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ICRAF

INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY

Annual Report 1989

The International Council for Research in Agroforestry (ICRAF) is an autonomous, non-profit international research council governed by a Board of Trustees with equal representation from developed and developing countries. ICRAF was established in 1978 with headquarters in Nairobi, Kenya. The mandate is to initiate, stimulate and support research leading to more sustainable and productive land use in developing countries through the introduction or better management of trees in farming and land-use systems. In pursuit of this mandate, ICRAF's strategy for the 1990s is threefold:

- To take a leading role in strengthening national capacities to conduct agroforestry research by encouraging inter-institutional collaboration and by promoting the dissemination of information on agroforestry through training and other activities

- To encourage and conduct, jointly with national institutions, applied and adaptive research leading to the development of appropriate agroforestry technologies through a rational selection of research priorities based on the identified needs and potentials of selected land-use systems in the major agro-ecological zones of Africa

- To conduct strategic research on selected topics of global importance in which a need has been recognized, arising out of collaborative applied research. ICRAF will also encourage its partners and others to undertake strategic research in areas outside its own comparative advantage.

ICRAF derives its operational funds from voluntary contributions by several bilateral, multilateral and private organizations. In 1989, donors to ICRAF's core budget were the Canadian International Development Agency (CIDA), the World Bank (International Bank for Reconstruction and Development—IBRD), the Ministry of Development Cooperation of The Netherlands, the Royal Norwegian Ministry of Development Cooperation, Swiss Development Cooperation, the Finnish International Development Agency (FINNIDA), the African Development Bank, the Swedish Agency for Research Cooperation with Developing Countries (SAREC), the Ford Foundation and the Government of France.

Donors providing restricted project grants and in-kind contributions were CIDA, the United States Agency for International Development (USAID), the Swedish International Development Authority (SIDA), the International Fund for Agricultural Development (IFAD), the Rockefeller Foundation, the Ford Foundation, SAREC, the programme for Direct Support to Training Institutes in Developing Countries (DSO) of The Netherlands, the German Ministry for Economic Cooperation (BMZ) with the German Agency for Technical Cooperation (GTZ), the International Development Research Centre (IDRC), the Australian International Development Assistance Bureau (AIDAB), Swiss Development Cooperation, the Government of France, the Nitrogen Fixing Tree Association (NFTA), the International Foundation for Science (IFS), the Norwegian Agency for International Development (NORAD) and the Government of Kenya.

Cover photo: A farmer in Kenya's Embu District takes fuelwood to market. Grevillea robusta *trees planted along the roadside are pruned to provide fuelwood and harvested at maturity for sale as construction poles. In the background, maize is intercropped with banana and a home compound is protected by a living fence.*

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Introduction

In my introduction to ICRAF's 1988 Annual Report, I predicted that 1989 would not be a 'normal' year. This certainly turned out to be an understatement. Indeed, 1989 was full of unusual and important events, many of which will have far-reaching repercussions for ICRAF well into the 1990s. Probably the most outstanding feature of 1989 at ICRAF, however, was the remarkable level of progress and productivity that the staff managed to achieve in spite of the unprecedented number of demands on time and resources. This introduction will begin with a brief description of some of these achievements.

In various statements in recent years, ICRAF has heralded an imminent 'explosion' of information on agroforestry resulting from the large number of research and development projects initiated by many organizations in the 1980s. Since 1986, ICRAF has been involved in collaborative research through the Agroforestry Research Networks for Africa (AFRENA) programmes, aimed at generating agroforestry technologies appropriate for the region. In 1989, results—concrete research results based on field experimentation and surveys—started to emerge from several of these programmes.

Although these are early results from trials that will continue for several more years, some of them are highly interesting. We decided to share some of these results with the readers of ICRAF's Annual Report for two reasons. The first, obviously, is that they are interesting in their own right. The second reason is that the AFRENA programmes have developed so rapidly and so successfully that few people outside ICRAF may know what and how much is happening. ICRAF's significantly expanded Annual Report for 1989 underlines the astounding amount of field research going on in these various collaborative research programmes.

Achievements in the areas of strategic research, training, information and communications were also impressive in 1989, in spite of an actual decline in staffing. Many ongoing research projects came to fruition and were reported during the year, for instance substantial work on the tree/crop interface, a review of agroforestry and soil conservation, and the *Datachain* software package. These and other projects are described in this report. In addition, two new programmes were substantially expanded in 1989, one on improvement of multipurpose-tree germplasm and one on on-farm research. Both of these will develop into major activities at ICRAF during the next three to five years.

In the areas of information and communication, a large backlog of editing work was cleared up, contributing to substantial publications during the year. These are listed in a separate section of this report. The year also marked the successful launching of ICRAF's quarterly magazine, *Agroforestry Today*, together with its French-language sister publication, *L'agroforesterie aujourd'hui*.

ICRAF's library maintained its position as the leading depository of agroforestry literature in the world, with a collection growing from 13,500 to 16,000 documents during 1989. Computer literature searches in response to requests for information increased from 520 in 1988 to 825 in 1989, and external visitors to the library nearly doubled.

Training and education activities also increased, largely within the framework of the various collaborative programmes. The popularity of ICRAF's annual three-week training course on agroforestry research for development increases every year: 350 people from developing countries all over the world applied for 40 places, compared with 300 applications in 1988.

Other signs of increased activity included visitors to ICRAF's field station at Machakos—more than 2000 in 1989, compared with 1400 in 1988. ICRAF staff members contributed papers to about 40 international conferences and workshops during the year, and the sale of ICRAF publications increased from US $16,000 in 1988 to US $55,000 in 1989.

To appreciate fully how remarkable this progress was, it is important to see it against the background of the many extraordinary activities that consumed significant resources in 1989 and also against the fact that available core resources and the number of professional staff did not increase during the year.

As already mentioned, several events occurred, or started up, in 1989 that were not 'normal'. Six of these are worth mentioning—both because of the important impact they had, or will have, on ICRAF's future and because of the significant time and resources they took up during the year. These were as follows:

1. A six-person panel conducted ICRAF's second five-year External Programme and Management Review in June and July. The panel was chaired by Mr. Moise Mensah of the International Fund for Agricultural Development (IFAD). Several pertinent and constructive questions were raised by the panel. These related to ICRAF's programmes and management. The Board of Trustees and management responded to the panel's findings and recommendations, and both reports were presented and discussed at the meeting of ICRAF's Donor Support Group in Washington, D.C., in late October. Most of the recommendations were welcomed by the Board, management and the donors. These have been integrated into the Council's strategic planning exercise and are now in various stages of implementation.
2. One of the most serious concerns of ICRAF's External Programme and Management Review and of the donors was a deficit in core funds incurred in 1988. Even before the review, ICRAF had started to take action to rectify the situation. This has included use of a specialist consultant, expansion of the finance and accounting departments and the introduction of efficient budgeting, cost-control and management-information systems. As a result, by the end of 1989 ICRAF's financial situation was running smoothly.
3. ICRAF's Personnel Section was strengthened substantially in 1989 and

ICRAF's Director-General, Dr. Bjorn Lundgren.

all staff policies were subjected to a major review. A new policy for professional staff became operational in July. The objective has been to create a more effective, systematic and transparent system for staff recruitment, promotion, the description of positions and remuneration.

4. A team from the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR) visited ICRAF on a fact-finding mission in early May. This visit coincided with the annual meeting of ICRAF's Board of Trustees, which was also attended by the chairpersons of the External Programme and Management Review panel and of ICRAF's Donor Support Group. The visit gave the TAC group an excellent opportunity to meet with a large group of people involved with ICRAF. The report produced by this team will form one of the bases for assessing ICRAF's possible membership in the CGIAR, a process that will not culminate until late 1990.
5. The United States Agency for International Development (USAID) commissioned a major midterm review in July and August of the AFRENA programme for the Bimodal Highlands of Eastern and Central Africa. The outcome of this review was a strong endorsement of the programme and a recommendation to the donor to support the second phase.
6. By far the most time-consuming 'extra' activity for management, Board members and professional staff during the year was the preparation of ICRAF's Strategy 2000. Initiated by the Board in late 1988, substantial work on the strategy began in early 1989, slowed down in the middle of the year during the three reviews already mentioned, and increased again towards the end of the year. Completion of ICRAF's strategy will require an intensive period of work and consultations in the first five months of 1990. The new strategy, with its operational structure and programme of work, will be put in place formally on 1 July 1990, but serious implementation will probably not start until later in the year due to recruitment of key directors and a continued shortage of core funds. The contents of the new strategy will be presented in ICRAF's annual report for 1990.

Let me finish this introduction by stating the obvious. It would not have been possible to achieve as much progress in 1989 and at the same time carry out all the extraordinary tasks described above with no increase in available core funds, had it not been for a quite unique sense of dedication and loyalty among ICRAF's staff at all levels. Also, the task would have been extremely difficult without the support and encouragement of the Board of Trustees and the donors. Another important factor that became clear in 1989 as ICRAF's collaborative programmes moved into full gear was the enormous support and encouragement we derive from our national collaborating institutions. ICRAF has chosen the path of true partnership in collaborative activities, and this choice is now starting to pay off.

A warm thanks thus to all staff, Board members, donors, our host country—Kenya—and to all our partners in agroforestry research and development. Your continued support and understanding will again be needed in 1990, a year that promises to be every bit as exceptional as 1989. The light is clearly visible at the end of the tunnel. My conviction is stronger than ever that ICRAF will contribute significantly to land-use improvements through agroforestry research and development in the 1990s.

Bjorn Lundgren
Director-General

An ICRAF Senior Scientist describes the performance of a Cassia siamea *provenance in a multipurpose-tree screening trial at Chipata, Zambia. In the background are members of ICRAF's Board of Trustees.*

Collaborative research with national partners

Collaboration with national institutions is a central feature of ICRAF's strategy—not only in the research programme, but also in training and information activities. The focus of collaborative work is primarily on Africa, where land-use systems are complex, needs are acute and the potential contribution of agroforestry is substantial.

In many countries, there is no national institution with a mandate for agroforestry and few national scientists have training or experience in the interdisciplinary and multicommodity methodologies required for agroforestry research. ICRAF is helping to address these problems through inter-institutional coordination within and across countries, joining in the implementation of agroforestry research and providing scientific collaboration to national institutions, plus short-term training and support for postgraduate education for national scientists. The goal is for each collaborating country to develop its own scientific capacity and research experience, to forge its own inter-institutional mechanisms and linkages, and to allocate appropriate levels of resources in order to carry out its own agroforestry research and development programmes.

Recognizing the potential benefits of collaboration among research projects in the same ecological zone, ICRAF has established four Agroforestry Research Networks for Africa (AFRENAs). These are the Unimodal Upland Plateau of Southern Africa, the Bimodal Highlands of Eastern and Central Africa, the Humid Lowlands of West Africa and the Semi-arid Lowlands of West Africa.

Once a national government expresses an interest in initiating an agroforestry research programme, ICRAF staff members make a promotional visit to brief senior policy-making and technical staff on agroforestry and on ICRAF's approach to research for development. Collaborative arrangements are then formalized through a Memorandum of Understanding between ICRAF and the national government. By the end of 1989, eight countries in Africa had signed such agreements. These were Kenya, Rwanda, Burundi and Uganda in the Eastern and Central Africa AFRENA; Malawi, Tanzania and Zambia in the Southern Africa AFRENA; and Cameroon in the AFRENA for the Humid Lowlands of West Africa.

