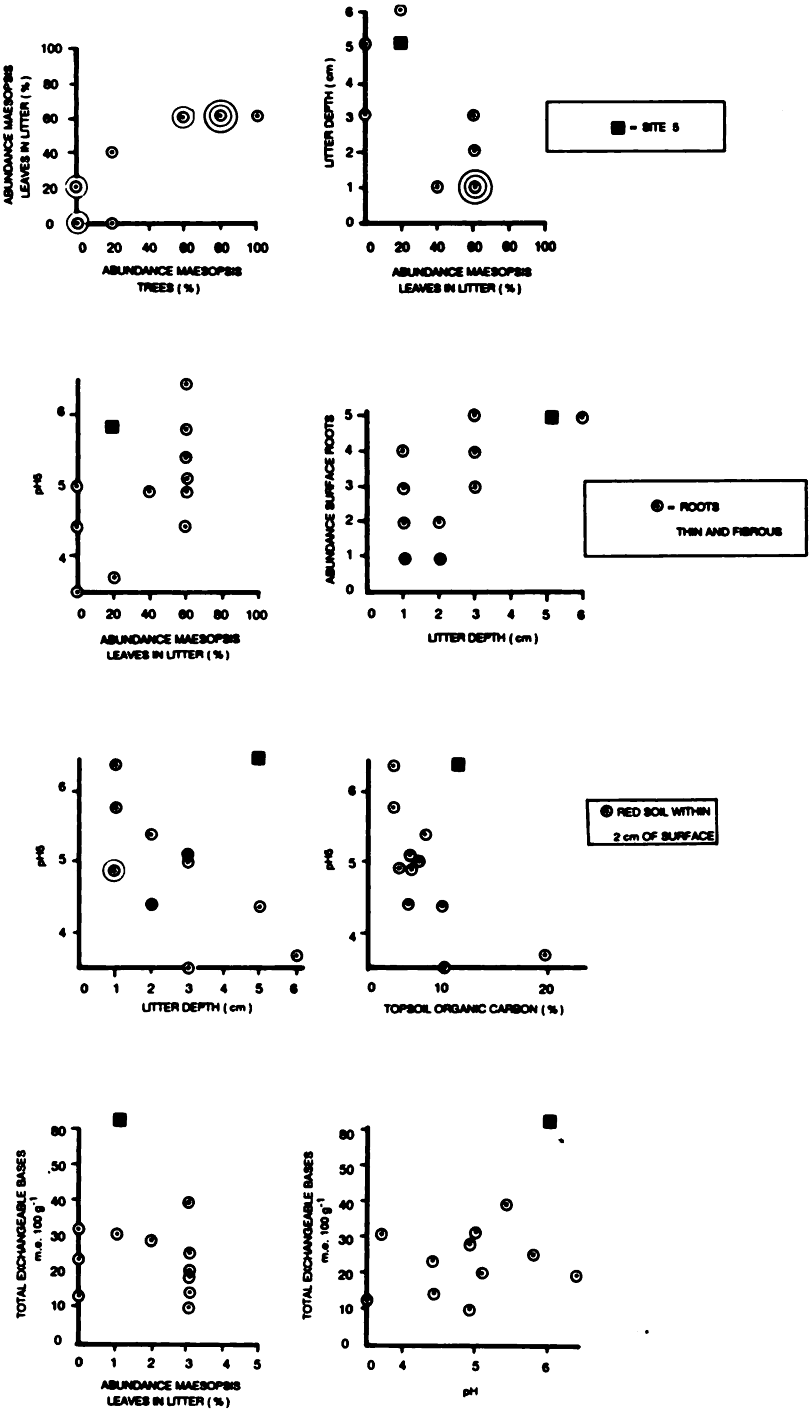

Fig. 30a. 1 Relationships of some vegetation and soil variables, along a transect extending from Maesopsis-dominated forest into natural forest.

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30a. Some Effects of *Maesopsis* on Litter and Soil on the East Usambaras

by A.C. Hamilton

After completion of the main soil studies, laboratory analyses were carried out on the effects of *Maesoposis* on litter and soil.

1. Background and methods

Work by Macfadyen, Mahunka and Taylor (this volume) has suggested that the presence of *Maesopsis* causes changes in the characteristics of the litter, soil fauna and other soil characteristics in comparison to natural forest. A study was undertaken in November 1987 to examine the question further. Twelve topsoil samples were collected at 10 m intervals along a transect line running along the slope (angle 25°) and extending from the old German *Maesopsis* plantation just below the Rest House at Amani into adjacent tall forest composed of indigenous species *(Allanblackia, Chrysophyllum, Englerodendron, Maranthes, Mesogyne, Parinari, Sorindeia)*. The following characteristics were noted at each site or measured on soil samples taken back to the University of Ulster:

- Relative abundance of *Maesopsis* trees to other trees within 15m of each site, estimated to the nearest 20%.
- Relative abundance of *Maesopsis* leaves to other leaves in the litter at each site, estimated to the nearest 20%.
- Thickness of litter (cm).
- Density of roots in the upper 2 cm of soil under the litter, recorded on an arbitrary 5-point scale (5 being most abundant).
- Measurements made on the upper 2 cm of soil under the litter:
  - Organic carbon by wet oxidation (modified Tinsley method as recommended in Kalembasa and Jenkinson (1973).
  - pH in $CaCl_2$ (Avery & Barcomb 1974).
  - exchangeable Ca, Mg, Na and K (Avery & Barcomb (1974).

2. Results (Fig. 30a.1)

Sample 5 is anomalous, with a much higher level of exchangeable bases than the other samples and an unusually high pH for its organic carbon content. Abundant millipede faeces were noted in this sample, suggesting a possible cause which could be further studied.

Exchangeable bases are notably abundant compared with the results of earlier work on the submontane forest soils (Chapter 10), a discrepancy which is not easily explained, although the shallower sampling depth may have contributed. Variations in the amount of exchangeable bases are

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not obviously related to other variables, such as organic carbon, as might be expected. This may be because the organic carbon fraction includes a great variety of substances, not just humus.

With the exceptions noted above, the results show clear relationships between the variables. Increasing abundance of *Maesopsis* trees is associated with a greater abundance of *Maesopsis* leaves in the litter, thinner litter, less organic soil and a higher soil pH. It was also observed in the field that soils under *Maesopsis* also contain abundant small *Maesopsis* branches in the litter, often contain only thin fibrous rootlets and lack the chubby mycorrhizal rootlets characteristic of natural forest, show the presence of red, clay-rich, soil near or at the surface and show obvious signs of soil erosion.

3. Conclusions

These results confirm earlier suggestions that *Maesopsis* radically alters the characteristics of the litter and topsoil. A full study of nutrient cycling is desirable. The evidence of increased soil erosion under *Maesopsis* is a cause for immediate concern.

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Acknowledgement

Many thanks to Debbie Rainey for carrying out the laboratory analyses.

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31. A Brief Study of the Relationships Between *Maesopsis* and Some Soil Properties in the East Usambaras

by Amyan Macfadyen

Thin upper organic soil horizons are often present beneath submontane forest, especially where slopes are less steep. These horizons disappear in gaps created by treefalls, but later reappear as the forest regrows. Organic horizons are also absent under *Maesopsis*. Reasons for these patterns are discussed. Field observations suggest that *Maesopsis* leaves decompose relatively rapidly. Feeding experiments show that *Maesopsis* leaves are relatively palatable to diplopods.

1. Introduction

Maesopsis is widely considered to be spreading rapidly in the East Usambara area and it is thought to be important to assess the effects of this spread on agriculture, forestry and forest conservation. This study aimed to determine whether there are any changes in soil properties associated with the establishment of *Maesopsis*, whether any such changes are consistent, and whether similar changes can occur under other trees or environmental conditions. The study also aimed to look for causal factors linked to such changes.

Since little over a month, at the end of the dry season, was available and since a very limited part of the mountain area was visited, any conclusions reached must be of limited value, but at least they raise questions to be investigated in further studies. It should be noted that the February – March period is one of maximum leaf fall, which facilitated the methods used but is probably associated with thicker litter layers than the annual average.

The main factors studied in order to relate them to the presence of *Maesopsis* leaf-litter were:

- the ratio of *Maesopsis* leaves to leaves of other species on unit area of the forest floor
- depths and any peculiarities of the organic soil horizons, namely Litter, Fermentation and Humus (L, F & H) layers
- any relevant observations concerning the presence and activities of soil invertebrates under different litter types.

2. Methods

The following simple techniques were used in an attempt to measure relationships between *Maesopsis* leaf litter and the properties of soil organic horizons. Preliminary measurements were made along two transects (A1 & A2), each between a *Maesopsis* tree and a tree of *Allanblackia*, which produces resistant coriaceous litter and appears to be associated with deep organic layers. This was followed by a further transect study (A3) to differentiate between the effects of slope and *Maesopsis* litter.

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Table 31.1 Leaf composition and soil horizon depth at site A1. At transect points 1 and 3 the F layer contained much mycelium. At transect points 1, 3 and 5 there was a conspicuous 'rootmat' in F and H. Isopod numbers declined from transect points 1 to 9; spiders and crickets increased.

Transect Point (metres)		1	3	5	7	9
Leaf	*Maesopsis*	45	43	47	61	48
Counts	*Allanblackia*	37	36	9	3	2
%	Other	17	21	44	36	50
Soil	L	5	4	5	3	3
Horizons	F	2	3	1	1	0.5
(cm)	H	7	2	2	1	0.5
Total LFH depth (cm)		14	9	8	5	4

Table 31.2 Leaf composition and soil horizon depth at site A2. The root mat was very evident at transect points 1, 3 and 5, patchy at 7 and absent at 9. Isopod numbers were irregular but spiders and crickets again occurred only in the last two positions. Diplopod faeces were very numerous at the first site.

Transect point (metres)		1	3	5	7	9
Leaf	{*Maesopsis*	12	14	23	31	55
Counts	{*Allanblackia*	80	71	60	23	6
%	{Other	9	14	17	46	39
Soil	{L	9	2	6	3	2
Horizons	{F	1	0.5	0.5	0.5	0.5
(cm)	{H	8	10	5	1	0
Total LFH depth (cm)		18	12.5	11.5	4.5	2.5

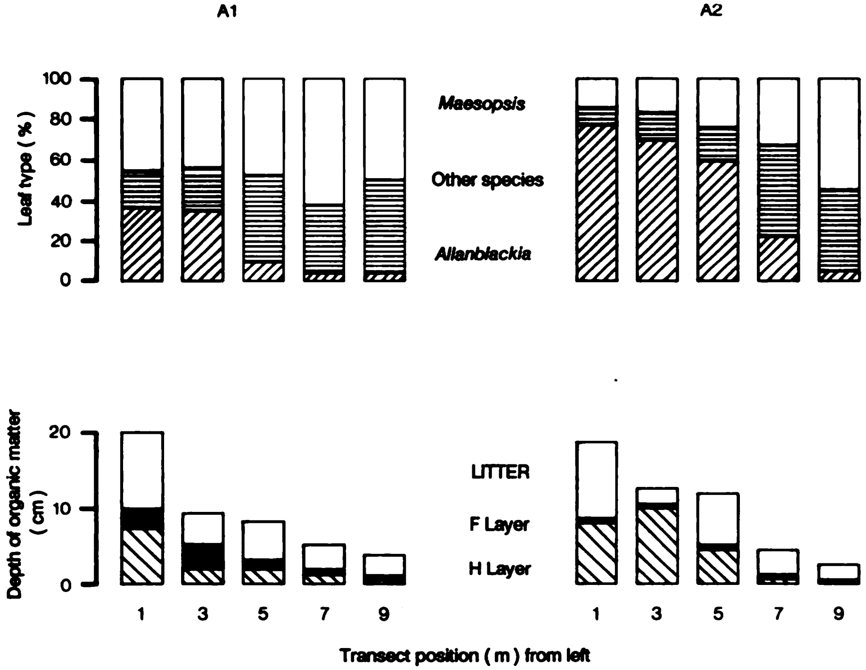

Figure 31.1 Field transects at sites A1 and A2, extending between Allanblackia trees on the left and Maesopsis trees on the right. The soil organic horizons become thinner towards Maesopsis.

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In the case of the tree fall and forest gap studies a two-dimensional sampling scheme was adopted, so as to relate site properties (leaf ratios and horizon depths) to both position along the fallen trunk and distance from the trunk at right angles.

Leaf collections were sorted on the spot into *Maesopsis* versus other categories, the latter sometimes being divided among named species. In one study the relative proportions of 'young' and 'old' leaves were measured in order to obtain an idea of the relative rates of decomposition.

Organic horizon depths were measured by means of a marked bamboo stick at a number of points and averaged. Litter (L), Fermentation (F) and Humus (H) layers were recognised and expressed by a formula such as 6/2/4, being the respective depths in cm. In addition, the presence of a mat of tree roots and evidence of diplopod and earthworm faeces were recorded.

Faunal counts were tried, simply observing any fauna which became active after exposing the F and H layers. This was not very productive and a set of 6 'Russian type' (air-dried) Berlese funnels was constructed from bamboo, string, paper and some nylon gauze. Approximate identifications were made to higher taxonomic categories, so as to detect obvious faunal changes. Some specimens have been preserved for examination by experts.

Earthworm extractions were made by the formalin method in association with Prof. Zicsi's work. Unfortunately the hoped-for heavy rains did not occur in time for extensive collections. [Editors' note: Prof. Ziczi's report is not yet completed but a comparative study of earthworm populations in natural and *Maesopsis* forests was undertaken later, during the rainy season, by Taylor – see Chapter 30.]