Technical agreements for collaborative work may also be signed with specific national, regional or international institutions. In 1989, such agreements were signed with the Kenya Agricultural Research Institute (KARI), the Bangladesh Agricultural Research Council (BARC) and the Institut de recherche agronomique et zootechnique (IRAZ)—a regional body based in Burundi and coordinating research in Burundi, Rwanda and Zaire.

Ongoing collaborative arrangements have been established with the Southern Africa Centre for Cooperation in Agricultural Research (SACCAR), which recognizes the Southern Africa AFRENA as an approved programme. In West Africa, ICRAF has signed collaborative agreements with the International Institute of Tropical Agriculture (IITA) and the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) and has proposed agreements with the Consultative Advisory Committee on Semi-arid Food Grains Research and Development (SAFGRAD) and the Institut du Sahel (INSAH).

One important aspect of ICRAF's institution-building activities is the creation of National Steering Committees and multidisciplinary task forces, often drawn from different institutions. This approach encourages discussion across bureaucratic and disciplinary barriers and provides the basis for the institutionalization of agroforestry at the national level.

Activities are coordinated at the regional level through Regional Steering Committees. During 1989, the Regional Steering Committee for the Southern Africa AFRENA met in Blantyre, Malawi, and the Regional Steering Committee for the Eastern and Central Africa AFRENA met in Kampala, Uganda. The Regional Steering Committee for the Semi-arid Lowlands of West Africa was established and held its first meeting in Ouagadougou, Burkina Faso. These meetings focused on reviews of ongoing and planned activities and the formulation of guidelines for future programmes.

The research process

Once collaborative arrangements have been initiated, the research process begins with an analysis of the problems and potentials of existing land-use systems. Multidisciplinary teams of national scientists, accompanied by ICRAF staff members, normally conduct an analysis of land-use systems at two levels.

The first of these is a macro diagnosis and design (D&D) exercise covering an entire ecological zone within a country. The aim is to assess existing production systems, agricultural policies, institutional arrangements, the current status of agroforestry and the potential for improvements in productivity and sustainability through agroforestry. In 1989, macro diagnosis and design studies were conducted in Ethiopia, Ghana, Burkina Faso, Mali, Niger and Senegal.

The macro diagnosis and design is followed by a national or regional workshop to analyse the common problems and potentials of the land-use systems of the zone, to identify agroforestry technologies with potential relevance for the zone as a whole and to establish research requirements for technology development. Participants are national scientists and government officials, along with scientists from ICRAF and other regional and international organizations.

The next step is a detailed analysis of a land-use system selected according to national priorities and institutional capabilities. This is referred to as a micro diagnosis and design. It leads to the preliminary design of promising agroforestry technologies and the identification of research priorities. In 1989, a micro diagnosis and design exercise was conducted in India.

Another objective of the diagnosis and design process is to identify national institutions that can contribute to the implementation of agroforestry research. Collaborative experimental work is planned according to the results of the micro diagnosis and design. The aim is to refine and test technologies on station and on farm in preparation for their extension to farmers.

The research plan typically consists of component experimentation designed to assess the biological potential of multipurpose trees and shrubs through general screening, technology-specific screening and management trials. Appropriate agroforestry tech-

Intensive land-use system in Kenya with Grevillea robusta, *tea, banana and food crops.*

nologies are designed, based on the needs, preferences and resources of land users, and these are tested both on station and on farmers' fields. Once technologies are ready for wide-scale dissemination, the project will include monitoring and evaluation of adoption—in collaboration with extension agencies—to provide feedback into the research process.

All these phases make up the process of agroforestry technology development. It is a dynamic process that requires effective interaction at each phase among biological and social scientists, farmers, extensionists, development planners and policy makers.

Current experimental work is conducted by ICRAF staff members stationed in collaborating countries, together with national scientists. In 1989, ICRAF and collaborating scientists were conducting 82 experiments at 13 field sites in 8 different countries under the AFRENA programmes.

These experiments are monitored, assessed and refined in a continuous process to make sure that all work is closely geared to the needs and opportunities of local land users. A strong emphasis is on communication and coordination among AFRENA research projects, particularly those in the same ecological zone.

Opportunities for collaboration go beyond information sharing among national programmes. They include a regional approach to research planning and implementation, leading to complementary activities in different countries, avoiding duplication of effort and thus saving scarce research resources.

Priorities for study

Information obtained through diagnosis and design studies has emphasized the overriding importance of soil-fertility problems in all the AFRENA regions. Thus, hedgerow-intercropping and improved fallow experiments have been initiated primarily to sustain and improve soil fertility. However, these and other agroforestry technologies may also be designed to provide tree products, such as fodder and fuelwood, depending on the priorities of local farmers.

Another widespread problem is soil loss through erosion. Experiments with contour bund planting and hedgerow intercropping address this issue. Finally, fodder shortages have been identified as a common problem across different ecological zones. At the present stage of experimentation, this problem is addressed primarily through fodder banks and also in conjunction with other objectives.

Trials to develop these technologies include: the general screening of different tree species and provenances for establishment, adaptation and growth in the local environment; technology screening to assess the productivity of promising agroforestry technologies using different species and planting arrangements; management trials to identify the most promising management regimes; and prototype trials to test fully designed agroforestry technologies before extending them widely to farmers. Table 1 lists the most important multipurpose-tree species included in technology screening and management trials in 1989.

Strengthening the institutional base

ICRAF's efforts to establish a strong institutional base for agroforestry research and development at the national level are beginning to show results. Several recent developments will illustrate this:

1. Agroforestry now features as an integral component in the medium-term research programmes of KARI and KEFRI (Kenya Forestry Research Institute), as well as in the national agricultural research priorities set by the Government of Tanzania.
2. Nearly all countries participating in the AFRENAs have developed some formal mechanism for coordinating agroforestry research. Agroforestry units or departments have been established in four countries: Malawi, Ghana, Niger and Senegal. In

Cameroon, agroforestry has become a component of the farming systems research programme.

3. There are many signs of increased political awareness, interest and commitment to agroforestry. In 1989, the Prime Minister of Uganda opened an AFRENA workshop, with several other ministers in attendance, while in Zambia, the AFRENA site was featured in the national World Food Day celebration.
4. ICRAF is increasingly receiving requests from national governments for assistance in developing agroforestry plans and strategies and implementing agroforestry research programmes. In 1989, such requests were received from the Governments of Mozambique, Botswana, Lesotho, Zaire and Benin.

Issues for the future

Certain issues arose in the implementation of ICRAF's collaborative research programmes in 1989, which will have to be addressed if the long-term objectives are to be realized. As more research results are made available from different sites, there is a pressing need to make comparisons and draw general conclusions.

This will require standardized procedures for collecting data and measuring and analysing different variables, such as climatic factors, soils, trees and crops. At the same time, it has been recognized that full standardization cannot be achieved, due to differences among land-use systems and experimental conditions and the importance of encouraging innovation.

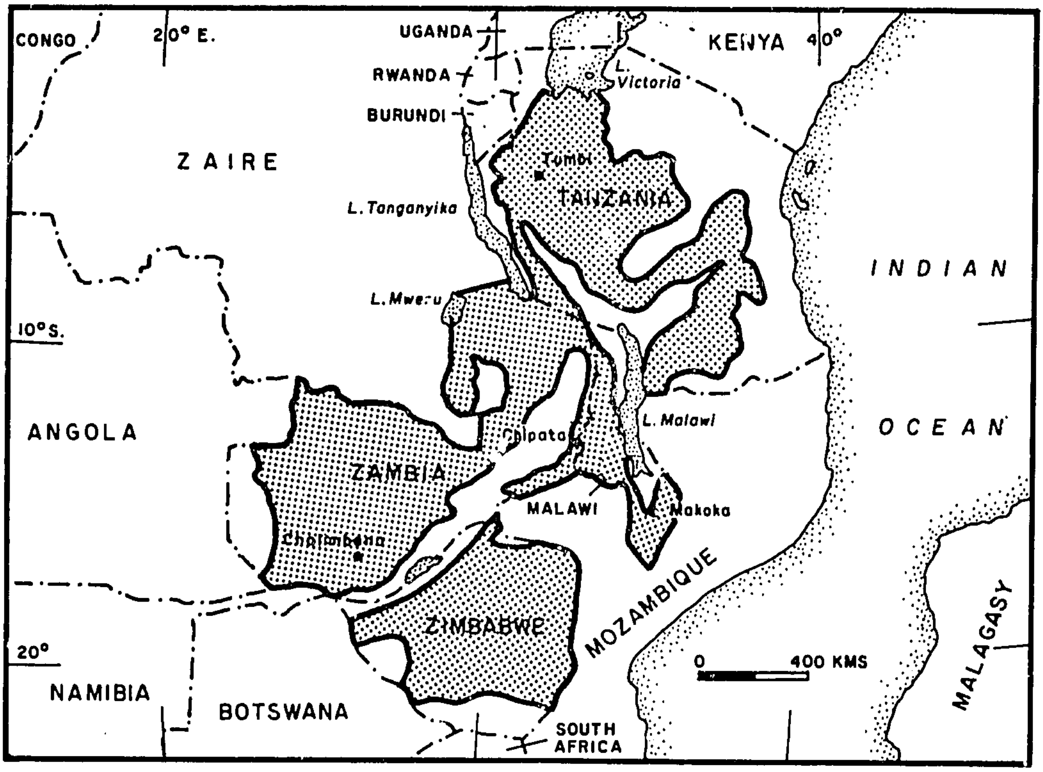
ICRAF's collaborative research efforts should lead to the development of agroforestry technologies that can be adopted by local farmers. To achieve this objective, scientists must work closely with farmers in technology generation and evaluation.

This requires a complementary strategy of on-station and on-farm research, along with economic and social assessments of the benefits and costs to farmers associated with the technologies being developed. In addition, to reach farmers as research partners and as the ultimate beneficiaries of collaborative work, ICRAF needs to expand its networks to include institutions that work directly with farmers, such as national agricultural and forestry extension services and nongovernmental organizations.

Table 1. Most important multipurpose-tree species in technology screening and management trials under the AFRENA programme in 1989: number of trials for each species.

	Southern Africa	Eastern and Central Africa	Humid Lowlands of West Africa	Total
Total number of trials	26	18	5	49
Trials including:				
Leucaena leucocephala	12	10	3	25
Sesbania sesban	14	9	1	24
Calliandra calothyrsus	1	11	1	13
Gliricidia sepium	2	1	2	5
Cajanus cajan	3	–	2	5
Cassia siamea	2	1	1	4
Casuarina equisetifolia	1	3	–	4
Other species	12	20	2	34

Unimodal upland plateau of southern Africa



Research Site	Associated National Research Station	Altitude	Temperature	Annual Rainfall	Soils
Zomba, Malawi	Makoka Agricultural Research Station	1000 m	15.0°C min 26.0°C max	850 mm	luvisols
Tabora, Tanzania	Tumbi Research Institute	1200 m	16.3°C min 28.0°C max	880 mm	ferric acrisols
Chalimbana (Lusaka) Zambia	Mount Makulu Research Station	1143 m	14.0°C min 28.0°C max	800 mm	luvisols
Chipata, Zambia	Msekera Regional Research Station	1020 m	13.8°C min 32.5°C max	1000 mm	ferric luvisols

The Southern Africa AFRENA programme was initiated in 1986 with funding from the International Development Research Centre (IDRC) of Canada and the Canadian International Development Agency (CIDA). The programme focuses on the plateau ecological zone of southern Africa, a region that covers approximately 1 million square kilometres at an altitude of 900 to 1500 metres.

Problems in the region include food shortages and deforestation. Most food is produced by smallholder farmers whose crop yields are declining due to pressure on land resulting in shortened fallow periods. At the same time, many farm families face critical shortages of fuelwood and livestock fodder, particularly during the long dry season.

National Steering Committees for agroforestry research have been established in Malawi, Tanzania and Zambia and teams of national scientists and ICRAF staff have conducted macro diagnostic and design studies in each country. These studies revealed that two major land-use problems affect farmers across the region—declining soil fertility and dry-season fodder shortages. Research projects were designed to develop agroforestry interventions that address these problems in the zone as a whole. This work is now in progress at Makoka in Malawi, at Tumbi in Tanzania and at Chalimbana in Zambia, with an ICRAF scientist based at each site.

In addition, participating countries have developed national agroforestry research projects with relevance for the entire zone but designed specifically to address the problems of a particular land-use system. ICRAF is participating in a national project initiated in 1987 at Chipata in Zambia. Funding is provided by the Swedish Agency for Research Cooperation with Developing Countries (SAREC).

In 1989, national projects were planned in Malawi and Tanzania, to begin in 1990. The project in Tanzania will be based at Shinyanga, with support from the Norwegian Agency for International Development (NORAD). The Malawi national project, focusing on on-farm research, will be based in Lilongwe. Project funding will be provided by IDRC, with ICRAF's participation supported by the Rockefeller Foundation. In 1989, national scientists also designed an agroforestry research project for Zimbabwe with assistance from ICRAF.

ICRAF helps coordinate all these activities in cooperation with SACCAR, which acts on behalf of the Southern Africa Development Coordination Committee (SADCC). Complementarity of research efforts is ensured primarily through regular zonal workshops and meetings of the National Steering Committees.

Malawi

ICRAF's collaborative research programme in Malawi is conducted at the Makoka Agricultural Research Station at Zomba. Within the zonal programme, Makoka has the major responsibility for the identification, acquisition and evaluation of multipurpose-tree germplasm. The objective is to identify promising multipurpose trees for further testing in relation to specific agroforestry technologies.

A total of 77 species and provenance accessions are under study at Makoka. The first screening trial, comprising 49 accessions, was planted in December 1988. Information is being collected on survival and growth, height and stem diameter, branching pattern and crown spread, biomass and nutrient content, flowering and fruiting, and incidence of pests and diseases. Coppicing ability is also evaluated, along with the quantity and quality of green manure produced. For 40 of the species, survival rates have been better than 90%.

The most promising species—*Sesbania sesban* (ex Magoye), *Acrocarpus fraxinifolius*, *Cassia spectabilis*, *Calliandra calothyrsus* and *Flemingia congesta*—will be evaluated for hedgerow intercropping during the 1990 growing season. *Calliandra calothyrsus*, *Acrocarpus fraxinifolius*, *Flemingia congesta*, *Gliricidia sepium*, *Albizia falcataria* and *Acacia julifera* have shown particularly good initial growth. At the height of the dry season, *Acrocarpus fraxinifolius*, *Calliandra calothyrsus*, *Albizia falcataria*, *Flemingia congesta*, *Acacia julifera* and a few other Australian acacias produced new leaves, showing active growth.

Prosopis cineraria, *Acacia murrayana*, *Acacia victoriae*, *Acacia pachycarpa*, *Cassia brewsteri* and *Robinia pseudoacacia* had low survival rates, while *Prosopis tamarugo* died on all plots. *Cassia siamea* and *Acacia auriculiformis* were severely infected by fungal mildew, although the attack appeared to be temporary. *Cassia brewsteri* was attacked by a leaf-chewing insect, resulting in poor survival.

A second screening trial focused on identifying the most promising provenances of well-known agroforestry species. Initiated in January 1989, this trial includes 17 provenances of *Leucaena leucocephala*, 4 provenances of *Sesbania sesban*, and 1 provenance each of *Sesbania bispinosa*, *Sesbania formosa* and *Sesbania macrantha*.

Apart from *Sesbania formosa*, the sesbanias had high survival rates and fast initial growth. In only three months, *Sesbania sesban*, *Sesbania macrantha* and *Sesbania bispinosa* attained a height of 3.5 to 4 metres and produced 15 to 21 tonnes of biomass (fresh weight) per hectare. However, when the sesbanias were cut at 30 centimetres above ground three months after planting, regrowth was slow and most regrowth in *Sesbania macrantha* and *Sesbania bispinosa* died back.

By contrast, most provenances of *Sesbania sesban*, and especially those from Magoye, Zambia, coppiced well and regrowth was vigorous. The leucaenas survived and grew well, although at a slower rate than the sesbanias. Initial growth among the different leucaena provenances was rather uniform. Due to their slower growth, they were not coppiced during the first year.

An experiment was established in February 1989 to observe the response of three sesbania species to different cutting regimes and evaluate the effect of the harvested biomass on maize yields when incorporated into the soil as green manure. The experimental plots were flooded from March to June and survival was poor for *Sesbania bispinosa* and *Sesbania macrantha*. By contrast, *Sesbania sesban* proved resilient to flooding and pests. Trees will be cut in early 1990, followed by application of green manure and maize planting.

Promising agroforestry technologies for the area include hedgerow intercropping, improved fallows, mixed intercropping, fodder banks, boundary planting and multipurpose trees for fruit and fuelwood production. The small size of landholdings in much of Malawi precludes the widespread use of fallows or of agroforestry species or technologies that take land away from crop production. For example, *Sesbania sesban* has been used successfully in the region to enhance soil fertility, but, due to rapid growth and spreading crowns, these trees take up considerable land and may be unsuitable for mixed intercropping in some situations.

Given these constraints, an experiment was initiated at Makoka in December 1989 to test an agroforestry arrangement that maintains the recommended population of maize plants while utilizing the soil-improving capability of the sesbanias. At the beginning of the growing season, maize was planted in pure stand and sesbania seedlings were interplanted at different stages of maize development. After harvesting the maize, the sesbania trees will be allowed to grow until the end of the dry season, when they will be harvested and leaves, flowers, pods, twigs and small branches incorporated into the soil. During the 1990/91 growing season, maize will be planted with different levels of inorganic fertilizer and sesbania interplanted again at different stages of maize growth. Maize production will be assessed under the different variations of this system and compared with maize grown in pure stand.

Tanzania

Collaborative research in Tanzania is based at the Ministry of Agriculture's Tumbi Research Institute. Maize and tobacco are the main crops in the area and livestock production is an important activity for local farmers. Major problems include poor soil fertility, fuelwood shortages and inadequate grazing during the dry season. The zonal mandate for agroforestry research at Tumbi focuses on multipurpose trees for fodder production. Specific objectives are:

- To evaluate multipurpose trees in terms of edible fodder yield, particularly during the dry season

- To examine livestock production potential using fodder from proven multipurpose tree species
- To evaluate leguminous species in terms of enhanced soil fertility and other services and products
- To develop agroforestry interventions that could enhance grain production for human consumption.

General screening trials at Tumbi focus on survival, growth rates and subsequent fodder and fuelwood production of Australian acacia species compared with *Faidherbia (Acacia) albida, Leucaena leucocephala* and *Sesbania sesban*. Six Australian acacias were planted with the other species in January 1988, and six other acacias were planted the following November. Among the first trees planted, *Acacia julifera* and *Acacia auriculiformis* showed particularly good early growth.

Screening trials were also conducted with eight provenances of *Leucaena leucocephala*, and one provenance each of *Leucaena esculenta* and *Leucaena diversifolia*. The *Leucaena leucocephala* provenances performed best in terms of survival, height and root-collar diameter, although some provenances showed poor survival rates due to termite damage. The *Leucaena esculenta* and *Leucaena diversifolia* showed signs of nutrient deficiency. Further work in 1990 will focus on establishing optimum cutting heights for these species, including assessment of coppicing ability.

In 1989, two experiments were in progress to investigate the potential of pigeon pea (*Cajanus cajan*) under local conditions as a dual-purpose grain and fodder crop. Work focused on growth and biomass production of 20 provenances, including 10 fodder types and 10 tree types. One experiment measured dry-matter production and litter fall of plants allowed to grow undisturbed, while the second explored the effects on biomass yield of cutting at different stages of plant growth.

Both fodder and tree-type provenances showed considerable variation in growth and phenology. Early cutting produced less total biomass but a higher percentage of edible matter. Insect pests were generally more important than diseases, but they were controlled by spraying and some provenances also showed a degree of resistance.

Sesbania species have considerable potential as sources of animal feed, because fodder yields are high and the herbage is both palatable and digestible. Sesbania has also been grown successfully for fuelwood and as a source of green manure. Studies at Tumbi in 1989 focused on root nodulation in seedlings, plant survival, growth, dry-matter yield and the effects of cutting height. They included 16 provenances of *Sesbania sesban*, 4 provenances of *Sesbania macrantha*, 2 provenances of *Sesbania greenwayi* and 1 provenance of *Sesbania quadrata*.

At the time of planting out, some seedlings were harvested in order to assess root nodulation. All the provenances were effectively nodulated, but the number of nodules varied widely. Among seedlings planted out, characters such as plant height, root-collar diameter, lateral growth pattern and time of flowering were also highly variable. However, no relationship was apparent between these parameters and biomass yields. In general, *Sesbania macrantha* consistently outyielded provenances of *Sesbania sesban*. No major pests or diseases were observed. However, low cutting heights (50 centimetres) were associated with increased mortality in most of the provenances studied.

Zambia: Chalimbana

A zonal agroforestry research project was established in 1987 at Mount Makulu Research Station in Chalimbana, Zambia. The zonal mandate for research at Chalimbana focuses on the contribution of agroforestry to soil fertility. Experiments in progress include multipurpose-tree screening trials and agroforestry technology trials based on hedgerow intercropping and improved fallows. Additionally in 1989, ICRAF helped plan and conduct the First National Agroforestry Seminar in Lusaka, organized and coordinated by the Zambian Department of Agriculture's Soil Conservation and Agroforestry Extension Programme.

The first screening trial at Chalimbana was established in 1987. It covers 16 multipurpose trees, including 10 local species. As shown in Table 2, all species have demonstrated good survival rates except *Sesbania grandiflora, Sesbania macrantha* and *Ventilago viminalis*. Among those that survived well, *Eucalyptus camaldulensis, Sesbania sesban, Eucalyptus grandis* and *Cassia siamea* showed the best height growth.

In January 1989, a second multipurpose-tree screening trial was established with 25 species and provenances. Information is collected on height and stem diameter, number and length of branches, time of flowering and podding, and incidence of pests and diseases. Two species—*Melia azedarach* and *Prosopis tamarugo*—died in the first three months after planting.