Feeding studies on the diet of diplopods and a few isopods were conducted in Petri dishes, the animals being offered a choice of different types of litter. Counts and weighings of faecal pellets were used to ensure that adequate amounts were consumed and leaves were checked for signs of feeding. The relevance of the choice of these two groups was that both were active in the dry season and are known to be major components of the soil fauna in some parts of the world.

Litter bags: 148 bags of nylon gauze, 1.5 mm mesh, were sewn and partly filled with fresh litter of four species. The bags were weighed empty and full, and a correction factor to dry weight determined by drying 3 replicates of each species to constant weight. Change in weight was measured on two subsequent occasions by drying and weighing the bags which have been exposed in two areas, one under *Maesopsis* and the other in natural forest.

3. Experiments and observations

3.1. Field transects, relating leaf composition to depth of soil horizons (with observations on fauna)

A number of preliminary observations indicated a consistent tendency for a reduction in depth of organic horizons under *Maesopsis* as compared with natural forest. Following this, three more careful transects were studied, as follows:

Site A1: South-west of Amani, west of road to Kwamkoro where a track doubles back towards the water extraction plant: Site slopes ca. 10°. Results are listed in Table 31.1 and illustrated in Fig. 31.1 (left-hand diagrams)

Site A2: An area of natural forest invaded by some *Maesopsis* west of Forest House 1, Amani: Site nearly level. Results are listed in Table 31.2 and illustrated in Fig. 31.1 (right-hand diagrams).

Conclusions from A1 and A2: The loss of soil organic horizons along transects from other trees towards *Maesopsis* seems clear, especially in the case of the H layer. The increase in percentage of *Maesopsis* leaf litter is convincing in A2; in the case of A1 the low figure at the final site may have been anomalous because it was in a depression where a lot of leaves of 'other' species had accumulated. The decline in *Allanblackia* leaves in the reverse direction is obvious in both transects. The fact that *Maesopsis* leaves do not reach more than 61% requires explanation. Possibly the lighter, softer leaves

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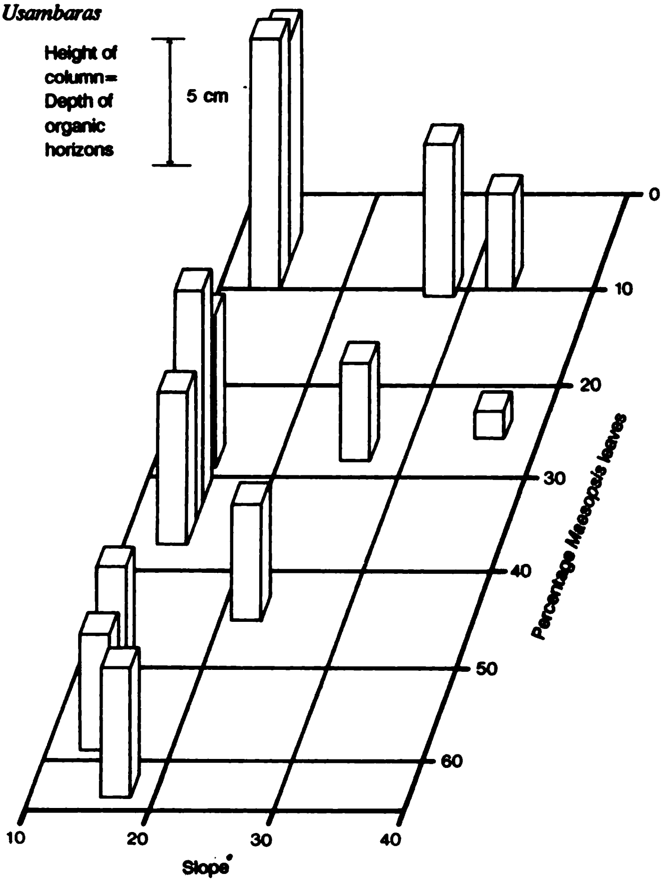

Figure 31.2 Field transects at site A3 near Amani Resthouse. The organic horizons are thickest where slopes are more gentle and where Maesopsis leaves are rarer in the litter.

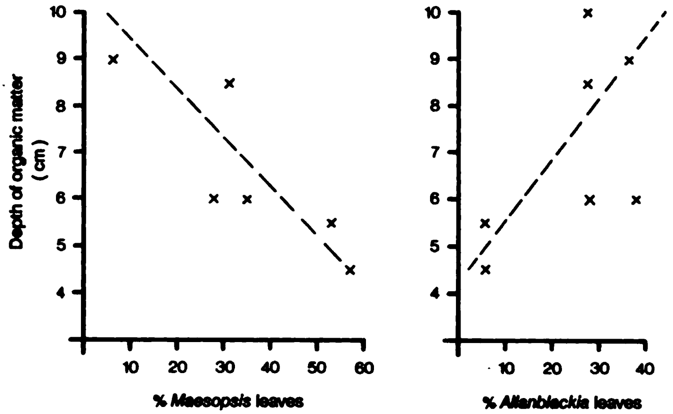

Figure 31.3 Relationship of organic matter depth to abundance of Maesopsis and Allanblackia leaves at site A3, transect X (which has a constant slope). Thickness of organic matter is lower where there are fewer Maesopsis leaves.

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coming from a relatively thin canopy drift further or, probably, due to their softer texture, they are more susceptible to faunal and microbial attack. The slightly larger numbers of spiders and crickets at the *Maesopsis* end of both transects may relate to the warming of the more exposed soil surface and, for the spiders, the likely prey which alight there from above the soil.

Site A3. Near Amani Resthouse: Two further transects were laid out, in order to differentiate between the effects of slope and *Maesopsis* litter, running in the form of a letter T at right angles. These were at the west end of the grassy terraces below Amani Resthouse, where a path slopes downward to the south from the road (leading to Kwamkoro). The path runs through a 'tongue' of natural forest sited along the summit and sides of a ridge. *Maesopsis* plantations occur in both directions (east and west) from the base of the ridge. Transect X was at constant slope, Transect Y varied in steepness.

In addition to leaf ratios between species and horizon depth measurements the angle of slope was measured with an Abney level. Along Transect X the ratio of 'young' to 'old' leaves (the criterion being continued presence of chlorophyll) was measured for *Maesopsis* and *Allanblackia* in connection with the need to assess relative decomposition rates. (See Section 4).

Fauna samples were taken along Transect X for Berlese extraction and pitfall traps were also set out along this transect. Since these transects were not (like A1 and A2) along a gradient between two contrasting tree types but encompassed a greater diversity of litter types, the horizon measurements should be related not to position along the transect, but to measured leaf ratios and slope (see Fig. 31.2).

Transect X (uniform slope, varying leaf ratios) shows a convincing relationship between increasing organic horizon depth and a decreasing proportion of *Maesopsis* leaves (Fig. 31.3). At the two sites with fewest *Maesopsis* leaves, the root mat was also absent. The results from Transects X and Y provide some evidence of reduced horizon depth with increasing slope (Fig. 31.2).

The separation of *Maesopsis* and *Allanblackia* leaves from the litter into 'young' and 'old' (see above) does show larger proportions of young in the first and old in the second species (55% vs. 25% young). While this may indicate more rapid decomposition in the former, other factors including phenology of leaf-fall could influence the ratios.

One point to remember about this study is that the site, being on a slope, was relatively well drained and in no case was a really thick humus layer found. While this supports the idea that drainage is a relevant factor, it also indicates that more obvious effects would have been found in a more nearly level site in the case of Transect X. On the other hand the fairly consistent trends shown in Fig. 31.2 are evidence that it is not necessary to to go extreme conditions to find effects related to both slope and presence of *Maesopsis* litter.

The pitfall trap results were disappointing: only large black ants were caught in numbers and these were seemingly distributed at random. A small number of isopods, a common large carabid beetle and a large grasshopper were caught.

Berlese funnel results were also not very interesting; there is a general tendency towards both greater numbers of 'species' and of individual animals as the percentage of *Maesopsis* leaves declines; i.e. high proportions of *Maesopsis* leaves are associated with a poorer fauna, especially of insect larvae and the small 'Trichonyscid' woodlice, which were found to feed best on fungus mycelium from the F-layer (notably scarce where *Maesopsis* predominates).

Site A4. The Gonja Escarpment Site: This site was visited on 17th February and again on 25th in the hope of finding a sudden transition from *Maesopsis* to natural forest and comparing soil horizons. The usual leaf litter ratios were determined, but were complicated because there was a very large number of tree species present and both natural forest tree leaves and *Maesopsis* leaves were present in approximately similar ratios in all sites. It was thought that this was due to the exposed site and near random mixing of litter by wind. If this is the case, it indicates that the other sites (A1 to A3), where

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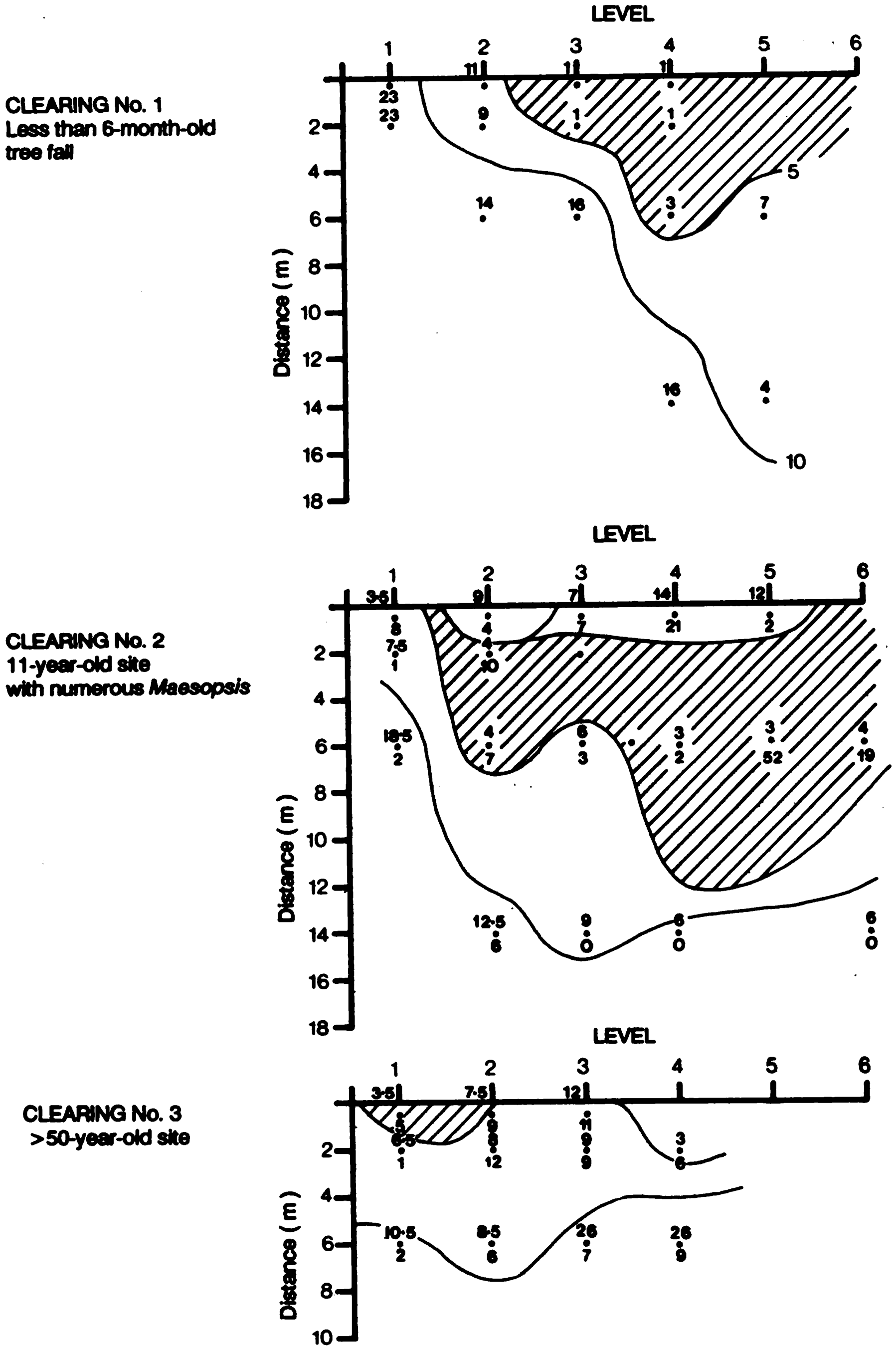

Figure 31.4 Soil organic matter depth under treefalls of different ages.
• = Point of observation defined by level along fallen trunk and distance from trunk.
Levels are 6 m apart. Distances in m. Figures above points are depths of organic soil horizons.
Figures below points are % Maesopsis in the leaf litter. Shading = <5 cm organic.

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ratios so precisely reflect proximity of appropriate trees, are not fully representative but, from the point of view of these studies, were a fortunate choice in a relatively sheltered area.

While at the Gonja site it was observed that, in the natural forest area, there were unusually large populations of earthworms, gastropod molluscs and diplopods. Collections were made for determination by experts. It was thought likely that the first two groups indicate a relatively high pH and calcium level in the soil and the National Soil Service was requested to examine a soil profile and carry out laboratory analyses to determine if the soil was distinctive. The site was on a ridge or upper slope and was well drained. It was also observed that, despite many measurements in the natural forest, no raw humus horizon was developed. The transition from organic layer to A horizon was gradual, reminiscent of a European 'brown earth'. It follows that the development of raw humus need not always occur in natural forest, possible factors in this case being pH, base status and/or drainage. In other words the analogy with European mor-forming species such as *Pinus* and *Calluna* does not necessarily hold.

[Editors' note: The results of the soil profile description and analyses carried out by the National Soil Service are given in Chapter 10. No exceptional features were noted, but, as mentioned in Chapter 10, this could be because of insensitive field methods.]

3.2 Studies of gap areas

Site B1. Pit-sawing gap, Kwamkoro Forest Reserve: This is a seven-year-old gap in a level site, associated with a sawpit. The main trunk was removed, but stump and canopy remained (for detailed map of the site, which was also studied by Binggeli, see Fig. 27.11). Four areas are defined:

- Crown area. A confused mass of branches and major trunks. Soil horizons were measured as 5/5/2, 3/1/4, 6/1/8, 3/2/17 (see methods), implying greater variability but mostly a deep humus layer. It appears that soil loss in this area is limited and probably the pre-existing humus layer is largely preserved.
- Close to the stump. An area of great disturbance due to removal of the main trunk, followed by growth of herbs, thorny sub-shrubs and creepers. Some small *Maesopsis* trees were present. Horizon measurement: 0.5/0/1, 0.5/0/0, 5/0.5/0, 2/2/2, 2/0.5/0.5, i.e. very shallow and patchy F and H layers. Numbers of spiders, opilionids, cockroaches and crickets were found.
- In the natural forest, 10 m beyond the end of the canopy. Horizon measurements were 3/1/8, 3/1.5/2, 5/2/6, 6/1/15, all with a good root mat in F and H horizons.
- At 10 m south (i.e. at 90° to main axis) from the stump. Thought at the time to be beyond the gap and under an *Anisophyllea* tree. There was little humus, as in area ii. This suggests the possibility that this species of tree is associated with loss of humus layers. In this study no leaf ratio measurements were made and so the significance of the presence of *Maesopsis* cannot be judged. It is at least equally likely that humus loss was linked with disturbance.

Site B2. Three natural treefall areas in Kwamsambia Forest Reserve: Three natural trees falls on a sloping hillside and of different ages were located by Binggeli, who made detailed maps (Fig. 27.12). At each site horizon thicknesses and leaf ratios in the litter were measured at intervals along the main trunk (starting from the stump) (called 'levels') and on lines at right angles to the main trunk (called 'distances'). The data are summarised in Fig. 31.4.

The features of the three clearings at site B2 were:

- Clearing No. 1: New fall. Less than 1 year old. Numerous *Maesopsis* seedlings were growing in the disturbed area but, being only about 10 cm high, contributed no leaves. (Only one of all litter counts contained one *Maesopsis* leaf). The area has been subject to only one rainy season (a 'short rains').
- Clearing No. 2: An 11-year old fall, where 36 young *Maesopsis* were found growing in the bare humus soil areas close to the fallen trunk. The site was confused with branches and fallen trees in the crown area. There was some accumulation of humus close to the trunk as well as at greater distances from it. Level 6 was beyond the canopy area.

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- Clearing No. 3: A 50+ year old tree fall area with the canopy now nearly closed above. Two large *Maesopsis* trees were established close to the fallen trunk and contributed to the leaf ratio figures. In this site the organic soil layers were almost at the level of the natural forest; thus there is no obvious indication that presence of limited numbers of *Maesopsis* leaves prevents organic layer formation.

Comparison between the three clearings at site B2:

- The first clearing demonstrates the almost immediate loss of organic layers around a recent natural treefall and that this occurs in the absence of *Maesopsis* litter.
- The second clearing shows organic layers not fully restored after 11 years except in the immediate vicinity of the trunk (where litter may drift due to wind?). This appears to happen even with *Maesopsis* leaf ratios up to 21%, but otherwise the highest *Maesopsis* leaf ratios are in places where organic layers are thin.
- The third clearing, which had only two *Maesopsis* trees, producing low ratios of its leaves, had the organic horizons almost up to natural forest levels, except very close to the trunk.

The general indications therefore are that ground exposure associated with tree falls leads to loss of organic horizons and, whilst *Maesopsis* colonization in disturbed areas is a striking phenomenon, the evidence that *Maesopsis* itself promotes or influences organic horizon loss is, at the most, very slender.

It should be mentioned that all three sites were on quite steep slopes and the erosion effect may well be less marked on flat sites. However, the pit-sawing site (B1) was almost level and organic horizons had still been removed.

3.3. Feeding experiments

An attempt was made to test the relative palatability of *Maesopsis* leaf litter to soil invertebrates, mainly diplopods (millipedes). Initial experiments (see methods) indicated that *Maesopsis* leaf litter was widely consumed even in some cases by diplopods found living in rotten wood; also that somewhat decomposed (brown) leaves were prefered to green. The animals were kept for up to a month and during that time rates of faeces production were used as an indication of acceptability of different foods. Thus animals given only one food at a time produced faeces at a normal rate if it was acceptable, a reduced rate if not. The opportunity was taken to weigh known numbers of dried faecal pellets (which were usually of very uniform size which correlated closely with the size of the animal). This was done so that, given estimates of field density of the diplopods, some idea could be gained of the proportion of the total leaf litter consumed and hence the relative importance of the animals.

The general conclusion of these studies (which did not include taxonomy) is that a number of species of diplopod (possibly 5 species) consume part-rotted *Maesopsis* leaves at levels which are probably adequate for normal metabolism. Although leaves of other species, mainly *Allanblackia*, were attacked by a few individuals, in all such cases consumption and consequent faeces production was very limited. Thus it could be expected that, under natural conditions where mixtures of leaves are likely, *Maesopsis* is probably selectively consumed. This could be a factor in the relatively low proportions of *Maesopsis* leaves found even under *Maesopsis* trees in all the transect studies.

One unexpected observation was that in three cases individual diplopods appeared to consistently make faeces of two markedly different size categories (one approximately a tenth the weight of the other). One reason for this could be that they re-consume previous faeces, a phenomenon familiar in the case of rabbits and suggested by the work of Oregaard Nielsen on the diplopod *Glomerus marginata* feeding on *Brachypodium* grass in Britain.

3.4 Litter bag studies

In order to obtain comparative data on rates of decomposition of *Maesopsis* and other forest tree litters, it was decided to expose litter in nylon mesh bags in two sites, one under *Maesopsis* and the other in natural forest, both within 200 m of Forest House No. 1 at Amani.

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48 bags were used, 24 in each site, each 12 containing one of four species, namely *Allanblackia struhlmannii, Anisophyllea obtusifolia, Chrysophyllum gorungosanum* and *Maesopsis eminii*. Of these species, the first and third have hard, coriaceous leaves, *Maesopsis* has soft leaves and *Anisophyllea* has leaves of somewhat intermediate texture. It was included on account of the slight suggestion that it could be linked with loss of humus layers (see B1 above).

Bags were weighed empty and after filling with undried litter; samples of the same material were dried to constant weight in order to obtain a conversion factor so that dry weights of the exposed samples could be estimated without having to dry the leaves before exposure. Conversion factors for the four species were: *Allanb* = 0.604 *Aniso* = 0.618 *Chryso* = 0.882 *Maes* = 0.520

Half the bags were lifted by Hamilton and Taylor at the end of two months (9 May) and the other half after a further month (9 June). On the first occasion the litter and the bags were lifted entire and weighed together after drying. However, since on that occasion some of the bag material appeared to have been lost by decay, the contents, on the second occasion, were emptied out and then dried and weighed.

The figures for percentage loss in weight, calculated as means of three samples are given in Table 31.3, the upper table being the data for the two-month exposure and the lower table those for the three-month exposure.

Table 31.3 Percentage changes in dry weight in litter bags.

Source of leaves	Area in which leaves were exposed: (a) after two months *Maesopsis* forest	Natural forest
Allanblackia	-16.2	-17.7
Anisophyllea	-1.0*	-48.4
Chrysophyllum	-58.9	-52.6
Maesopsis	-57.1	-73.2
	(b) after three months	
Allanblackia	-17.7	-18.0
Anisophyllea	-48.4	+28.3*
Chryosphyllum	-52.6	-23.7
Maesopsis	-73.2	-15.5

It is clear that some of the samples (* on Table 31.3) in at least two categories increased in weight (possibly due to invasion by roots, fungi or animals) and that, since most of the three-month samples showed little or no further weight loss compared with the two-month ones, such effects may have been operating on many of the bags. (Any future study should allow for such factors and certainly bags should be weighed after one month or even less). In the present case it is best to ignore the three-month samples and the two-month figure for *Anisophyllea*.

A comparison of two-month weight losses between exposure localities shows little difference, even in the case of *Maesopsis*. A comparison between the tree species indicates that, whilst *Allanblackia* clearly decays more slowly, there is no significant difference between *Chrysophyllum* and *Maesopsis*. In other words the decomposition rate of the latter is not necessarily uniquely great when compared with at least one 'coriaceous' species.

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[Editors' note: On lifting the bags in June it was seen that those from the natural forest had been 'invaded' by rootlets coming from the thick root mat, which is a characteristic feature of such forest. The bags in *Maesopsis* forest had not been invaded; a rootmat is typically poorly developed in *Maesopsis* forest.]

4. Conclusions

From the field studies of transects (Sites A1, A2, A3) and the treefall gap observations (Sites B1, B2), it is clear that *Maesopsis* is nearly always associated with loss of organic soil horizons. Only one small area in mixed forest was found where, in a damp depression, there was thick humus associated with *Maesopsis* litter.

However loss of organic horizons can also occur very rapidly after soil exposure, in the total absence of *Maesopsis*, and this effect is exacerbated on steeper slopes (A3, B2). It could even be said that it is the creation of deep organic horizons in most natural forest which is in greater need of explanation. They may be poorly developed when there is good drainage (A3) and suspected high base status (A4).

Organic horizon loss may be associated with other types of litter, e.g. *Anisophyllea* (B1), but evidence is very slender. It is clearly linked with soil disturbance by man, including cultivation. It also occurs naturally in association with forest gaps caused by tree falls, both on level (B1) and sloping (B2) sites.

The persistence of organic horizons therefore seems to require the presence of certain tree species which occur in natural forest, poor drainage and low base status, in unknown combinations.

As for mechanisms involved in the gain and loss of organic horizons, many factors must be involved, including the rate of production of leaf litter of diverse species and the decomposition rate of that litter:

- on the tree before leaf fall
- by soil microorganisms
- by soil fauna
- as influenced by radiation and rain.

Although the soil fauna studies in the field are inconclusive, the results with captive diplopods do indicate greater palatability of *Maesopsis* leaves, especially after slight decomposition. In general the fauna can be expected to comminute litter, thus increasing surface area for microbial attack, change leaf chemistry and levels of allochemical and antibiotic substances, release inorganic nutrients (N, P and K) to the benefit of microorganisms and higher plants and mix litter material with deeper soil particles.

If *Maesopsis* litter is indeed broken down more quickly, it would reduce accumulation of organic layers and expose soil (A horizon) to the action of wind, water and radiation. At the least this might delay the re-establishment of organic layers after disturbance.

Release of inorganic nutrients in natural forest would be expected to be quickly recovered by the root mat, which lies superficially in the F and H layers. *Maesopsis* itself however appears to have a deep rooting system and not to produce a root mat (Chapter 30). Thus it is possible that nutrients would be leached out of the soil under *Maesopsis* unless either they are recovered by the deeper roots or they are recovered by herbs and undergrowth which can flourish under *Maesopsis*. Thus the question of nutrient loss remains open until the total flora is studied, especially because deeper roots may bring up fresh nutrients from sub-soil. It is even possible that, in the short term and from an agricultural point of view, soil under *Maesopsis* is enriched and made more suitable for the culture of e.g. cardamom. On the other hand the drier microclimate under *Maesopsis* (Chapter 33) is probably an argument against using *Maesopsis* to shade this crop.

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5. Applications

A study such as this must form part of a comprehensive investigation of the whole forest, including herbs and shrubs as well as trees.

If there is any foundation for the ideas mentioned in the last paragraph of Section 4 above, the spread of *Maesopsis* could be important for agriculture and forestry. But the implications of its invasion of gaps in natural forest are of even greater importance from the point of view of conservation. In that respect the importance of wider-ranging research, including competitive effects between different tree species and the influence of management practices, must be recognised and acted upon before practical recommendations are possible.

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Raphael Abdallah excavating a pit in the old Maesopsis plantation at Amani (910 m) to expose the roots (Chapter 30). May, 1987. Credit DP.

32. Preliminary Study of the Soil Fauna of Primary and Secondary Submontane Rain Forests on the East Usambaras

by S. Mahunka

The soil faunas of primary and *Maesopsis*-dominated secondary submontane forests on the East Usambaras contain similar numbers of arthropod individuals, but the faunas are very different in terms of species composition and diversity. *Maesopsis* soils have a rather uniform fauna, while the fauna changes greatly from place to place within primary forest. Many of the oribatid mites collected in 1987 are new to science.

1. Methods

Soil organisms were collected by means of Berlese traps from topsoil samples from primary undisturbed submontane forests and from forests rich in *Maesopsis*. The sites were the same as those which Prof. Pocs used for studying undergrowth vegetation (Chapter 28).

2. Results: Arthropoda in general

There was little difference in the numbers of individuals of arthropods in primary forest and *Maesopsis* forest. The numbers of Isopoda collected in Berlese trap samples from the various forest samples are shown in Table 32.1.

Table 32.1 Numbers of Isopoda in Berlese trap soil samples.