A hedgerow-intercropping trial was established in December 1987 to assess the effects of *Leucaena leucocephala, Flemingia congesta* and *Sesbania sesban* interplanted with maize. The hedgerows were pruned at heights of 50 or 100 centimetres one year after planting and subsequently on a monthly basis during the growing season. All or no prunings were applied to the maize rows. Inorganic fertilizer was applied at the recommended rate to some plots and not to others.

According to preliminary results, the sesbania showed the best height growth, biomass production and wood yield, followed by flemingia and leucaena. Wood yields were highest for all three species

Table 2 Height (cm) and survival (%) of 16 multipurpose-tree species established *in December 1987 at Chalimbana Research Station, Zambia. Heights are averages of 16 trees planted for each species, or of survivors. Figures in brackets are standard deviations.*

	Height March 88	Height July 88	Height December 88	Height August 89	Survival August 89
Sterculia africana	30 (3)	50 (7)	62 (13)	75 (9)	79
Eucalyptus camaldulensis	95 (12)	197 (14)	222 (56)	532 (86)	100
Albizia adianthifolia	12 (2)	18 (4)	60 (23)	145 (42)	100
Acacia ataxacantha	46 (23)	66 (8)	78 (17)	98 (14)	100
Casuarina cunninghamiana	31 (8)	6[illegible] (18)	94 (29)	188 (34)	81
Eucalyptus grandis	65 (8)	96 (13)	—[a]	380 (104)	85
Sesbania macrantha	203 (14)	359 (16)	—[a]	504 (20)	40
Acacia polyacantha	81 (10)	112 (26)	134 (40)	233 (53)	100
Leucaena leucocephala	61 (14)	147 (11)	179 (24)	293 (22)	100
Cassia siamea	64 (6)	158 (12)	210 (34)	335 (35)	100
Flemingia congesta	63 (15)	137 (27)	200 (40)	—[a]	99
Ventilago viminalis	11 (4)	24 (8)	42 (8)	—[a]	55
Afzelia quanzensis	15 (3)	—[a]	27 (4)	—[a]	74
Sesbania sesban	157 (30)	313 (71)	—[a]	—[a]	94
Sesbania grandiflora	81 (13)	150 (44)	—[b]	—[b]	0
Faidherbia (Acacia) albida	45 (4)	67 (8)	94 (40)	133 (28)	100

[a]No data.
[b]No survivors.

when trees were cut at 50 rather than at 100 centimetres. Although some of the results were variable, Table 3 shows that maize grain yields were highest on plots where tree prunings were applied to the soil together with inorganic fertilizer at the recommended rate.

Yields from plots with tree prunings plus fertilizer were higher than yields from plots with fertilizer alone, regardless of cutting heights. However, yields from plots with prunings but without fertilizer were consistently lower than from plots with fertilizer alone.

In 1989, a second hedgerow-intercropping trial was established to investigate the effects of intercropping *Leucaena leucocephala*, *Sesbania sesban* and *Sesbania macrantha* with maize under three livestock-feeding regimes: all prunings removed and used as fodder for calves; all prunings removed, used as fodder for calves and all manure returned to the soil; and all prunings returned to the soil as mulch. Preliminary results will be available in 1990.

An improved-fallow trial was established in 1989, involving *Sesbania sesban* planted in one-, two- and three-year rotations with maize, with and without fertilizer. Soil samples were analysed for baseline physical and chemical properties in order to assess soil changes over a 10-year period. The sesbania grew quickly during the first year, in some cases shading adjacent maize plots. This problem will be addressed as the experiment continues.

The incidence of weeds and insect pests was recorded for all trials throughout the year. The blister beetle (*Mylabris dicincta*) was observed in *Sesbania sesban* during

Table 3. Maize grain yield under hedgerow intercropping with leucaena, flemingia and sesbania, with and without inorganic fertilizer, at Chalimbana Research Station, Zambia. Figures in brackets are standard deviations.

Species	Cutting Height (cm)	Fertilizer[a] Application (kg/ha)	Grain Yield (kg/ha)	Increase/Decrease over Control (%)
Leucaena leucocephala	50	0	1859 (613)	-66
	50	150	7204 (337)	+31
	100	0	1947 (337)	-64
	100	150	7301 (773)	+33
Flemingia congesta	50	0	2819 (441)	-49
	50	150	6912 (1216)	+26
	100	0	3699 (1021)	-33
	100	150	6133 (876)	+12
Sesbania sesban	50	0	2823 (1608)	-49
	50	150	5841 (1012)	+6
	100	0	2725 (337)	-50
	100	150	5739 (2490)	+4
Control (maize only)	—	150	5497 (1769)	—

[a]Urea applied as top dressing 14 days after planting.

flowering and podding and seemed to cause substantial damage.

Zambia: Chipata

A national agroforestry project was initiated in 1987 at Chipata in Eastern Zambia. Work is conducted by the Zambia Government's Agriculture and Forestry Departments, with a project leader provided by ICRAF and support from SAREC.

Objectives are to screen multipurpose-tree species capable of improving soil fertility and providing supplementary dry-season fodder and other products, to evaluate management regimes for multipurpose trees under such technologies as hedgerow intercropping and improved fallows, and to design and test prototype technologies suitable for local land-use systems. Soils at this site are highly acidic and low in all major plant nutrients, indicating a need to select acid-tolerant species and to treat the soil to correct nutrient imbalances.

Multipurpose-tree general screening trials were in progress in 1989, including 19 species. Most showed good growth, but *Casuarina equisetifolia* was completely destroyed by termites at two locations on the site. *Sesbania grandiflora* appeared to be unsuitable for the upland conditions at Chipata: seedlings were stunted, increasing their susceptibility to termites and other insect pests, which resulted in high mortality.

Table 4. Labour requirements for first weeding of Sesbania sesban *according to method of establishment.*

Establishment Method	Mean Person-days/Ha for Weeding
Seed broadcast/complete weeding	108.0
Bare-rooted seedlings/ complete weeding	31.6
Potted seedlings/complete weeding	22.3
Bare-rooted seedlings/spot weeding	14.0
Potted seedlings/spot weeding	10.9

Chamaecytisus proliferus ssp. *palmensis* and all *Prosopis* species included in the trials also failed to establish.

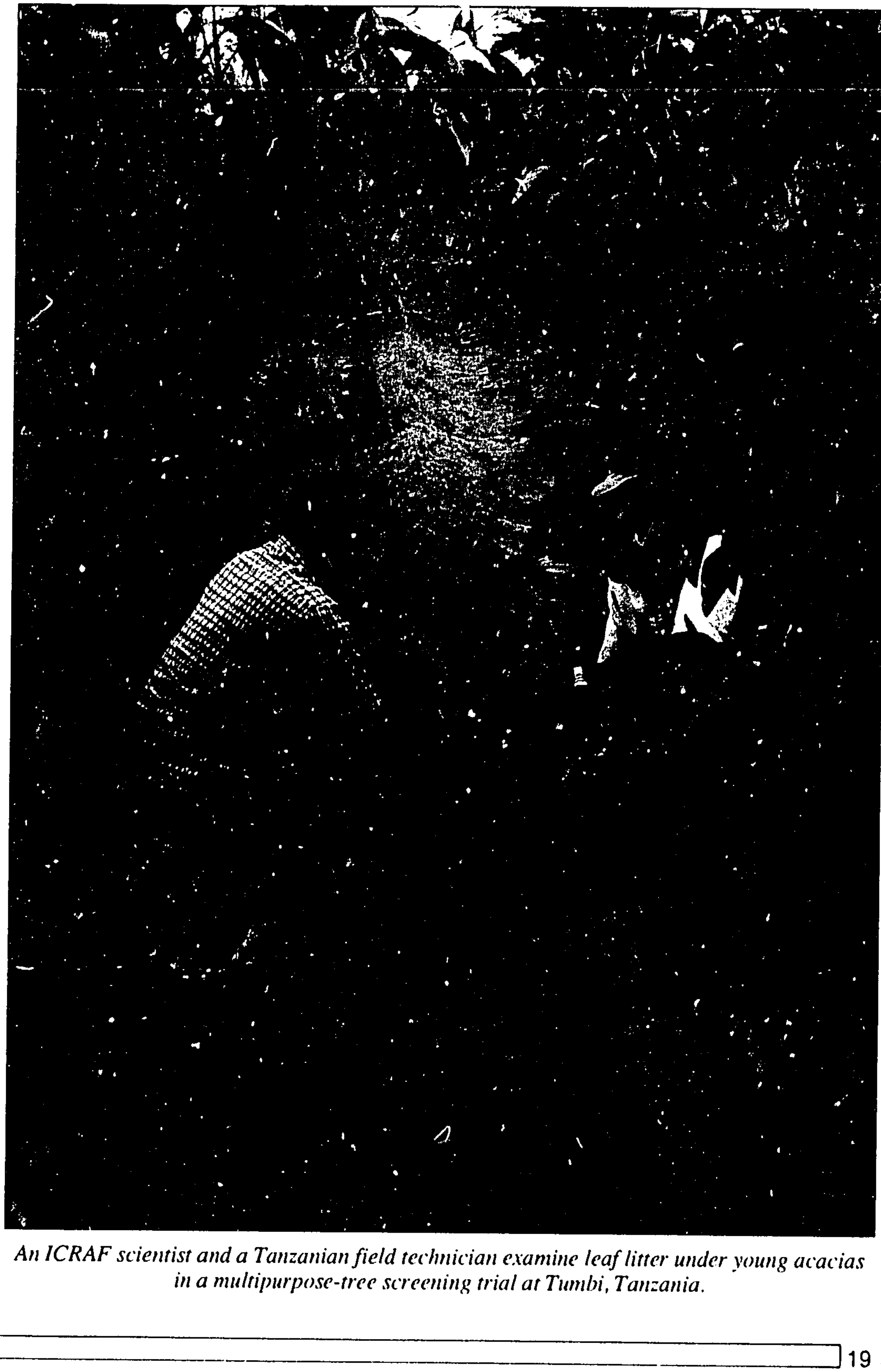
After slow growth in the first season, *Flemingia congesta* recovered quickly by the end of the dry season and produced considerable leafy biomass after the first few rains. However, when cut and applied as green manure, the leaves decomposed very slowly, even when incorporated into the soil. Towards the end of the rainy season, this species produced a profusion of seeds, suggesting that it could become a weed if not harvested before seeding.

Another screening trial focused on 15 provenances of *Gliricidia sepium*. Preliminary observations of height, stem diameter, branching and leafing showed considerable variability, but final results will only become available after destructive sampling. The objective is to identify provenances that will produce the maximum biomass for green manure and dry-season livestock fodder.

Labour requirements are a major factor in considering the introduction of agroforestry technologies. A *Sesbania sesban* establishment trial compared different methods of tree establishment in terms of labour required for planting and first weeding.

The results, as shown in Table 4, indicate that seed broadcasting, although less labour-intensive as a planting technique, leads to much greater weeding requirements than planting potted or bare-rooted seedlings. The implication is that seedling production in nurseries may become an important aspect of agroforestry development in the region. As a follow-up to this study, tree-establishment rates using different planting techniques will be assessed at the end of the dry season in 1990.

Hedgerow-intercropping trials included *Flemingia congesta, Cassia siamea* and *Leucaena leucocephala*. When hedgerows were pruned after one year's growth, cassia yielded more leafy biomass than the other two species. However, application of cassia leaf mulch resulted in low maize yields compared to plots where leucaena or flem-



An ICRAF scientist and a Tanzanian field technician examine leaf litter under young acacias in a multipurpose-tree screening trial at Tumbi, Tanzania.

ingia mulch was applied. This may be due to cassia's relatively slow decomposition rate, implying that nutrients are not released to the maize crop during the growing period when they are most needed.

One hedgerow-intercropping trial showed that the application of *Leucaena leucocephala* or *Flemingia congesta* mulch enhanced maize production when inorganic fertilizer was also applied. However, without fertilizer, maize production was poor, even with tree mulch.

An improved-fallow trial involved growing *Sesbania sesban* for one year, removing the trees from the plot and planting maize. Preliminary results suggested that the sesbania fallow may complement the effects of inorganic fertilizer.

After fallowing, differences in maize stover, cob and grain weights were insignificant whether 66% or 100% of the recommended fertilizer level was applied. This suggests that improved fallows may significantly reduce subsequent fertilizer requirements. The beneficial effect of the fallow appeared to increase when trees were densely planted—at a spacing of 50 x 50 centimetres. Another improved fallow trial is in progress using *Flemingia congesta*.

Zimbabwe

Following a macro diagnosis and design exercise in 1987, a team of Zimbabwean scientists and ICRAF staff joined in 1989 to survey ongoing agroforestry programmes conducted by the Forestry Commission, the University of Zimbabwe, the Agricultural Technical and Extension Services and the Department of Research and Specialist Services. ICRAF staff collaborated in the design of an agroforestry research project for Zimbabwe within the context of the Southern Africa AFRENA.

Multipurpose-tree survey

In May and June 1989, researchers conducted a multipurpose-tree survey in several districts around Chipata in Zambia and Makoka in Malawi. A total of 78 farmers were interviewed. They identified 112 useful plant species, including 58 used for fuelwood, 52 for fruit, 39 for medicinal products, 33 for construction poles and timber, 17 for browse, 15 for shade around homes, 11 to improve soil fertility and 9 as living fences.

Among other interesting findings, farmers reported that more than 30 indigenous fruit-tree species were in wide use as food supplements. These are listed in Table 5. Previous studies on some of these species indicated that the fruits are rich in sugars and essential vitamins and many of the fruit kernels are also rich in vegetable oils and protein. Farmers would like to plant these fruit trees on farm boundaries and around their homesteads.

Thus, later in the year, scientists at Makoka launched a research project to collect germplasm of indigenous fruit trees, to investigate their seed-germination requirements, to identify suitable nursery techniques for seedling production and to assess their growth and fruit yield after planting out. This work should lead to the identification of the most promising species for testing on farm in order to identify tree characteristics that are important to farmers and to design appropriate management regimes.

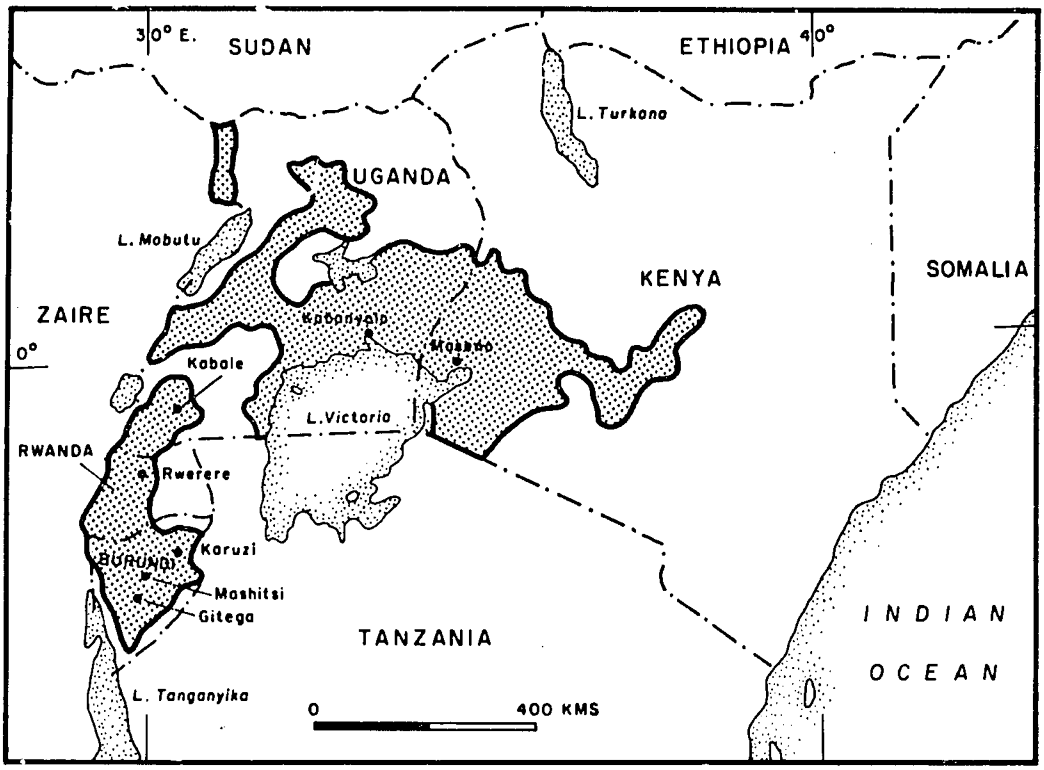
In 1989, researchers conducted a similar study in four districts of Tabora region, Tanzania. Farmers were asked to name the most important services and products they would like to obtain from trees. Their top priorities were soil-fertility improvement, fruit and fuelwood, followed by fodder, medicinal products and living fences. There was little interest in planting indigenous fruit trees as these were already available, but the interest in exotic fruit trees was strong, probably due to good marketing potential.

More detailed results of these surveys will be published in 1990.

Table 5. List of indigenous fruit trees identified during multipurpose-tree surveys in Zambia and Malawi, May-June 1989.

Botanical Name	Local Name
Annona senegalensis Pers. ssp. *senegalensis*	mpovia, mpoza
Anisophyllea pomifera	mfungo
Azanza garckeana (F. Hoffm.) Exell and Hillcoat	nkole
Bauhinia petersiana	mpundu
Berchemia discolor (Klotzsch) Hemsley	mtacha
Bridelia cathartica	mpasa
Bridelia micrantha (Hochst.) Planchon	mpasa
Dombeya rotundifolia	matowo
Flacourtia indica (Burm. f.) Merr.	ntuza, nthudza
Garcenia livingstonii	mpule
Guibourtia coleosperma (Benth.) J. Leonard	muzauli
Lannea discolor (Sonder) Engl.	—
Lannea stuhlmannii	shaumbu, kaumbu
Mimusops zeyheri Sonder	muchenja
Parkia filicoidea Welw. ex Oliver	mkundi
Parinari curatellifolia Planchon ex Benth.	muula
Piliostigma thorningii (Schum.) Milne-Redh.	msekese, chitimbe, msehe
Ricinodendron rautanenii Schinz	mkusu
Sclerocarya caffra	msewe
Strychnos cocculoides Baker	mteme, mateme
Strychnos innocua Del.	kabulubulu
Strychnos spinosa Lam.	mzai
Swartzia madagascariensis Desv.	mchelekete
Syzygium cordatum Hochst. ex Krauss	—
Syzygium guineense (Willd.) DC.	mchisu
Trichilia emetica Valh ssp. *emetica*	msunguti, mbvunguti
Uapaca kirkiana Muell. Arg.	masuku
Uapaca nitida Muell. Arg.	kasokolewe
Vangueria infausta Burchell	maviru
Vangueriopsis lanciflora (Hiern) Robyns	mauviyo
Vitex doniana Sweet	mfimfya
Ximenia americana L.	matundulukwa, mtundu, mthundu
Ziziphus abyssinica	kankhande

Bimodal highlands of eastern and central Africa



Research Site	Associated National Research Station	Altitude	Temperature	Annual Rainfall	Soils
Maseno, Kenya	Forestry Department Nursery/Veterinary Farm	1500 m	14.0°C min 25.0°C max	1736 mm	luvisols, nitosols
Rwerere, Rwanda	Institut des sciences agronomiques du Rwanda (ISAR)	2300 m	10.0°C min 20.0°C max	1160 mm	ferralsols
Karuzi (Gitega), Burundi	Institut des sciences agronomiques du Burundi (ISABU)	1600 m	10.0°C min 20.4°C max	1220 mm	ferralsols
Mashitsi, Burundi	ISABU and Institut de recherche agronomique et zootechnique (IRAZ)	1624 m	10.0°C min 24.5°C max	1180 mm	ferralsols
Kabanyolo (Kampala), Uganda	Makerere University Farm	1205 m	17.0°C min 26.0°C max	1470 mm	ferralsols
Kabale, Uganda	Kachwekano District Farm Institute	2050 m	10.0°C min 23.0°C max	1250 mm	ferralsols

The AFRENA programme for the Bimodal Highlands of Eastern and Central Africa was launched in late 1986 with support from the United States Agency for International Development (USAID). The programme focuses on the sub-humid to humid highland areas, at altitudes between 1000 and 2500 metres, in Kenya, Rwanda, Burundi and

Uganda. In 1989, Ethiopia joined the network under separate funding.

As a result of favourable climates and fertile soils, population density is high, farm sizes are small and land-use systems are among the most intense in Africa. Agricultural practices have not always kept pace with increasing pressure on the land, often resulting in a decline in land and tree resources. Macro diagnosis and design studies conducted in each country by teams of national scientists with ICRAF staff showed that the potential for agroforestry is high, both to help reverse environmental degradation and to increase the productivity of local land-use systems.

The key principle in the design of research projects for the zone is *complementarity*. Initial research concentrates on selection trials for multipurpose trees and the development of agroforestry technologies to address soil-fertility and soil-erosion problems in food-crop plots. Fodder, fuelwood and staking material are potential by-products. Such work in Rwanda concentrates on the development of technologies for the highest altitude range in the zone (2000–2500 metres), work in Burundi concentrates on technologies for the medium-altitude range (1500–2000 metres) and the programme in Kenya concentrates on the lowest range (1000–1500 metres).

The AFRENA project in Uganda, which started up a little later, complements work in the other three countries, concentrating on the development of technologies for the entire altitude range using upperstorey trees in and around food-crop plots (boundary planting). More recently, work in Uganda and Burundi has been expanded to include agroforestry technologies for banana plots, and studies have been launched in Rwanda on agroforestry technologies for coffee plots and high-altitude grazing lands.

In 1989, all research was conducted on station. However, a midterm evaluation during the year led to a recommendation to test some potential agroforestry interventions on farm. This is being initiated in 1990 in all four participating countries.

Kenya

At the Maseno Agroforestry Research Centre in western Kenya, collaborative research is conducted by ICRAF, KEFRI and KARI. By the end of 1989, 10 experiments had been established plus 4 observation studies. A special feature in 1989 was the unusually high annual rainfall, at around 1900 millimetres, resulting in vigorous growth of trees and crops.