	Primary Forest		Secondary *(Maesopsis)* Forest	
	Kwamsambia FR	Amani West FR behind Forest Houses	Kwamkoro FR	Amani West FR below Forest Houses
	81	93	118	103
Replicate	83	61	75	82
samples	65	90	61	171
	63	82	65	98
	80	67	82	108

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The samples contain Coleoptera, Hymenoptera, Isopoda, Aranea, Symphyla, Heteroptera, Orthoptera, Opilionidea and Pseudoscorpionidea, more than 80% of the species falling in the first five groups.

There are 30–40% fewer species of larger Arthropoda in the *Maesopsis*-rich forests than in the primary forest and there is also a change in the composition of the community. This is especially obvious in the Kwamkoro area where the *Maesopsis*-dominated stand had many more rapacious species (e.g. Coleoptera: Carabidae, Aranea) than the primary forest. This is probably related to the openness of the canopy. On the other hand, the number of litter-inhabiting, humicol species (e.g. Coleoptera Pselaphidae) is much less in the *Maesopsis* forest.

Samples from *Maesopsis* forest show a rather uniform picture, both in terms of numbers of individuals and in species composition. This contrasts with samples from primary forest, where there is much more diversity, even between samples only 50–60 m distant from one another and without any obvious habitat differences. This phenomenon was especially well demonstrated by the Coleoptera, Oribatida and Aranea in Kwamsambia Forest Reserve, where it proved hard to find the same species in two traps.

3. Results: soil mites (Acari: Oribatida)

In the Amani West and Kwamsambia samples a total of nearly 200 oribatid species was trapped. The number of endemics is exceedingly high; more than 150 of the species are as yet scientifically undescribed.

The difference between the oribatid faunas of primary and secondary forests was less than that found in some other groups of Arthropoda, but, as mentioned above, the diversity between individual samples is much higher in primary than secondary forest. *Maesopsis* plots always had the same 6–8 species as dominants, while different 3–4 species dominated in each of the samples collected from the primary forest in Kwamsambia Forest Reserve.

In many tropical montane rain forests, one or another group of oribatids shows explosive evolution. This phenomenon is not seen on the East Usambaras, where almost all oribatid orders are represented very evenly and equally.

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33. A Comparison Between *Maesopsis* and other Forest Trees with Respect to Radiation, Water and Nutrient Factors

by Amyan Macfadyen

Explanation of Diagram (Fig. 33.1)

1. General

BOXES represent static amounts of a substance or factor at one time. CHANNELS represent the magnitude of flows to and from boxes.

COMPARISONS of box sizes and channel widths should mainly be made between tree types, not within one tree.

DOTTED SYMBOLS = Energy flow, SOLID SYMBOLS = Nutrient (N, P and K) cycles, OPEN SYMBOLS = water cycles.

2. Assumptions

In comparison with natural forest *Maesopsis* has relatively:

- thin canopy, passing more light and rain
- well developed tap root
- poorly developed shallow roots
- shallow organic soil horizons
- nutrient-rich and decomposable leaf litter
- dry atmosphere between the trees
- horizontal branches, thus less stem flow
- high pH.

3. Possible arguments in consequence of the above

3.1 Water loss to the atmosphere versus the catchment system

In favour of *Maesopsis* evaporating relatively more to the atmosphere, it can be argued that:

- at the soil surface enhanced radiation provides more latent heat for evaporation and re-radiated reflected energy for convection.
- the more open canopy maintains a lower relative humidity and encourages evaporation from soil and from canopy and loss through transpiration.

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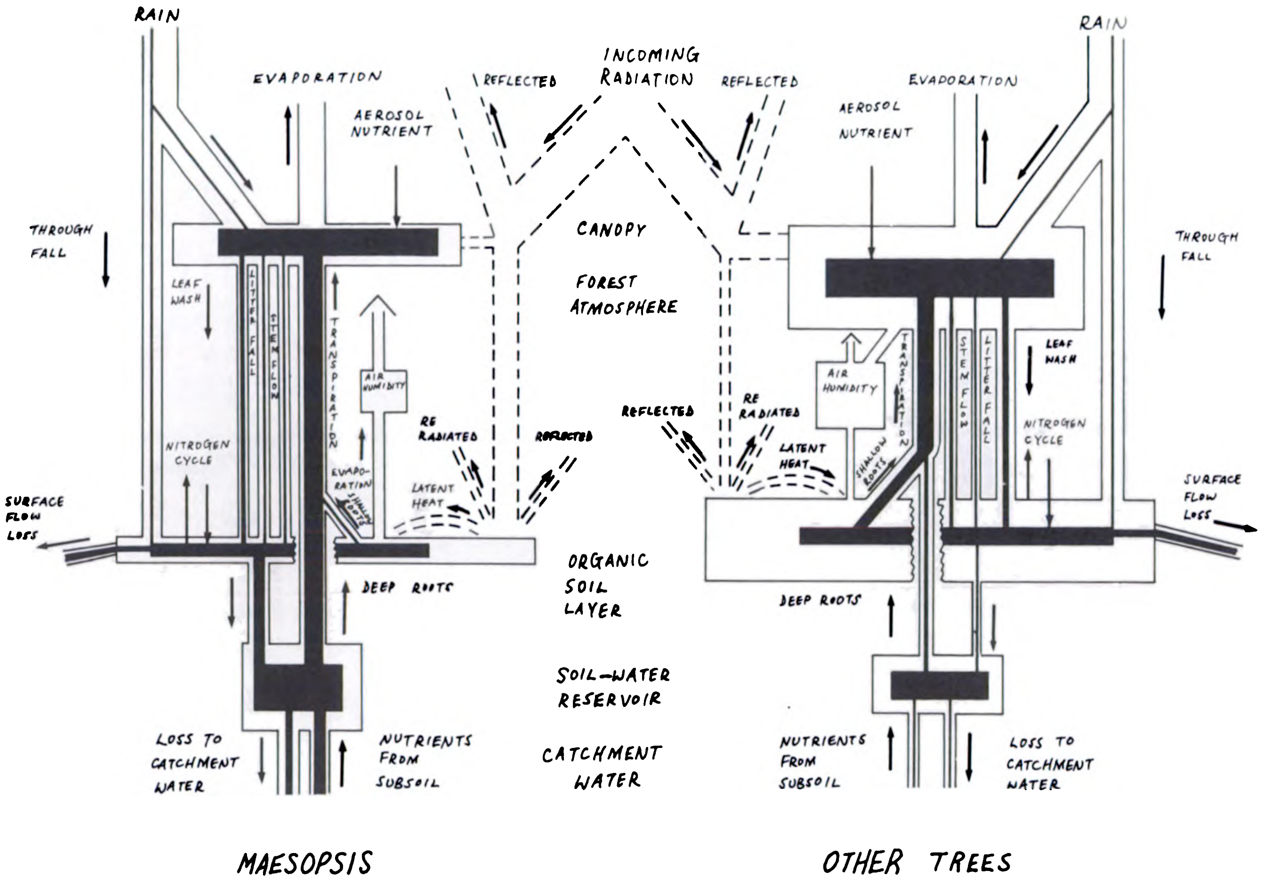

Figure 33.1 Comparison between Maesopsis and other trees with regard to radiation, water and nutrient flow.

- the deeper tap root allows more continuous supply from the soil-water reservoir, promoting both evaporation and transpiration.

In favour of *Maesopsis* passing more water to the catchment, it can be argued that:

- there is less interception by canopy, so more reaches the ground.
- there is less interception by the organic soil, so more reaches the soil-water.
- the fewer shallow roots leads to lower recovery of soil-water.

In conclusion, much will depend on other plants in the different forest layers and climatic factors. Possibly water would pass to the catchment more erratically under *Maesopsis*, due to more surface flow and lack of organic horizons at times of high rainfall. In general the arguments favour more water going to the atmosphere in the long-term.

3.2 Nutrients

Nutrient inputs would be similar except that possibly more N-fixation would be encouraged in the low pH, more anaerobic humus of the natural forest. The deep roots of *Maesopsis* could lead to nutrient recovery from the subsoil and more nutritious litter to accumulate temporarily at the soil surface. This could be lost by leaching and surface run-off, but could also benefit herbs and sub-shrubs growing in the relatively high light conditions under *Maesopsis*.

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Mr. Ruffo expounding on a sacred forest at 950 m on Mt. Mlinga. Abdallah to his right and Israel Mwasha on the left of the stone. At least one other forest patch on the East Usambaras is conserved for religious reasons. May, 1987.

A (tripped) animal trap in Kwamsambia Forest Reserve, 300 m. When set, the large logs are suspended above the barriers and a bait is placed inside. Traps are very common in the forests; other types include snares and pit-fall traps. September, 1986.

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34. The East Usambara Fauna

by Kim Howell

The forests of the East Usambaras have many rare species in all groups of animals, except mammals. The fauna is exceptional: the Usambaras have been compared to the Galapagos Islands in terms of their biological importance. Arguments are presented for forest conservation.

1. Introduction

Only about 2% of Tanzania's entire surface area is covered by moist tropical forest. In addition to plants which are adapted to living only under the specific ecological conditions found in such forests, a number of animal species are also forest dependent. They appear not to be able to live outside of (or at least not far from) moist tropical forest. This means that the distribution of such animals is strictly limited to where suitable natural forest is present. Some of these species are endemic to single forest localities in Tanzania, while others are found along an entire chain of block-faulted mountains known as the Eastern Arc mountains (see Chapter 21). The East Usambara Mountains are in this Eastern Arc chain of forests and contain animal species found in other mountain forests as well as large numbers of endemics.

Although the fauna of the Usambaras as a group and especially that of the East Usambaras has sometimes been regarded as 'well studied' compared to others in Tanzania, this evaluation is very subjective and reflects more the lack of knowledge of the other forests rather than any detailed, extensive information on the Usambaras.

Despite the classical ecological studies of Moreau (1934, 1935) in the Amani area and his later works dealing with birds (e.g. Moreau 1966), very little detailed information is available about the biology of entire classes and orders of animals, especially invertebrates. Even among the vertebrates, only the birds have been studied in any detail with respect to distribution and ecology.

In spite of the incompleteness of our knowledge of the East Usambara fauna, a few groups have received at least some attention from collectors and taxonomists. In almost every group examined, species new to science and usually endemic to the East Usambaras have been discovered. Comparisons of numbers of new and endemic species with those of other mountain forest areas is difficult because of both lack of material from these areas and of lack of recent taxonomic studies. The following information, summarised from IUCN (1983) and updated where possible, gives some idea of what is known about endemism in the East Usambara animals. In some cases it has not always been possible to extract data on the East Usambaras alone from summary data given for the Usambaras as a whole; in others, studies from other isolated forests, such as the Ulugurus, have been mentioned when these findings are relevant to the East Usambaras.

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2. Invertebrates

Arachnida

Acari: Collecting in mountains such as the Ulugurus and the West Usambaras has yielded many new species of mites, and there is every reason to think that many new species await identification from the East Usambaras. Mite collections made by participants in the recent IUCN study in the East Usambaras are in the process of being identified (Chapter 32).

Araneae: Spiders form a conspicuous element of the forest fauna, but few studies seem to have dealt with the Usambara spider fauna. Jocque and Scharff (1986) list Linyphiidae spiders from Tanzanian mountain forests and describe four new endemic species from the East Usambaras.

Crustacea

Decapoda: Freshwater crabs are commonly seen in the streams as well as on the forest floor; numerous species are described from East Africa, and at least two have been described from the East Usambaras, but the group is badly in need of taxonomic revision (Bott 1955).

Insecta

Orthoptera: The Usambaras have a number of endemic species and genera.

Coleoptera: High numbers of endemics can be expected, based on what has been found in the Ulugurus.

Trichoptera: Recent collecting by Stoltze indicates many new species.

Dermaptera: It has been suggested that the earwig fauna of the Usambaras will contain many endemics, as does that of the Ulugurus.

Lepidoptera: The butterflies, as diurnal, often brightly coloured animals, have received the most attention from insect collectors and are the most studied of the insect groups. At least 5 species are endemic to the Usambaras.

Hymenoptera: Only one wasp family, the Sphecidae, has received the detailed attention of specialists; there may be as many as 27 species of this family endemic to the East Usambaras.

Diplopoda

Only the Amani area has received intensive attention of millipede collectors. 41 species are known from the Amani forests; 26 of these have not yet been described, and most are endemic to the East Usambaras. A recent visit to Mt Lutindi during IUCN field work in 1986 resulted in the collection of a new species. The millipedes as a group seem to be poor dispersers, and it is likely that even within an area as small as the East Usambaras, each forest patch may have its own endemic species.

Mollusca

10% of the species of the entire East African land mollusc fauna are found in the Usambaras. Very high levels of endemism are found in some groups, in which 75% of the species may be endemic. There is some evidence to suggest that species now regarded as endemic to the Usambaras may have existed outside these mountains, but due to forest destruction, are now found only in these mountain forests.

It will be noticed that whole groups of invertebrates have been omitted in the above list. This simply indicates the lack of ecological and collecting work done in the Usambaras as well as a dearth of museum taxonomists able to devote their attention to the East African fauna. Only Jago and Masinde

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(1968) appear to have published any ecological studies on East Usambara invertebrates. The most casual collecting of almost any invertebrate group will yield new species and, in many cases, new genera, which will be endemic.

3. Vertebrates

Amphibians and reptiles

There are 30 species of amphibians and reptiles which can be regarded as dependent on natural forest on the Usambaras. Of these, 15 are endemic. In the East Usambaras alone, there are 7 endemic taxa: two micro-hylid frogs, one of which is placed in an endemic genus; *Chamaeleo spinosus* a rare chameleon; a very rare lizard *Bedriagaia moreaui*, and a colubrid snake, *Dipsadoboa werneri*.