General multipurpose-tree screening trials at Maseno included 58 provenances of 28 species. Poor survival rates were recorded for *Croton macrostachys*, *Erythrina abyssinica*, *Sesbania grandiflora* and *Alnus nepalensis*. The fastest-growing species was *Sesbania sesban*, with an average height increment of more than 4 metres in 12 months. This was followed by *Calliandra calothyrsus* and *Cassia spectabilis*, with average height increments of 3.5 to 4 metres over the same period.

Plots were thinned at different intervals by cutting a few trees of each species at ground level. Among the species cut after 12 months, fresh-weight biomass production was highest for provenances of *Calliandra calothyrsus*, *Gliricidia sepium* and *Acrocarpus fraxinifolius*. These all produced between 12 and 20 kilograms of fresh biomass per tree. Harvested biomass from trees cut after 12 months was much greater than harvested biomass plus regrowth of trees cut after 6 to 8 months.

A hedgerow-intercropping trial was established in April 1988 to assess the effects of *Leucaena leucocephala*, *Calliandra calothyrsus*, *Gliricidia sepium*, *Sesbania sesban*, *Cassia siamea* and *Erythrina caffra* on interplanted maize. The trees were interplanted with beans in both growing seasons of 1988, with maize and beans in the first season of 1989 and maize in the second. Fertilizer was applied at the recommended rate in every growing season but the last.

The highest cumulative leafy biomass yield was recorded for *Calliandra calothyrsus*, with 18.1 kilograms (fresh weight) per metre of hedgerow from six cuttings over the first 20 months. This was followed by *Sesbania sesban* with 12.5 kilograms and *Leucaena leucocephala* with 10 kilograms. However, the sesbania died after four cuttings. All hedgerow plots produced better maize yields than plots with maize in pure stand, except the plots with *Calliandra calothyrsus* during the first season of 1989. In the second season of 1989, maize dry-grain yields were 10 to 50% higher in hedgerow plots than in plots where maize was planted in pure stand, despite a 25% lower maize population in the hedgerow plots.

Another experiment was conducted to determine the best cutting height for *Leucaena leucocephala* to produce the greatest leafy biomass for use as fodder. Results clearly showed an increase in harvested leafy biomass (fresh weight) with an increase in cutting height—from six cuttings, leafy biomass was 8.2 kilograms per metre when hedgerows were cut at 10 centimetres above the ground and 12.1 kilograms per metre when hedgerows were cut at 90 centimetres. No clear relationship has emerged so far between different hedgerow cutting heights and the performance of maize between the hedgerows.

Fodder supplies in the East African highlands are often inadequate, particularly during the dry season. Livestock owners have addressed this problem by planting grasses, in particular *Pennisetum purpureum*, on bunds along the contours of sloping fields. Although this has improved general fodder availability, protein shortages still occur since most of the grasses drop in nutritional value during the dry season. For this reason, an experiment was initiated at Maseno in 1988 to examine the possibility of introducing a woody perennial on contour bunds to provide protein-rich supplementary fodder during the dry season.

Rows of *Leucaena leucocephala, Sesbania sesban* and *Calliandra calothyrsus* were planted on contour bunds, either in pure stand or combined with *Pennisetum purpureum*. Once both trees and grass reached maturity in 1989, the leucaena and calliandra appeared to benefit from the combination with pennisetum—single lines of trees combined with grass produced more than

Table 6. Leafy biomass production (kg fresh weight/m) from rows of multipurpose trees and fodder grass planted on contour bunds, at Maseno, Kenya.

Species Planted	April 1988-March 1989 Trees	Grass	Total	April-November 1989 Trees	Grass	Total	2-Year Total
Leucaena leucocephala (2 rows)	4.3	–	4.3	8.4	–	8.4	12.7
Sesbania sesban (2 rows)	17.6	–	17.6	8.9	–	8.9	26.5
Calliandra calothyrsus (2 rows)	9.6	–	9.6	10.3	–	10.3	19.9
Pennisetum purpureum (2 rows)	–	31.8	31.8	–	69.0	69.0	100.8
Leucaena + pennisetum (1 row each)	4.4	—[a]	4.4	7.4	37.0	44.4	48.8
Sesbania + pennisetum (1 row each)	14.5	—[a]	14.5	5.3	37.5	42.8	57.3
Calliandra + pennisetum (1 row each)	6.8	—[a]	6.8	6.5	24.1	30.6	37.4

[a]Pennisetum was not planted in combination with shrubs until November 1988.

50% of the leafy biomass produced by double lines of trees (Table 6). The productivity of *Sesbania sesban* dropped dramatically during the second year, and by the end of the year all the sesbanias had died. Table 6 also suggests that the pennisetum benefited from association with leucaena and sesbania, but produced less biomass when associated with calliandra.

Another experiment in progress in 1989 was designed to compare maize production under hedgerow intercropping with *Leucaena leucocephala* and in pure stand, using different levels of inorganic fertilizer. Plots under both systems received zero, 30 or 60 kilograms of nitrogen per hectare, plus the same amount of phosphate. On the hedgerow-intercropping plots, all leucaena prunings were applied as green manure to the maize crop. During the first growing season, the maize crop showed a positive response to the fertilizer, but little response to the leucaena. In the second season, however, the maize crop showed a favourable response to the green manure. Maize dry-grain yields with fertilizer at a rate of zero or 30 kilograms per hectare were considerably higher in the hedgerow-intercropping plots than in the pure maize plot.

The problem of reduced space available for crops under hedgerow intercropping was addressed in another experiment, comparing maize production under different hedgerow densities and crop distances from the hedge. Early results indicated that outer maize rows planted at 37.5 centimetres from a hedgerow of *Leucaena leucocephala* had on average only 12% lower dry-grain yields than outer maize rows planted at 75 centimetres from the hedgerow. This suggests that hedgerows might be interplanted with maize without reducing the overall maize population.

Rwanda

In 1989, ICRAF signed a memorandum of understanding with the Government of Rwanda, formalizing arrangements for collaborative research with the Institut des sciences agronomiques du Rwanda (ISAR). Research is conducted at Rwerere Research Station in northern Rwanda. The govern-

Species screening trial for hedgerow intercropping at Maseno, Kenya. Sesbania sesban *is on the left and right,* Leucaena leucocephala *in the background and beans in the foreground.*

ment also asked ICRAF to help draw up a 10-year national programme for agroforestry research.

Ten experiments were in progress at Rwerere at the end of 1989. These included general multipurpose-tree screening trials, screening trials with management interventions, hedgerow-intercropping trials and hedgerow trials for soil conservation and fodder production, with and without grasses interplanted.

A hedgerow-intercropping trial, set up in April 1988, compared mulch production by *Calliandra calothyrsus*, *Sesbania sesban* and different provenances of *Leucaena leucocephala* and *Leucaena diversifolia*. Researchers also assessed the effects of tree mulch on interplanted wheat crops with the addition of inorganic fertilizer. *Sesbania sesban* was the fastest growing species, permitting four harvests over 20 months. All the other species could only be harvested twice during the same period, with the initial harvest one year after establishment.

The sesbania performed best in terms of leafy biomass production, with an average total production of 13.8 kilograms fresh weight per metre of hedgerow at the end of 1989. However, this species ranked lowest in terms of its interaction with the wheat crop, resulting in 25 to 50% lower wheat yields compared with the other three hedgerow species.

The *Calliandra calothyrsus* and the two provenances of *Leucaena diversifolia* produced substantially more leafy biomass than the three provenances of *Leucaena leucocephala*. Wheat yields were highest under intercropping with *Calliandra calothyrsus*, but in general the effects of mulching on wheat did not appear to be substantial.

A second hedgerow-intercropping experiment, parallel to work in Kenya, compared the effect of intercropping wheat with hedgerows of *Sesbania sesban* and *Leucaena leucocephala* with the application of nitrogen fertilizer at zero, 30 or 60 kilograms per hectare. Again, the sesbania produced considerable leafy biomass but appeared to have a negative effect on the interplanted wheat crop. Otherwise, the wheat did not show any significant response to intercropping with leucaena or to the different fertilizer levels.

Research is in progress at Rwerere in parallel with work at other sites in the region to assess the fodder-yield potential of trees grown with grass on contour bunds, a technology that also addresses soil-erosion problems. In April 1988, *Sesbania sesban* and *Calliandra calothyrsus* were planted on bunds in double rows or in single rows combined with rows of *Pennisetum purpureum* or *Setaria sphacelata* var. *splendida*. The land in between was planted with wheat, alternating with beans.

As shown in Table 7, the trees appeared to benefit from combination with the grasses—single lines of trees combined with grass produced considerably more than 50% of the leafy biomass produced by double lines of trees. The *Setaria splendida* also appeared to benefit from combination with the trees. However, yields of *Pennisetum purpureum* grown in combination with trees were substantially less than yields from the grass grown in pure stand.

The different combinations of tree and grass species had different effects on the wheat crops grown next to the bunds. Farmers in the area most commonly plant contour bunds with pennisetum—interestingly, this species reduced crop yields considerably. *Sesbania sesban* also reduced crop yields, either in pure stand or in combination with grasses.

A small experiment on propagation methods for *Sesbania sesban* indicated that bare-rooted seedlings survived and grew as well as potted seedlings when planted out in the field. These results, which need to be confirmed by repeating the trial in 1990, could be important in the African highlands where transport of seedlings often poses problems. Exploratory trials are also in progress aimed at simplifying propagation techniques for *Leucaena leucocephala* and *Calliandra calothyrsus*.

Burundi

ICRAF is conducting collaborative research with the Institut des sciences agronomiques du Burundi (ISABU) at two sites, Karuzi and Mashitsi Research Stations. At Mashitsi, some experiments are also conducted in collaboration with IRAZ.

At the end of 1989, eight experiments were in progress at Mashitsi and three at Karuzi. Four of these were general multipurpose-tree screening trials, two focused on tree screening for hedgerow intercropping, one on trees for banana plots and one explored different management possibilities for *Chamaecytisus proliferus*, a promising leguminous shrub. Two other experiments explored the combination of grasses and leguminous shrubs on field bunds—one focusing on different species combinations and the other on different planting sequences. Finally, one hedgerow-intercropping experiment was in progress to test the effects of green manuring with *Leucaena diversifolia* plus different levels of nitrogen fertilizer.

General screening trials included a total of 16 species. The fastest growing were *Acrocarpus fraxinifolius, Casuarina cunninghamiana, Maesopsis eminii, Grevillea robusta, Tipuana tipu, Cordia abyssinica* and *Alnus acuminata*.

Screening trials for hedgerow intercropping included different provenances of *Cassia spectabilis, Sesbania sesban, Calliandra calothyrsus, Leucaena diversifolia* and *Leucaena leucocephala*. *Sesbania sesban* showed the fastest initial growth and greatest biomass production, followed by *Calliandra calothyrsus* and *Leucaena diversifolia* (except one provenance). All provenances of *Leucaena leucocephala* showed poor growth.

In the experiments testing combinations of grasses and trees on contour bunds, biomass yields of *Pennisetum purpureum* were not affected when the fodder grass was planted simultaneously with *Leucaena diversifolia* or *Calliandra calothyrsus*. However, biomass yields of calliandra were substantially reduced when the trees were planted simultaneously with pennisetum.

Uganda

Collaborative research in Uganda has been initiated at two sites—the Kabanyolo

Table 7. Leafy biomass production (kg fresh weight/m) from rows of multipurpose trees and fodder grass planted on contour bunds, at Rwerere, Rwanda.

Species Planted	April 1988-March 1989			April-November 1989			2-Year
	Trees	Grass	Total	Trees	Grass	Total	Total
Calliandra calothyrsus (2 rows)	0.90	–	0.90	2.75	–	2.75	3.65
Sesbania sesban (2 rows)	2.08	–	2.08	2.87	–	2.87	4.95
Setaria splendida (2 rows)	–	0.25	0.25	–	6.87	6.87	7.12
Pennisetum purpureum (2 rows)	–	1.19	1.19	–	20.13	20.13	21.32
Calliandra + setaria (1 row each)	1.04	0.21	1.25	1.88	3.37	5.25	6.50
Calliandra + pennisetum (1 row each)	1.21	0.33	1.54	1.63	4.62	6.25	7.79
Sesbania + setaria (1 row each)	2.94	0.20	3.14	1.88	3.38	5.26	8.40
Sesbania + pennisetum (1 row each)	3.10	0.28	3.38	1.75	6.13	7.88	11.26

University Farm near Kampala in November 1988 and the Kachwekano District Farm Institute in Kabale District in April 1989. National organizations participating in the AFRENA programme are the Nakawa Forestry Research Institute of the Ministry of Natural Resources and Environment, the Namulonge Agricultural Research Institute of the Ministry of Agriculture, the Ministry of Animal Industries and Fisheries, Makerere University and the Ministry of Planning and Economic Development through the National Research Council.

At the end of 1989, five experiments had been established in Kachwekano and three at Kabanyolo, with an emphasis on screening promising upperstorey species for boundary planting at different altitudes. The objectives were to assess fuelwood, pole and small timber production and to evaluate the effects of boundary plantings on three companion crops–beans, maize and sorghum. Species included were *Cedrela odorata*, *Grevillea robusta*, *Artocarpus heterophyllus*, *Alnus acuminata*, *Alnus nepalensis*, *Casuarina cunninghamiana* and *Markhamia platycalyx*.

Another experiment was designed to test the effects of spacing and understorey variations on the performance of *Grevillea robusta* as an upperstorey tree interplanted with *Calliandra calothyrsus* and the fodder grass *Pennisetum purpureum*. Specific objectives were to determine the production potential of this tree species, to assess the effects of the trees on the understorey plants and *vice versa* and to evaluate the effects of the trees and understorey plants on adjacent bean crops.

A prototype trial was also initiated in 1989 to test the overall productivity of different arrangements of *Calliandra calothyrsus* hedgerows with *Pennisetum purpureum* and mountain pawpaw (*Carica papaya*) on contour bunds on steeply sloping land. The trial will assess the growth and productivity of the multipurpose trees, the fruit trees and the fodder grass.

Ethiopia

In Ethiopia, a national agroforestry seminar, held in November 1988, led to the formation of a National Steering Committee of scientists from government departments, universities and research institutes, plus research staff from the International Livestock Centre for Africa (ILCA) and ICRAF. In 1989, a team appointed by the National Steering Committee conducted a macro diagnosis and design exercise, with assistance from the two international centres. Funding was provided by SAREC. The objective was to identify the major land-use systems in the Ethiopian highlands and to identify agroforestry potentials and research needs according to the opportunities and constraints of local farmers.

The study area was delineated as the land between 1500 and 3000 metres above sea level, with a minimum annual rainfall of 700 millimetres. Within this area, the team identified three main agro-ecological zones: the high-potential perennial crop zone, the high-potential cereal crop zone and the low-potential cereal crop zone. Each zone was further divided into land-use systems on the basis of altitude,topography and intensity of land use.

Using these criteria, the team identified 15 major land-use systems. Although problems varied, many of these systems were characterized by poor soil fertility, soil erosion and fodder shortages. The potential of agroforestry to alleviate these problems appeared to be greatest in systems at altitudes below 2500 metres.

Within Ethiopia, agroforestry has been elevated to the status of a national commodity programme, which will come into place in 1993. Meanwhile, agroforestry research is conducted on a regional basis under the guidance of the National Steering Committee. ICRAF has been asked to continue collaborating in future agroforestry research activities.

An ICRAF field technician shows visitors from USAID the different multipurpose-tree species under trial at Karuzi, Burundi.

Kenya national programme

Agroforestry enjoys strong interest and support within the Kenya Government and a large number of government departments, donor agencies and nongovernmental organizations are involved in agroforestry research and development work. As host country, Kenya provides a solid base for ICRAF's collaborative research programmes and other activities and ICRAF has been able to play a supporting and catalytic role in a variety of agroforestry activities in Kenya. In addition to the AFRENA programme for Eastern and Central Africa, ICRAF is involved in two collaborative projects in Kenya that are managed and funded separately.

Dryland agroforestry research project

In 1983, ICRAF scientists, in collaboration with scientists from the National Dryland Farming Systems Research Station and the Machakos Integrated Development Project, conducted a diagnosis and design study of the land-use system in the Kakuyuni area of Machakos District, Kenya. Based on this study, KEFRI initiated the Dryland Agroforestry Research Project in collaboration with the other two national organizations, with ICRAF acting in an advisory capacity and funding provided by IDRC.

Research is conducted both on station, at the National Dryland Farming Systems Research Station, and on farm. The project focuses on the Kakuyuni catchment area, where conditions are typical of the district. Farm sizes in this semi-arid area vary widely, from 3 to 17 hectares, and much of the land is sloping. Draught oxen are used for cultivation and farmers also keep cattle and goats.

After two years of on-station experiments, hedgerow-intercropping trials were established on three local farms in 1985 and extended to six additional farms in 1988. It has been difficult to obtain precise data from these trials, due to variations in site conditions and in the farmers' management of hedgerows and crops. However, by the end of 1989, it was possible to make some general observations.

Two hedgerow species, *Cassia siamea* and *Gliricidia sepium*, proved to be well adapted to the environment and suitable for hedgerow intercropping under on-farm conditions. *Leucaena leucocephala* was introduced on the first farms, but was not planted on the farms that joined the study in 1988 because it was highly susceptible to browsing by wildlife and domestic animals.

Choice of crops and decisions on crop management were left to the farmers, who usually planted maize, beans, cowpeas and/or pigeonpeas. Although planting densities varied widely, crop densities under hedgerow intercropping, with hedges spaced at 4-metre intervals, were not necessarily lower than under pure stand.

Hedgerows were coppiced twice a year at the beginning of the two rainy seasons and were sometimes coppiced twice more during the growing seasons. Some participating farmers let their hedgerows grow tall, observing that intercropped maize and beans appeared to benefit from shading in this hot, dry environment.

Biomass production from each hedgerow cutting averaged from 0.5 to 1.0 kilogram (fresh weight) per metre, with wide variations. It was not possible to analyse crop-yield data because of differences in choice and management of crops and problems with sampling and measurement.

Some of the participating farmers expressed concern about the level of labour required to manage the system. Thus, the project included an assessment of labour requirements for hedgerow establishment and management.

The preparation of furrows by ox ploughing required 9 to 12 person-hours per hectare. Transplanting seedlings required another 30 to 50 hours, excluding transportation of the seedlings to the field, and hedgerow pruning required about 30 hours per hectare. With low biomass yields from the hedgerows, it is not yet certain whether hedgerow intercropping can make a sufficient contribution to soil fertility in the

Farmer in a semi-arid area of Machakos District, Kenya, examines his citrus and papaya trees intercropped with maize.

semi-arid environment of Kakuyuni to justify the costs in terms of land and labour.

However, the high variability of hedgerow and crop production between different farms, and even between different fields on the same farm, raises some interesting questions for more intensive on-station research. These include the effects of different crop densities and spacings on overall crop and hedge performance and the effects of different soils and micro-climatic conditions.

Farmers in Kakuyuni have a strong interest in fodder improvement, particularly for their draught oxen. These animals tend to be weak and undernourished at the end of the dry season, precisely when draught requirements for land preparation are highest. Although hedgerow-intercropping experiments were established on farms in this area primarily to address local soil-fertility problems, the farmers tended to use the harvested material to feed their livestock, indicating the importance they place on animal fodder.

As a result, fodder banks of *Leucaena leucocephala* were established on four of the participating farms in October 1988. The trees were pollarded for the first time in July 1989. Fresh biomass, measured on one farm only, averaged 0.6 kilogram per tree.

Local farmers have also expressed an interest in fruit-tree production, including citrus, papaya, mango and banana, because of good marketing potential in the area. Thus, at the beginning of the 1989 April-June growing season, the project helped 11 farmers establish citrus and papaya trees. Survival and early growth rates were good and several other farmers planted fruit trees in November.

Agroforestry for development (Kenya) project

There is no single institution or agency in Kenya with broad responsibilities for agroforestry and, as a result, there is a pressing need to consolidate and evaluate the information generated by numerous scattered initiatives over the past decade. In response to this need, ICRAF joined the Kenya Ministry of Environment and Natural Resources in March 1988 to carry out a two-year project aimed at collecting, synthesizing and publishing training and extension material based on agroforestry research and development activities in Kenya. This project is being conducted in close collaboration with other ministries and departments of the Kenya Government and with several nongovernmental organizations. Funding is provided by the Swedish International Development Authority (SIDA).

Work in 1988 focused on collecting information and photographic documentation on agroforestry projects, policies and institutional involvement in different regions of Kenya. Results of this survey were presented at the Second Kenya National Seminar on Agroforestry, held at ICRAF in November 1988.

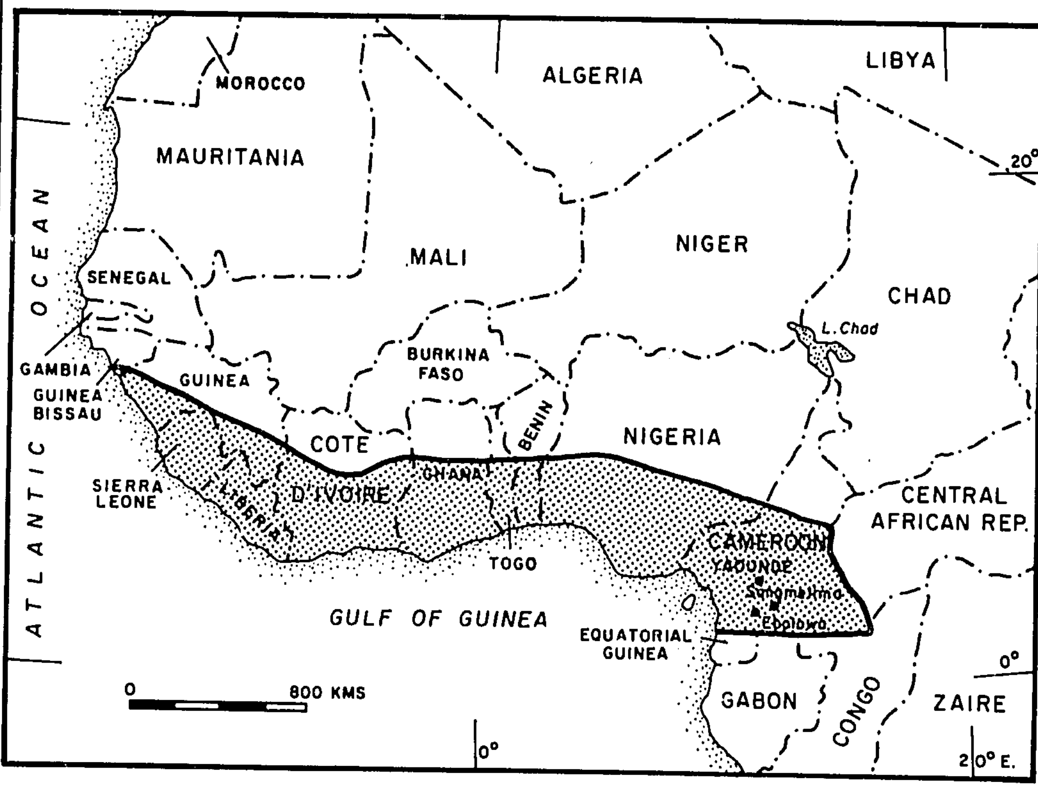
The emphasis in 1989 was on analysing the information collected in order to publish an agroforestry training and extension resource guide and an annotated bibliography of documents related to agroforestry development in Kenya. The guide to training and extension resources will include as an annex a field identification guide to 125 multipurpose-tree species found in Kenya.