Birds

The birds of the Usambaras have recently received detailed attention from Stuart (1983). He notes that of the 122 species of birds in the Usambaras, only 38 would be likely to be able to survive large-scale forest clearance. Of the very rare species with extremely restricted distributions, all are forest dependent; four of these cannot even survive in non-forest habitat directly adjacent to the forest! More detailed information is given in Chapter 33.

Birds which are totally dependent on the forest and which have extremely restricted geographical distributions include: Long-billed Apalis, *Apalis moreaui;* Amani Sunbird, *Anthreptes pallidigaster;* Banded Green Sunbird, *A. rubritorques;* Usambara Eagle Owl, *Bubo vosseleri;* Usambara Ground Robin, *Dryocichloides montanus* (only in the West Usambaras, not the East); Dappled Mountain Robin, *Modulatrix orostruthus;* and Usambara Weaver or Tanzanian Mountain Weaver, *Ploceus nicolli* (may already be extinct in the East Usambaras as it has not been seen there for many years). All of these are regarded as rare and included in the IUCN Red Data Book (Collar & Stuart 1985).

Mammals

Unlike the other animal groups of the East Usambaras, the mammals have very low levels of endemism. Only one subspecies of tree hyrax *Dendrohyrax validus terricola* has been suggested as endemic, and it is of doubtful validity. Swynnerton's squirrel *Paraxerus vexillarius* is endemic to the Usambaras. A subspecies of *Beamys hindeii*, the Lesser Pouched Rat, is known only from the East Usambaras and the Kenyan coast. Recently the IUCN Carnivore Group has called attention to an isolated population of a rare mongoose *Bdeogale crassicauda omnivora*, believed to be found only in the Mtai area (known only from a single specimen) and from the Arabuko-Sokoke coastal forest in Kenya. Abbott's Duiker, *Cephalophus spadix*, is a forest-dependent species found in the Usambara and other mountain forests. The need for protection of this species has been discussed by Wilson (1986).

4. Scientific interest and conservation of the East Usambara fauna

The Usambara mountains have been compared to the Galapagos Islands in terms of their species richness and biological importance. A number of points should be kept in mind when considering the biological values and conservation of the East Usambara fauna.

Though there has been little collecting and few ecological and taxonomic studies have been done, there is every indication that among the invertebrates, many species new to science remain to be found. From experience both in the Usambara and other forests in Tanzania, many of these will also prove to be endemic. Even in the case of vertebrates, there still may be new, undescribed species present; two new frog species have recently been described from the West Usambaras.

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Except for the birds, all of the animal groups are poorly known; while this is especially true for the invertebrates, as noted above, it also applies to other vertebrate groups. No quantitative, and in many cases not even qualitative, studies have been made on habitat requirements etc. of the various species dependent on the forest. Our lack of knowledge on such basic questions as the role of various groups in forest leaf-litter decomposition, nutrient cycling etc. represents a serious gap in our understanding of the ecology of the natural forest.

One of the most important aspects of the East Usambara forests is their wide altitudinal range. This is especially true when one considers that some of the forest birds make seasonal altitudinal migrations, moving to the warmer lowland forests in the colder periods (Stuart 1983). It is thus important to preserve and protect the entire altitudinal range of forest.

The East Usambara forests are already highly fragmented and in many cases separated from each other by non-forested, agricultural, densely populated land. This in itself makes both conservation and protection efforts difficult. Many authors have shown that, wherever possible, it makes sense to preserve as large areas of forest as possible.

The East Usambaras form part of a group of forests known as the Eastern Arc Forests, in Tanzania including the Pare, Usambara, Uluguru and Uzungwa mountain forests. These are extremely important areas for rare birds as well as other animals. These same forests have been postulated as an Eastern Forest Refugium during the Pleistocene (Hamilton 1982) and are therefore of major biogeographic importance. This importance has been recognised by both the World Wildlife Fund and IUCN.

For many species which are not strictly endemic to the East Usambaras but which also are found also in the West Usambaras or in a few other forested localities, destruction of the East Usambara forests would mean elimination of more than half of their world habitat and population. There is already some evidence which indicates that some species which were once found outside the East Usambaras in such localities as coastal forest in Kenya are now extinct except where they have received protection in the East Usambaras. For example, it is well known that the Arabuko-Sokoke and Taita Hills forests are under threat (Beentje, Ndiangui & Mutangah 1987). There is certainly a case to be made for many of the East Usambara forests to be declared nature reserves and to receive total protection.

Amani, in addition to being of great agricultural, botanical and historical interest, is also of major interest as the site where some of the earliest ecological studies in Africa were conducted. It would indeed be ironic if the very cradle of studies on Tanzania's tropical forests was destroyed. Instead, if the forests are preserved in nature reserves, Tanzania would be almost unique in Africa in having natural forests which have ecological data collected from the 1930's as a basis for further continuing studies.

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Cardamom near Kilanga Forest Reserve. September, 1986.

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35. The Forest Bird Fauna of the East Usambara Mountains

by Simon Stuart

The number of bird species in the East Usambara forests is higher than in other forests in the region. There are nine species regarded as threatened or nearly so. Several species of birds move altitudinally between lowland and submontane forest during the course of the year.

The East Usambaras have been extensively surveyed by ornithologists over the years (Moreau 1935; Sclater & Moreau 1932–3; Stuart 1983). The main interest has always been in the forest avifauna, which is noteworthy for its rare and near-endemic species. Collar and Stuart (1985) list six threatened and three near-threatened bird species in the ICBP/IUCN Red Data Book (RDB). These are:

Species	RDB Category	Distribution outside East Usambaras
Usambara Eagle Owl *Bubo vosseleri*	Rare	West Usambaras
Dappled Mountain-robin *Modulatrix orostruthus*	Rare	Uzungwas; Mt. Namuli
Long-billed Apalis *Apalis moreaui*	Rare	Njesi Plateau
Amani Sunbird *Anthreptes pallidigaster*	Rare	Sokoke Forest
Banded Green Sunbird *Anthreptest ubritorques*	Rare	West Usambaras; Ngurus; Ulugurus; Uzungwas
Tanzanian Mountain Weaver *Ploceus nicolli*	Rare	West Usambaras; Ulugurus; Uzungwas
Southern Banded Snake-eagle *Circaetus fasciolatus*	Near-threatened	Coastal eastern and southern Africa
Plain-backed Sunbird *Anthreptes reichenowi*	Near-threatened	Coastal Kenya, Tanzania and Mozambique
Uluguru Violet-backed Sunbird *Anthreptes neglectus*	Near-threatened	Coastal Kenya, Tanzania and Mozambique

Of these, the Tanzanian Mountain Weaver is particularly rare in the East Usambaras and has not been recorded since the 1930's. It is possible that it still survives in the poorly explored higher altitude

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Lutindi Forest Reserve. The East Usambaras appear to be the major locality for the Long-billed Apalis and are clearly a very important one for the Usambara Eagle Owl (which must have a low world population) and the Amani Sunbird. The Banded Green Sunbird is common only in the East Usambaras, being decidedly rare elsewhere.

The forest avifauna of the East Usambaras, including that of the lowland foothill forest, is also remarkable for its diversity — 110 species, which is the highest in this part of Africa. With the exception of the Pygmy Kingfisher and the Black Cuckoo-shrike, which are cold season visitors, all these species are known, or believed, to breed in the forests. The forest species of the East Usambaras are listed in Table 35.1, with information on their altitudinal distributions and their degree of adaptability to forest disturbance. On the basis of research by Stuart (1983) on the vulnerability of forest bird species in the Usambaras to habitat change, species can be assigned to three broad categories of adaptability:

- Those which live in forest but are not dependent upon it for their continued survival (31 species in the East Usambaras).
- Those which live in forest and 'overspill' into adjacent habitats, but are dependent upon forest for their continued survival (48 species).
- Those which can only survive in forest and hardly 'overspill' into adjacent habitats (31 species).

Details of the adaptability of each species are given in Table 35.1. It should be noted that all the threatened and near-threatened species are in categories 2 and 3.

Table 35.1 Forest avifauna of the East Usambaras.

Species	Altitude	Adaptability
Green Ibis *Bostrychia olivaceum*	Foothills up to 900 m	3
Harrier Hawk *Polyboroides radiatus*	Throughout	1
Southern Banded Snake-eagle *Circaetus fasciolatus*	Throughout	2
Great Sparrowhawk *Accipiter melanoleucus*	Throughout	1
Little Sparrowhawk *A. minullus*	Throughout	1
African Goshawk *A. tachiro*	Throughout	2
Mountain Buzzard *Buteo oreophilus*	Above 900 m	2
Ayres's Hawk-eagle *Hieraaetus dubius*	Throughout	2
Crowned Eagle *Stephanoaetus coronatus*	Throughout	2
Kenya Crested Guineafowl *Guttera pucherani*	Foothills up to 600 m	2
Buff-spotted Pygmy Crake *Sarothrura elegans*	Foothills up to 600 m	1
Lemon Dove *Aplopeha larvata*	Above 900 m	3
Olive Pigeon *Columba arquatrix*	Above 900 m	2
Bronze-naped Pigeon *C. delegorguei*	Throughout	3
Tambourine Dove *Turtur tympanistria*	Throughout	1
Green Pigeon *Treron australis*	Throughout	1
Fischer's Turaco *Tauraco fischeri*	Throughout	2
Barred long-tailed Cuckoo *Cercococcyx montanus*	Throughout (but below 900 m only in cold season)	3
Emerald Cuckoo *Chrysococcyx cupreus*	Throughout	2
Klaas's Cuckoo *C. klaas*	Throughout	1
Yellowbill *Ceuthmochares aereus*	Throughout	2
Usambara Eagle Owl *Bubo vosseleri*	Above 900 m	3
African Wood Owl *Ciccaba woodfordii*	Throughout	2
Bohm's Spinetail *Neafrapus boehmi*	Above 900 m	1
Mottled-throated Spinetail *Telacanthura ussheri*	Throughout	1
Narina's Trogon *Apaloderma narina*	Foothills up to 900 m	3
Bar-tailed Trogon *A. vittatum*	Above 900 m	3

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Species	Altitude	Adaptability
Pygmy Kingfisher *Ispidina picta*	Foothills up to 900 m (cold season Apr – Sept only)	1
Green Wood-hoopoe *Phoeniculus purpureus*	Foothills up to 300 m (outside forest above this altitude).	1
Silvery-cheeked Hornbill *Bycanistes brevis*	Above 500 m	2
Trumpeter Hornbill *B. bucinator*	Foothills up to 1200 m	2
Crowned Hornbill *Tockus alboterminatus*	Foothills up to 300 m (outside forest above this altitude).	1
White-eared Barbet *Buccanodon leucotis*	Throughout	1
Green Barbet *B. olivaceum*	Throughout	3
Moustached Green Tinkerbird *Pogoniulus leucomystax*	Above 900 m	2
Green Tinkerbird *P. simplex*	Foothills up to 900 m	2
Pallid Honeyguide *Indicator meliphilus*	Foothills up to 300 m	1
Scaly-throated Honeyguide *I. variegatus*	Throughout	2
Eastern Honeybird *Prodotiscus zambesiae*	Throughout	2
Golden-tailed Woodpecker *Campethera abingoni*	Throughout	1
Little-spotted Woodpecker *C. cailliautii*	Foothills up to 900 m	1
Cardinal Woodpecker *Dendropicos fuscescens*	Throughout	1
Olive Woodpecker *Maesopicos griseocephalus*	Above 900 m	2
African Broadbill *Smithornis capensis*	Throughout	3
Green-headed Oriole *Oriolus chlorocephalus*	Foothills up to 1200 m	2
Square-tailed Drongo *Dicrurus ludwigii*	Throughout	3
Pale-breasted Illadopsis *Trichastoma rufipennis*	Foothills up to 1200 m	3
Black Cuckoo-shrike *Campephaga flava*	Throughout (cold season: Apr – Sept only)	1
Grey Cuckoo-Shrike *Coracina caesia*	Throughout	3
Shelley's Greenbul *Andropadus masukuensis*	Above 450 m	2
Stripe-cheeked Greenbul *A. milanjensis*	Above 450 m (throughout in cold season:Apr – Sept only)	2
Little Greenbul *A. virens*	Foothills up to 1200 m	2
Yellow-bellied Greenbul *Chlorocichla flaviventris*	Foothills up to 900 m	1
Nicator *Nicator chloris*	Foothills up to 900 m	2
Tiny Greenbul *Phyllastrephus debilis*	Throughout	3
Fischer's Greenbul *P. fischeri*	Foothills up to 300 m	3
Yellow-streaked Greenbul *P. flavostriatus*	Throughout	2
Olive Mountain Greenbul *P. placidus*	Above 600 m	3
Brownbul *P. terrestris*	Foothills up to 300 m	1
White-chested Alethe *Alethe fuelleborni*	Above 450 m	2
Eastern Bearded Scrub-robin *Cercotrichas quadrivirgata*	Foothills up to 300 m	1
Red-capped Robin-chat *Cossypha natalensis*	Foothills up to 900 m (but above 700m only in hot season: Oct – March)	1
Dappled Mountain-robin *Modulatrix orostruthus*	Around 900 m only	3
Spot-throat *M. stictigula*	Above 900 m	3
Red-tailed Ant-thrush *Neocossyphus rufus*	Foothills up to 900 m	2
White-starred Forest-robin *Pogonocichla stellata*	Throughout (though a large scale movement to lower altitudes in the cold season: April – Sept)	2
Sharpe's Akalat *Sheppardia sharpei*	Above 600 m (but only below 900 m in the cold season: Apr – Sept.)	
Olive Thrush *Turdus olivaceus*	Above 900 m	3
Orange Ground-thrush *T. gurneyi*	Above 450 m (but only occurs below 900 m in the cold season: Apr – Sept).	3
Black-headed Apalis *Apalis melanocephala*	Throughout	2
Long-billed Apalis *A. moreaui*	900 – 1000 m	2
Bar-throated Apalis *A. thoracica*	Above 200 m	2
Evergreen Forest Warbler *Bradypterus barratti*	Above 900 m	2
Grey-backed Camaroptera *Camaroptera brachyura*	Foothills up to 1200 m	2
Southern Hyliota *Hyliota australis*	Foothills up to 300 m	2
Kretschmer's Longbill *Macrosphenus kretschmeri*	Throughout	2

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Species	Altitude	Adaptability
Red-capped Forest Warbler *Orthotomus metopias*	Above 900m	2
Yellow-throated Woodland Warbler *Phylloscopus ruficapilla*	Above 900 m	3
Dusky Flycatcher *Muscicapa adusta*	Above 900 m	1
Ashy Flycatcher *M. caerulescens*	Foothills up to 300 m	2
Lead-coloured Flycatcher *Myioparus plumbeus*	Foothills up to 300 m	1
Forest Batis *Batis mixta*	Throughout	3
Black-and-white Flycatcher *Bias musicus*	Throughout	1
Little Yellow Flycatcher *Erythrocercus holochlorus*	Foothills up to 800 m	3
White-tailed Crested Flycatcher *Elminia albonotata*	Above 900 m	3
Paradise Flycatcher *Terpsiphone viridis*	Throughout (but occurs above 600m only in the hot season Oct – March)	1
Crested Flycatcher *Trochocercus cyanomelas*	Foothills up to 900 m	3
Black-backed Puffback *Dryoscopus cubla*	Throughout	1
Black-fronted Bush-shrike *Malaconotus multicolor*	Throughout	3
Four-coloured Bush-shrike *M. quadricolor*	Foothills up to 300 m	2
Retz's Helmet-shrike *Prionops retzii*	Foothills up to 450 m	1
Chestnut-fronted Helmet-shrike *P. scopifrons*	Foothills up to 300 m	2
Black-breasted Glossy Starling *Lamprotornis corruscus*	Foothills up to 900 m	2
Waller's Chestnut-winged Starling *Onychognathus walleri*	Throughout	2
Kenrick's Starling *Poeoptera kenricki*	Above 450 m (but only below 900 m in the cold season: Apr – Sept).	2
Collared Sunbird *Anthreptes collaris*	Throughout	1
Uluguru Violet-backed Sunbird *A. neglectus*	Foothills up to 1200 m	3
Amani Sunbird *A. pallidigaster*	Foothills up to 900 m	2
Plain-backed Sunbird *A. reichenowi*	Foothills up to 300 m	3
Banded Green Sunbird *A. rubritorques*	Above 750 m	2
Eastern Double-collared Sunbird *Nectarinia mediocris*	Above 1200 m	2
Olive Sunbird *N. olivacea*	Throughout	1
Yellow White-eye *Zosterops senegalensis*	Above 900 m	2
Dark-backed Weaver *Ploceus bicolor*	Throughout	3
Tanzanian Mountain Weaver *P. nicolli*	Probably above 1200 m (formerly down to 900 m)	3
Red-faced Crimson-wing *Cryptospiza reichenovii*	Above 900m	2
Peter's Twinspot *Hypargos niveoguttatus*	Foothills up to 300m	1
Green-backed Twinspot *Mandingoa nitidula*	Throughout	2
Red-headed Bluebill *Spermophaga ruficapilla*	Foothills up to 1000 m	3
Oriole Finch *Linurgus olivaceus*	Above 1000m	2

It is worth noting that the Red-headed Bluebill is represented in the East Usambaras by an endemic and very isolated subspecies *Spermophaga ruficapilla cana*. Nearly all the montane species in the East Usambaras occur at much lower altitudes than is normally the case in East Africa. This phenomenon has also been observed on other mountain ranges in eastern Tanzania. A number of species also undergo seasonal altitudinal migrations, and further fieldwork will probably demonstrate this phenomenon in a wider range of species. In general, montane species tend to breed at higher altitudes between October and March, and migrate to lower levels in the cold season between April and September.

Many non-forest species also occur in the East Usambaras, but these are of very limited conservation concern. The remarkable forest avifauna is of great interest and most of the species (79 of them) will only survive if their habitat is adequately conserved.

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Kwamkoro Tea Estate. September, 1986.

Deforested land on the lower slopes of the escarpment at Kizara. Forest on the slopes has been replaced largely by grass and shrubs. Note the paddy fields in the valley: the river used for irrigation originates in Lutindi and Kilanga Forest Reserves. September, 1986.

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36. Some Arguments for Biological Conservation

by Amyan Macfadyen

Arguments for biological conservation are given and various practical matters relating to the conservation of tropical forests discussed.

1. Introduction

Leaving aside arguments based on moral and aesthetic values it can be shown that there are sound practical advantages to be gained from biological conservation both by local people and by mankind as a whole. Uncontrolled exploitation of natural resources threatens the survival of life at three levels: the single species, the ecosystem and the earth's entire biosphere.

2. The survival of species

A species of plant or animal is not simply a fixed type: one only has to look at a herd of cows or crowd of humans to realize that they are all different and unique members of a population. Such populations change progressively with time (evolve) and differ in different parts of their range according to habitat factors which influence rates of birth and death. Also an individual needs to vary with life stage, age and sex, if functions such as feeding, mating, reproduction and sheltering are to be successful.

Thus, even if a species population is not exterminated outright, the loss of even part of its range can reduce its capacity to withstand adverse circumstances and, if it is a species exploited by man, the genetic diversity available to withstand future threats by disease, competition, climatic change and so on. This applies especially in the context of the East Usambaras where some species are endemic and others, although occurring elsewhere, are certain to have in their genetic make-up, characteristics appropriate to local conditions, which could be useful in the future.

At present it is estimated that thousands of species are being eliminated from the earth annually due to man-induced environmental change. These will never re-appear. They have taken more than a million years even to become separate from the most closely-related other species. In most cases the loss is not designed by man but follows from major changes in the environment, such as forest clearance. Man has in fact domesticated and used for biological control, food, drugs, fibres and building materials a minute proportion of all species. But as his numbers increase and threats from disease and shortages due to exhaustion of chemical resources increase, it is certain he will have to turn more and more to natural products.

3. The survival of ecosystems

The full range of plants, animals, microbes and fungi, together with the physical and chemical features which both determine their environment and which are modified by the presence of the

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organisms, is called an ecosystem. The climate, soil and atmosphere within a forest, for instance, are more different from those outside the forest than in other forests in very different latitudes and altitudes. The full complexities of even the simplest of ecosystems, such as a pond or tea-estate, have never yet been unravelled. Our experience has been that surprising and very remote relationships often determine the survival of individual species. Examples are the effect of pleasure-boat disturbance on the water dock, which is the food plant of the now extinct Great Copper Butterfly in Britain, the effect of introducing a mite which ate the eggs of a coconut-mining beetle and caused the beetle to become a pest, and the extinction of the Large Blue Butterfly in England by flattening ant-hills; this flattening altered the micro-climate. Tropical forests are the most complicated ecosystems known to man and have been shown to be the most vulnerable: impossible to restore even after quite minor changes in management. The maintenance of undisturbed forest – which is not static but undergoes natural cycles of tree-fall and regeneration – by means of nature reserves is therefore essential.

Although tropical forests carry the greatest mass of living matter growing anywhere, they do not in fact produce new matter faster than forests of other regions and they keep most of the mineral nutrients (fertility) in the trees rather than the soil. This means that removal of trees involves removal of fertility – as is demonstrated by the very short period during which crops flourish after forest removal.

Nature reserves must be large because:

- There is need for buffer zones to reduce the climatic and other effects of adjacent land-use types.
- Many organisms require extensive ranges because they range far in search of food, have seasonal migrations, need to be widely spaced to prevent over-exploitation by others that feed on them or can only exist in rather special habitats which occur occasionally and for short periods.
- The practical reason that a number of small reserves have a much larger boundary for a given area than one large one, and are therefore more difficult to guard against trespass.

4. The survival of the biosphere

The biosphere is the entire complement of life on earth, man included. Life as we know it lives within a very narrow range of physical and chemical conditions. Even small changes in temperature, light and rainfall lead to extinctions and other great changes – as is shown by the effects of ice ages. We know already that the level of CO_2 in the atmosphere has increased some 50% in the last century, causing higher temperatures at the earth's surface. This is due to burning of fossil fuels and the clearance of forests. Quite possibly local changes in climate in the Usambaras acknowledged by Amani people are a result of tree felling. Many other changes in climatic and chemical conditions are certain to result from removal of major ecosystem types such as tropical forest.

From the above it will be seen that uncontrolled exploitation of forests is a threat not only to people living in or near the forests but to mankind as a whole. From a local point of view it is clear that short-term gain is possible by growing a cash crop in natural forest or wastefully felling single forest trees without regard to the consequences for the forest. Both are of short-term benefit and the whole history of plantation crop industries points to their temporary nature. The question that most stable societies have, through history, answered in the negative is whether the advantages of such individual, temporary gain should prevail against the longer-term survival of people's way of life. There is a need to balance the short-term gains, which in tropical countries are often whittled away by conditions of international trade in any case, against longer-term survival of local people and all life on earth. This has been appreciated by most successful human cultures and, when ignored, has led to the extinction of many others, from the Sumarians and the Egyptians to the Maya and the Aztecs. This is surely one of the lessons of history that we must learn before it is too late – for the whole of mankind is now in the same boat.

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37. Priorities for Research in the East Usambara Forests

by A.C. Hamilton

The priorities for research in the East Usambara forests are discussed. The organisation of research is important and should take account of the cultural context of knowledge. The desirability of an ecological research station on the East Usambaras is briefly considered.

1. Introduction

The time has come for ecology to come to the forefront of biological research in the East Usambaras. We need to know how the forests function as living systems, how they influence and interact with other components of the environment and how they are liable to react to disturbances. Both pure and applied research are needed, although the distinction between the two should not be over-emphasized; the pure research undertaken at the former agricultural research station at Amani has found wide application in the compilation of the present management plan. Pure research would seek to establish how the forest ecosystems function; applied research would seek empirical solutions to practical problems, without necessarily knowing why the solutions work.

Up to now, most biological research in the East Usambaras has consisted of compilation of lists of species, often entailing the collection of specimens. Indeed, so marked has this been that local people who have assisted visiting biologists are surprised to find a botanist whose main intention is not the collection of herbarium specimens or a zoologist whose main aim is not to kill and preserve animals. Having said this, some further research of this type is still desirable. New records are frequently made for the mountains and quite often there are discoveries of completely new species. Little is known about the geographical distribution in the East Usambaras of most species of animals. There has been a problem in deciding which of the lowland forests are of greatest value for biological conservation, since we have insufficient information about their floras and faunas. More attention should be paid by taxonomists to examining how distinctive are populations on the East Usambaras of species which also occur elsewhere.

2. Suggested research areas

Research area 1: forest dynamics and life-history strategies of trees

Foresters working on the East Usambaras have often assumed that there are two types of forest tree: fast-growing, light-demanding pioneers and slower-growing, shade-tolerant climax forest species; some forest practices have been established accordingly. There is some truth in this simple

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classification, but it can be inadequate for management. The model has failed to predict the consequences of some forestry activities. The introduced tree *Maesopsis* is classified by foresters as a pioneer, but it is a longer lived and more aggressive species than the indigenous species classified as pioneers. It seems that not all 'pioneer' species are ecologically equivalent. During mechanical logging, occasional specimens of desirable species, all of which are classified as climax forest species, are supposed to be left standing to act as seed sources; *Maesopsis* was regarded as a pioneer species under which seeds of the desirable species would germinate and new plants become established. In fact, the environment under a *Maesopsis* canopy is such that this rarely occurs.

Each of the over 200 species of tree in the forests must be ecologically unique and caution is necessary in classifying them into a few, especially just two, ecological categories. We need to know a lot more about how these plants flower, produce and distribute their seeds, under what conditions the seeds germinate, the factors influencing seedling survival, how the species grow thereafter, the effects of pathogens and the ways in which they interact with the soil, with animals and with other plants. In short, we need to undertake autecological studies into life-history strategies.

Tanzania is not unique in its ignorance of how rain forests work: this is a worldwide problem. Forest dynamics is a comparatively new field of research. Some clues are however beginning to emerge, particularly realization of the importance of disturbance to the growth and survival of species. In natural forests, trees become established, grow at widely varying rates and some mature. Eventually they all die, either by slowly falling to pieces or violently through falls. Opportunities are then available to other plants to utilize freshly released resources of light, nutrients and water. A key to understanding rain forest ecology seems to be through studying how different species react to these opportunities. Forestry research in Tanzania should become committed to the study of rain forest dynamics, especially through detailed studies of the life-history strategies of selected species.

Research area 2: faunal studies

There are many areas of zoological research which should be pursued. First, information is needed on the distributions of species in nearly all groups over the range as a whole; if such information had been available today, it would have influenced the recommendations made in this report. Second, studies are needed on animal ecology in relation to forest disturbance by man. Third, work is needed on the population dynamics of forest vertebrates, especially those which are likely to be endangered by forest destruction or modification. Fourth, the dispersal of plant disseminules by birds and bats should be investigated.

Research area 3: nutrient cycling, water flow and soil erosion

It has often been stated that the natural forests of the East Usambaras have very tight nutrient cycling. It is also believed that nutrient cycling is different under plantations of teak and *Maesopsis* and when the land is placed under agriculture. It is time to investigate this process. Recommendations are made for studies into the storage and movement of nutrients in different types of forest, with emphasis on decomposition processes.

It is also speculated that plantation trees and various systems of agriculture alter the characteristics of the hydrological system. Studies are needed with the practical objective of devising systems of land management which help to retain good catchment properties. The monitoring and evaluation of low flows in rivers draining the East Usambaras should be undertaken.

More information is also required about soil erosion under different kinds of land-use. There is evidence from elsewhere that soil erosion increases under teak compared with natural forest and we believe that this is also true of *Maesopsis*.

Research area 4: forest stability and climatic change

In one area in which we have undertaken detailed work, we have evidence that many large trees have recently fallen, more than expected if the forest were in a state of equilibrium. It is possible that,

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naturally, there are waves of tree falls passing through the forests and that by chance our area happened to be situated just where one was passing. Another, and more probable, explanation is that large areas of the forest really are not in a state of equilibrium, having been disturbed by some external change in the environment. Climatic change would seem to be the most likely culprit. Further research is needed to determine what is happening and to assess its consequences. Clearly it would be desirable to have at least one reliable, well instrumented, meteorological station on the East Usambaras.

Research area 5: invasive species

We have undertaken some studies of one of the invasive species, *Maesopsis*, but more work needs to be done on this and other invaders, both plants and animals. A practical reason is to seek ways of controlling these species in the nature reserve and elsewhere.

Research area 6: management of the *Maesopsis* forest

For reasons stated elsewhere in this report, *Maesopsis* in the *Maesopsis* 'plantations' in Kwamkoro Forest Reserve needs to be eliminated and replaced by indigenous trees. Great care is needed in undertaking activities in Kwamkoro, which is very important as a catchment and which has readily erodible soils. It is probably impossible, and thus a useless objective, to try to return the forest to its natural state. Experimental areas of *Maesopsis* should be felled through both clear-felling and selective-felling, and various methods tried for encouraging the growth of desirable indigenous species and discouraging the re-emergence of *Maesopsis*. If 'shade trees' are shown to be necessary, then only indigenous species should be used, perhaps in combinations.

Research area 7: enrichment planting

Methods of management need to be devised for parts of the forest open to pit-sawyers and pole-cutters. The restoration of degraded forests, such as parts of Lutindi and Kilanga Forest Reserves, is a related field of research. It must be remembered that all forests in which pit-sawing is permitted will certainly be exploited for poles; silvicultural systems should aim at producing crops at two very different tree sizes. Only species indigenous to the East Usambaras should be used for enrichment planting and we have prepared a list of species which are used for poles at the present time (Chapter 19). In any case, planting should always be of several species to avoid monocultures.

It is worth pointing out that the yields of poles and timber from the natural forests, even when these are well managed, will never approach those obtainable from plantations.

Research area 8: developing silvicultural systems for timber harvesting by pit-sawing

Experiments are needed to determine a suitable size for pit-sawing coupes, the types, sizes and spacings of trees to be cut and necessary pre- and post-logging measures.

The effects of pit-sawing and pole-cutting on forest ecosystems need to be studied, for instance to determine whether these activities result in a significant drain on nutrient reserves.

Research area 9: social and regulatory aspects of pit-sawing and pole-cutting

Socio-ecological research is needed to determine who the pit-sawyers and pole-cutters are, how they choose where and how to work and how they relate to the wider society. This information is needed to help devise more efficient systems of control.

3. The organisation of research

Some of the areas of research outlined above are traditional fields for forestry research in Tanzania, although the actual amount of research which has been carried out in natural forests is very little, when compared to research in softwood plantations. Sparse resources make the selection of priorities difficult, but certainly some reallocation of resources in favour of research into natural forests is desirable. Kalaghe and Kessy (1986) have pointed out some of the problems facing forestry research

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in Tanzania, including shortages of manpower, funds and facilities, deficiencies in administrative organisation and a low morale among research workers. Some support from outside bodies would be desirable.

The study of rain forest dynamics is essentially a new field of research for Tanzania and needs an infusion of ideas. Indeed, new ideas are required in many other areas of research as well. Frequent contact with other scientists is generally essential for success in science. The particular problems of Tanzania are its relative isolation from the main centres of world forestry research and its shortage of experienced active manpower.

Given the continuing need for wider contacts, it is suggested that long-term links be established between organisations dealing with particular aspects of forestry research in Tanzania and carefully selected organisations elsewhere, these being chosen for their competence. These must be two-way relationships. The foreign researchers (if chosen properly) should be able to offer up-to-date theoretical guidance, but they are likely to come to Tanzania without detailed knowledge of local biological and social conditions. They too have a lot to learn. The development of personal relationships within the institutional link is considered essential for success, especially for reinforcing in Tanzanian workers the idea that their efforts are valuable. Professional attitudes are difficult to maintain when one is poor. It is in fact very encouraging that many Tanzanian researchers do try to maintain professional attitudes and standards despite the difficulties.

Turning to give a few more practical suggestions for one particular area of research, rain forest dynamics, it is a fact that expertise worldwide is in short supply and that only a few institutions are suitable as sister institutions. One of these should be approached. The initial basis for establishing a two-way relationship will be that people in the foreign institution will be able to offer insights into the theory and research methods involved in the study of rain forest dynamics, while their Tanzanian colleagues will have knowledge of particular species in the forests. A possible way to start would be to select two research students, one Tanzanian and one from the linked institution, who should work closely together, each studying, for example, the life history strategy of a particular species. There should be two supervisors, one from each organisation, and these will also be involved in the learning experience.

Foreign institutions in this type of link are unlikely to be able to supply funding and in any case it is probably undesirable that they do so. It may be best to distinguish clearly between the monetary and intellectual aspects of research support. A third party is thus required to provide funding. Funds are needed to pay for travel of staff between the two institutions, to assist with the accommodation and subsistence of scientists, especially when they are not working in their own countries, to provide means of transport to research sites in Tanzania, to buy equipment and to help establish or upgrade research stations. Field research stations should not be over-elaborate; if sophisticated equipment is needed then, if possible, this should be placed in central research stations, such as that already existing at Lushoto.

4. The possibility of a forest ecology research station on the East Usambaras

There has been a suggestion that a centre for research into tropical forest ecology be established on the East Usambaras. If this is done, it should form part of an existing biological or forestry research organisation in Tanzania, probably the Silvicultural Research Station at Lushoto, or at least be very closely linked. There should be ties with Dar es Salaam and Sokoine Universities. A foreign-dominated centre may do useful research, but lack of adequate Tanzanian involvement may hinder the application of the results. However, whilst the aim would be to promote a productive cooperative programme, the scientific contribution of the lone expatriate research worker should not be discounted. The research centre should act primarily as a field base for workers from Tanzanian forestry research organisations and their linked institutions.

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The East Usambaras have a number of advantages as the site for establishment of a tropical forest research station. The forests are of exceptional biological interest. Many applied research problems are already identified . Two major types of forest, lowland and submontane, are represented. There is some more or less intact, unexploited forest left; this is very valuable for studying the ecology of species. The presence of the centre should help to maintain the integrity of the nature reserve; possibly the centre could also serve as the administrative headquarters for management of the nature reserve and the botanical garden.

Reference

Kalaghe, A.G. & Kessy, B.S. (1986). The state of forestry research in Tanzania. Tanzania Forestry Research Institute, Ministry of Natural Resources & Tourism. Mimeo.

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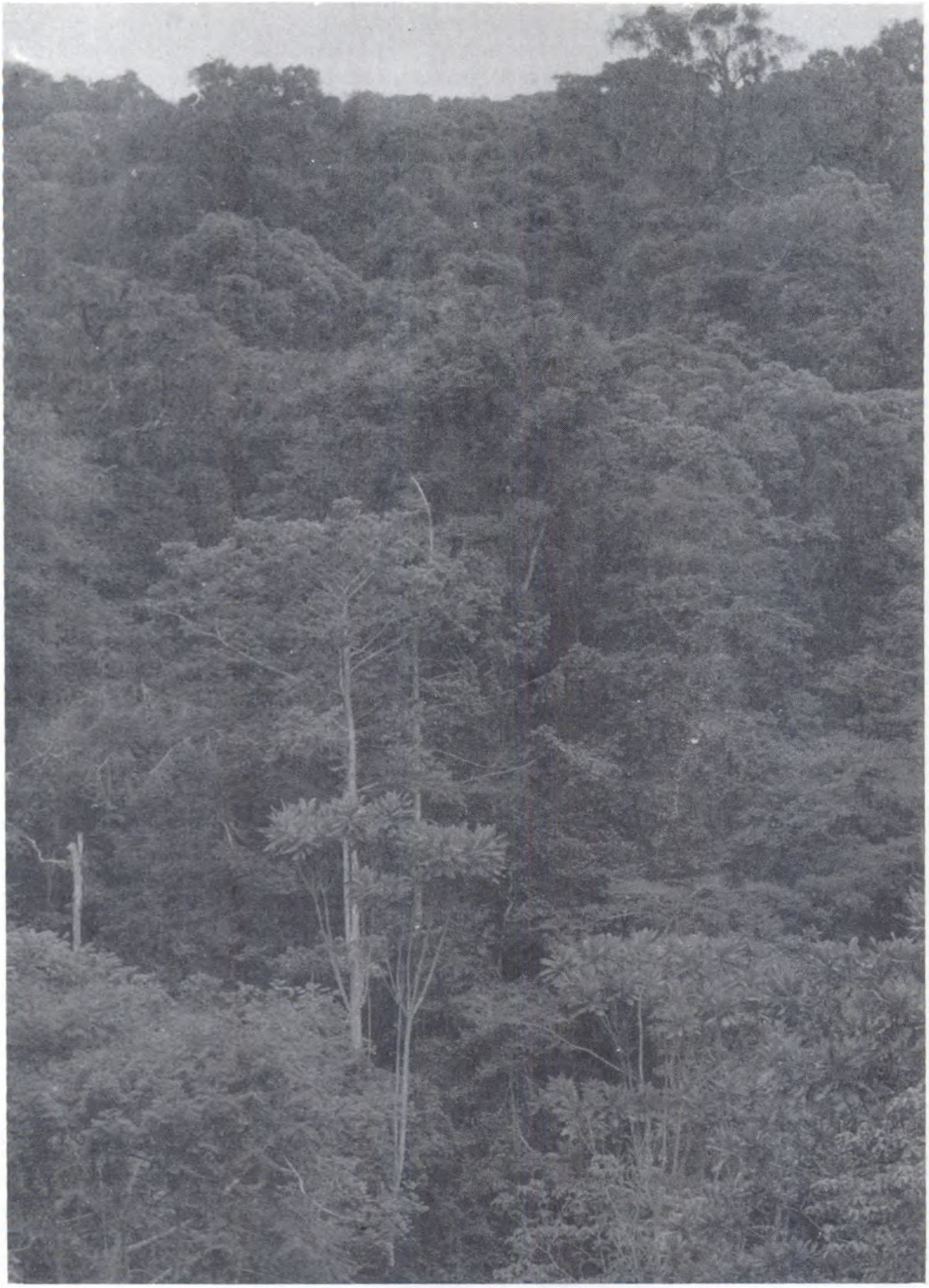

Submontane forest on the north-western side of Kwamkoro Forest Reserve, about 950 m. This forest has been lightly exploited. Note the uneven appearance of the crowns of the emergent trees which is typical of submontane forest. The large-leafed species in the foreground is Anthocleista grandiflora. May, 1987.

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Tree of Ficus exasperata broken by a climber; the Ficus is sending up fresh shoots. The tree fall occurred in January 1987 while IUCN workers were recording the nearby mid-slope profile plot in Kwamgumi Forest Reserve, 230 m (Chapter 25).

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Trunks of Polyscias (left) and Anthocleista (right), which originally established themselves on the trunk of a naturally fallen tree, hence the stilt roots. (Chapter 27). The trunk has now rotted away. Kwamsambia Forest Reserve, 980 m. January, 1987.

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Mr. Ruffo standing in a 2-year old gap caused by pit-sawing in Kwamkoro Forest Reserve, 1000 m. The dense tangle (here 2.5 m tall) of shrubs and climbers found in more open parts of gaps (foreground) makes treee establishment difficult. Ruffo is pointing at a young Maesopsis which has become established, while behind him are the large leaves of Macaranga, another pioneer tree. January, 1987.

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Maesopsis (trunk on center right) and Macaranga (trunk on left) established in the trunk area of a Newtonia felled by pit-sawyers in 1978 (Chapter 27, site A). March, 1987.

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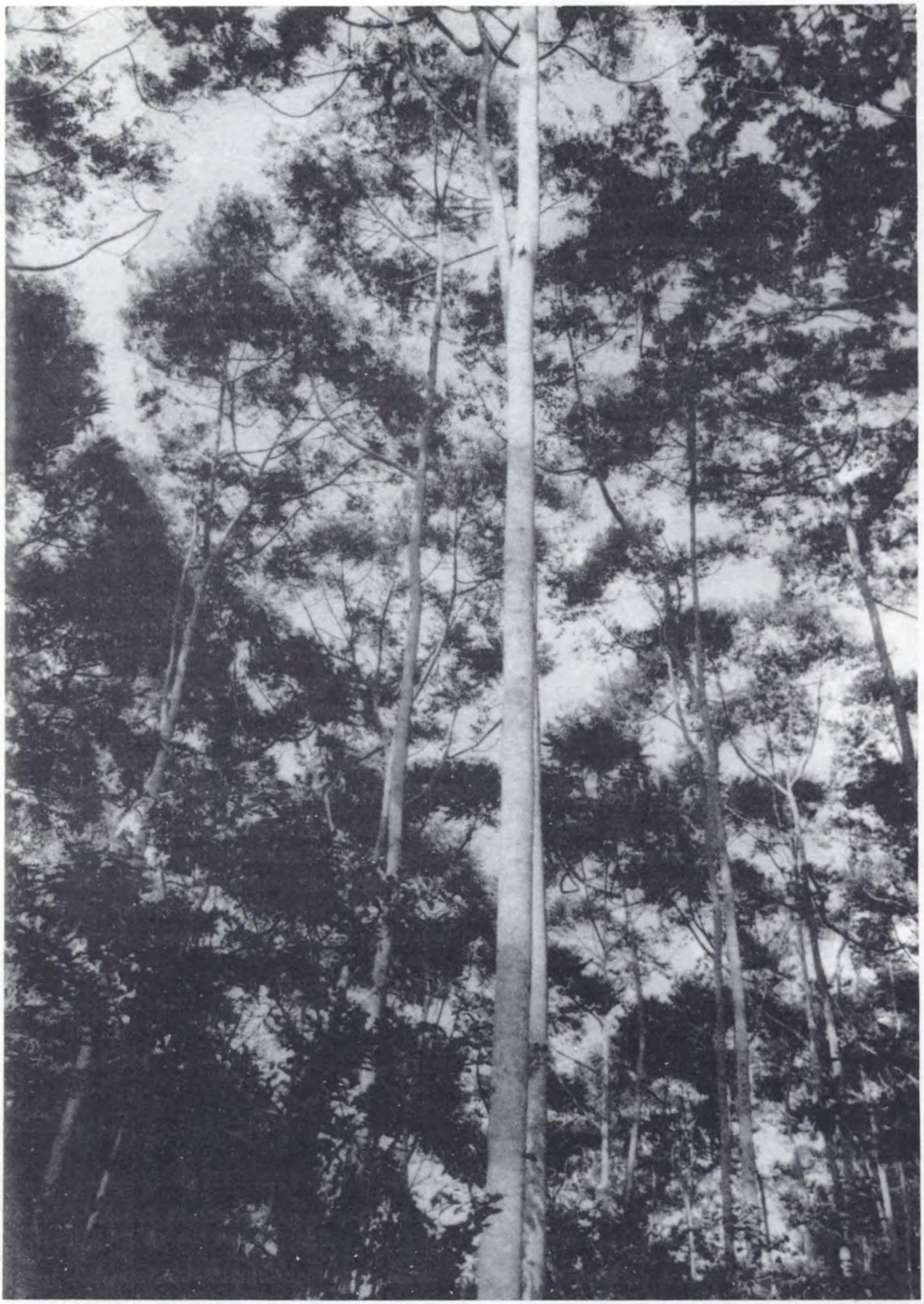

Maesopsis stand in a logged area of Kwamkoro Forest Reserve, 950 m. Note the open canopy. There is an understory, largely of Harungana. February, 1987.

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Carpet of self-sown Maesopsis seedlings in Amani West Forest Reserve, 930 m. (Chapter 27, site F). February, 1987. (Credit PH).

Mechanical logging in submontane forest, Kilanga Forest Reserve. Dragging a log from the forest. September, 1986.

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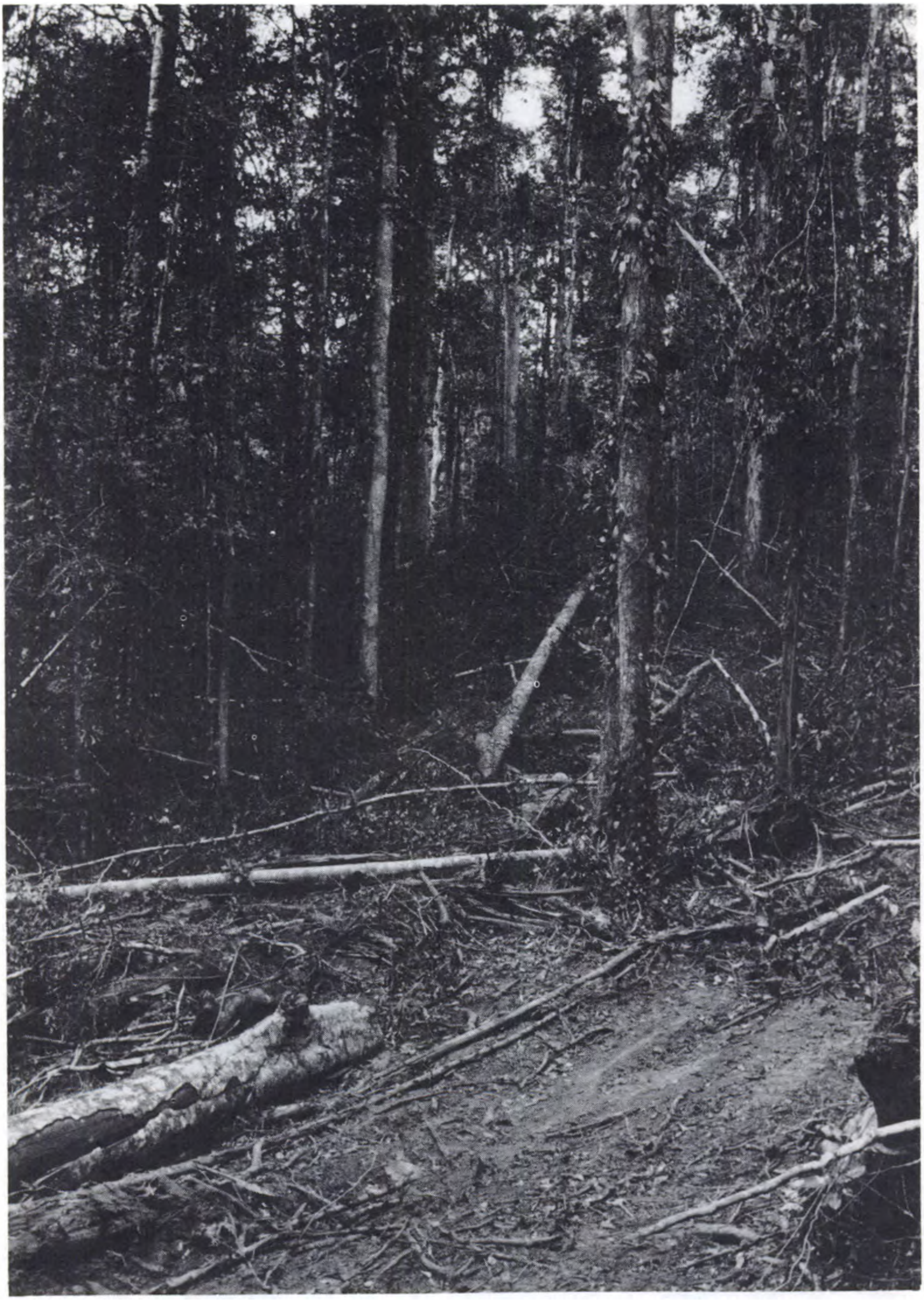

Damage caused by industrial logging in Kwamkoro Forest Reserve, 950 m. July, 1986.

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Teak at Longuza, planted in 1974. September, 1986.

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Forest cleared to plant maize, near Monga Tea Estate. May, 1987.

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Bananas planted on a farm near Kwamkoro Tea Estate (visible behind). Note the bad infestation with the fern Pteridium, which is a very common weed in cultivated land on these poor soils. January, 1987.

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Editors' Acknowledgements

We are grateful to the Norwegian Agency for International Development (NORAD), who funded the project, and especially to Per Prestgard for his strong support and involvement throughout.

Many authors have contributed to this report and any merit it has derives from the quality of the articles they have submitted. Other organisations and individuals who have assisted include:

- the Forest Division, at many levels. At national level we are indebted to E.M. Mnzava (Director), R.E. Kimariyo and many others; in Tanga special thanks is due to G.O.R. Mndambi (Catchment Forest Officer); at Kwamkoro we would like to thank Messrs. Lyimo, Assey, Rwamugira, Nkomwere and Materu.

- K.M. Rajabu, Regional Natural Resources Officer, Tanga Region, who has constantly encouraged this work.

- the Regional Development Director, Tanga (I. Aboubakar) and his staff, especially A.Kiwambo, who tirelessly collected statistical data.

- Pierre Binggeli, who kindly helped a great deal with the editing of this report.

- the Director (Dr. S. Irare) and many others members of the National Institute for Medical Research at Amani, including Messrs. Ortona, Muro (who supplied meteorological data), Kibaja (library facilities), Mtoi and Mwaiko (both of whom helped with analysis of water and soil samples), Kitundu, Matola, Mazige (and Amina and Josephine in the Resthouse), Mutabingwa and Kimweri (and his children Hadija and Hakumani). We are especially grateful to the Institute for the use of a house.

- Matti Maatta, the AFIMP project manager, with whom we have had a productive and enjoyable collaboration throughout the forest study and the continuing work on the forest management plan.

- Finnish foresters working on the AFIMP project, especially Messrs. Niemitalo, Heinonen, Rautiainen and Ahola, and of course Taina Veltheim.

- the Water Department, Tanga, especially S.M. Kamugisha.

- the Tropical Pesticides Research Institute at Arusha, especially W. Mziray (Head, Tanzania National Herbarium). TPRI allowed Messrs. Kibuwa and Abdallah to work for IUCN.

- the Silvicultural Research Centre at Lushoto, including A. Kalaghe (Silviculturalist-in-Charge), T.H. Msangi, Mr. Shoo and Christina Mmari, who, as Ruffo's field assistant, helped to collect and identify plants, and kept up his morale with good cooking.

- the East African Herbarium, National Museums of Kenya, for help with identification of plants, especially C.H.S. Kabuye (Botanist-in-Charge), H. Beentje, E.P.K. Kay and J.G. Mutungah.

- the Herbarium at the Royal Botanic Gardens, Kew, especially Diane Bridson and B. Verdcourt.

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- the National Soil Service, Tanzanian Agricultural Research Organisation, Mlingano, especially Ans Brom, Frits Vanderwal and A.F. van Kekem.

- the Integrated Usambara Rain Forest Project, especially Prof. O. Hedberg and Svein Iversen. Also the Royal Swedish Academy of Science for inviting me to Stockholm to attend a conference.

- Kwamkoro, Marvera and Karimi tea-estates (D. Mwema, Sheik Osman and V. Kessy), including for the loan of meteorological data.

- Tanga Integrated Rural Development Project, including for use of their library and for maintenance of project vehicles.

- the Director, Tea Research Institute, Tanzanian Agricultural Research Organisation, for the loan of meteorological data.

- the University of Dar es Salaam, especially various members of the Institute of Resource Assessment, who helped to prepare vegetation maps, notably Messrs. Yanda, Kajula and Msuyo.

- the Department of Forest Biology, Sokoine University of Agriculture, especially S.A.O. Chamshama and J.A. Maghembe. Also Shatsi Pocs for hospitality.

- the Regional Centre for Services in Surveying, Mapping and Remote Sensing at Nairobi, especially Allan Falconer.

- Neil and Liz Baker, for their continued interest and willingness to help.

- Lut Zylstra, Paul Box and Edward Klopp, who showed that international cooperation can sometimes be effective.

- staff at the IUCN office in Nairobi, especially Esther Wamae, Liz Jarvis and David Pratt.

Personal acknowledgements by A.C. Hamilton

It has been a pleasure to work with all those who have contributed articles to this report. They are not further acknowledged here, except for:

- C.K. Ruffo, without whom little could have been accomplished and who has been personally very supportive;

- David Taylor, who agreed at short notice and considerable sacrifice to himself to substitute for me as a lecturer at the University of Ulster and further, also at short notice, cut short his work on the East Usambaras to return to the University to mark an examination;

- I.V. Mwasha, who went beyond the call of duty in introducing me to the problems of forest management on the East Usambaras;

The unsung hero of the field-work is Mr. Raphael Abdallah, always willing and uncomplaining: a great pillar of strength.

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I am indebted to my three postgraduate students at the University of Ulster, David Taylor, Benny Browne and Andrew Large, for supporting me in this venture for IUCN, despite (presumably) problems incurred by my absence. I hope that their work has not suffered unduly. I am indebted to my various colleagues in the Department of Environmental Studies for support, notably J. Morrow, N.McDowell (photographer), G. Bell, S. Tinkler and K. McDade; Bill Carter, C. Edwards, J. Coward (the last three for encouraging David Taylor in his new teaching role); A. Cooper, B. Rippey, G. Nevin and K. Cadman (these last four for assuming some of my duties during my absence). B. Rushton kindly provided useful critical comments on Chapter 27. I am extremely grateful to the University of Ulster for agreeing to second me to IUCN at only a few weeks notice.

My wife, Naomi, and my children, Susan and Patrick, have fully supported me during my absence from home for almost a year. They believe, as I do, that I could not in conscience refuse an opportunity to help in this project, aimed as it is, at trying to conserve the internationally outstanding and rapidly disappearing rain forests of the East Usambaras.

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Published by IUCN, in collaboration with the Forest Division, Ministry of Lands, Natural Resources and Tourism, Tanzania and funded by the Norwegian Agency for International Development (NORAD)

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