Technical bulletins have also been prepared on four multipurpose trees with considerable potential for introduction into Kenyan farming systems—grevillea, casuarina, perennial sesbania and calliandra. This work will be completed in 1990 with publication of the major documents.

The analysis of data obtained through this project has led to a number of interesting results related to the biophysical and economic productivity of agroforestry technologies in Kenya. In addition to collecting and disseminating useful information, the project has also enabled ICRAF to extend technical services and support to departments and research institutions of the Kenya Government as well as to nongovernmental organizations engaged in agroforestry research, training and extension work in Kenya. Assistance has been provided through participation in numerous training workshops, short courses and planning sessions—all designed to train the trainers and extension supervisors responsible for agroforestry and social forestry projects in Kenya.

In 1989, these activities included social forestry refresher courses for Provincial and District Forestry Extension Officers, agroforestry training for District Soil-Conservation Officers, planning and management training for forestry project staff under the Ministry of Environment and Natural Resources, training in agroforestry project evaluation and monitoring for CARE International field staff, and a training workshop on biomass energy sponsored by the Kenya Energy and Environment Organizations (KENGO).

Humid lowlands of West Africa



Research Site	Associated National Research Station	Altitude	Temperature	Annual Rainfall	Soils
Yaounde, Cameroon	Institut de la recherche agronomique (IRA)	700 m	19.2°C min 28.6°C max	1600 mm	ferric acrisols
Sangmelima, Cameroon	IRA	720 m	19.0°C min 28.5°C max	1680 mm	ferric acrisols
Ebolowa, Cameroon	IRA	710 m	19.2°C min 28.6°C max	1650 mm	ferric acrisols

The Humid Lowlands of West Africa, at an altitude of less than 1000 metres, include parts of Guinea Bissau in the west, through Guinea, Sierra Leone, Liberia, Cote d'Ivoire, Ghana, Togo, Benin and Nigeria, to Cameroon in the east. Annual rainfall is bimodal, averaging more than 1500 millimetres. The vegetation is tropical rainforest and the growing period is 270 to 365 days a year. Within the region, ICRAF has been engaged in a Collaborative Agroforestry Project in Cameroon since 1986 and initiated a second collaborative project in Ghana in 1989.

ICRAF participates with IITA and ILCA in the Alley Farming Network for Tropical Africa (AFNETA), based in Nigeria. ICRAF also cooperates with IITA, as well as Oregon State University (USA), in a project to screen local and exotic multipurpose trees and determine their potential for hedgerow intercropping and other technologies in the region. A work programme for this project was formulated in 1989, to be based at IITA in Nigeria.

Cameroon

One of the objectives of the Cameroon Government's current Five-Year Plan (1986–91) is to increase food crop production to meet the needs of the urban population—expected to increase by 70% by the year 2000. The emphasis is on smallholder farmers.

The Institute of Agronomic Research (IRA) under the Ministry of Higher Education, Computer Services and Scientific Research focuses on improving food and cash crop production. Given the fragile soils of the region and the limited resources of most farmers, which preclude the use of high-cost inputs, IRA has emphasized agroforestry as an important approach to agricultural development. The IRA/ICRAF Collaborative Agroforestry Project was initiated in 1986 and became operational in 1987 under IRA's Farming Systems Programme.

A joint diagnosis and design exercise carried out in 1986 led to the selection of the cocoa/food crop production system in Cameroon's southern plateau region as the focus for collaborative work. Food production within this system is characterized by shifting cultivation. Maize, groundnut, yam and cassava are the main crops.

A more detailed survey was conducted in 1987, including information on local knowledge and utilization of multipurpose trees potentially suitable for soil fertility improvement. This work focused on two departments—Lekie near Yaounde and the less densely populated Dja et Lobo centred at Sangmelima.

Yaounde is now the main site of ICRAF's collaborative on-station and on-farm agroforestry research. In addition, one multipurpose-tree screening trial was established in Sangmelima in 1988. This trial is now being monitored, but without further expansion. Another site will be added in 1990 at the IRA research station in Ebolowa, in part to serve as an agroforestry demonstration for the Cameroon National Agro-pastoral Show.

The focus of ICRAF's work is on improving food crop production. The major problems identified in the surveys were low soil fertility, high labour requirements for land clearing, preparation and weeding, and crop destruction by free-ranging livestock. Research in 1989 focused on the selection of suitable multipurpose-tree species and the assessment of hedgerow-intercropping and improved fallow technologies. Soil monitoring was an important aspect of all research activities, including the analysis of soil changes under agroforestry.

The surveys conducted in the region mentioned several exotic and local woody species as potential candidates for agroforestry interventions. However, little was known about the performance of exotic trees under local conditions and hardly any information was available on the establishment and management requirements of local trees. Thus, two vigour/phenology trials were established to identify which multipurpose tree species might be well adapted to local conditions and suitable for agroforestry. Both are on-station trials conducted on land made available by IRA.

The trial at Yaounde, initiated in 1987, included *Leucaena leucocephala*, *Gliricidia sepium*, *Sesbania grandiflora*, *Sesbania formosa*, *Cassia siamea*, *Cassia javanica*, *Calliandra calothyrsus*, *Acacia auriculiformis*, *Acacia mangium* and *Paraserianthes falcataria*. Each species was planted in pure stand and also intercropped with maize at standard spacings. Figure 1 shows average plant heights at the end of 1989. As shown in the figure, growth of all species was restricted by intercropping with maize. Differences in stem diameter, which is a better indication of total biomass production, followed a similar pattern. The two sesbanias died during the second year, so they are not included in the results.

In the second trial, initiated in 1988 at Sangmelima, the sesbanias were replaced with two promising local species, *Chlorophora excelsa* and *Duboscia macrocarpa*.

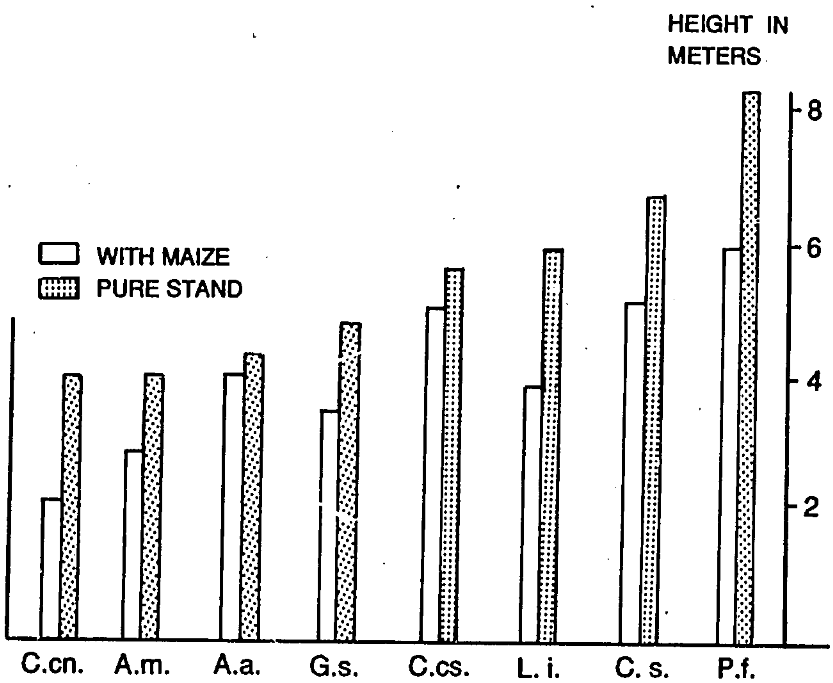
Cassia javanica was also replaced with *Dialium guineense*. Trees at Sangmelima were planted in pure stand and intercropped with groundnut. Results in 1989 suggested that intercropping with groundnut did not inhibit tree establishment or growth.

Four hedgerow-intercropping experiments were in progress in 1989. At Yaounde, an on-station experiment, established in 1987, compared the effects on food crops of mulch provided by different multipurpose-tree species. Objectives were to determine desirable levels of mulch application for optimum crop yields and to monitor soil changes under hedgerow intercropping. Hedgerows of *Leucaena leucocephala, Gliricidia sepium, Sesbania sesban, Sesbania grandiflora, Calliandra calothyrsus, Cassia siamea* and *Acacia auriculiformis* were established by direct seeding.

Establishment was uneven and biomass production was generally poor. When the trees were coppiced at the end of one year, the two sesbanias failed to survive, so they were dropped from the experiment. In 1989, maize was interplanted with the hedgerows and mulch from the trees was applied at rates of zero, 100 and 200% of total biomass harvested from each plot (achieved by adding all the mulch from the zero plots to the 200% plots). Maize plant heights and grain yields showed no significant differences related to the different tree species or the amount of mulch applied.

Earlier work in the humid zone suggested that hedgerow intercropping may not

Figure 1. Average heights (m) of eight multipurpose-tree species 24 months after planting at Yaounde, Cameroon. Trees were intercropped with maize or planted in pure stand. The least significant difference (p = 5%) between species for the same treatment was 2 metres.



Key: C.cn. = *Cajanus cajan;* A.m. = *Acacia mangium;* A.a. = *Acacia auriculiformis;* G.s. = *Gliricidia sepium;* C.cs. = *Calliandra calothyrsus;* L.l. = *Leucaena leucocephala;* C.s. = *Cassia siamea;* P.f. = *Paraserianthes falcataria.*

be sufficient to maintain and restore depleted, fragile soils without the use of some level of inorganic fertilizer plus fallowing. The effects of the three practices—hedgerow intercropping, fertilizer application and fallowing—appear to complement each other in situations where none would be adequate on its own.

Thus, a second hedgerow-intercropping experiment, initiated in 1988, examined the effects on crop production of mulch from four multipurpose trees combined with different levels of fertilizer application. The four species selected for this experiment were *Leucaena leucocephala, Gliricidia sepium, Calliandra calothyrsus* and *Acacia auriculiformis*. These had shown the best initial performance in the first hedgerow-intercropping trial in terms of biomass yield and regrowth potential after coppicing. In 1989, maize was interplanted with these hedgerows and nitrogen fertilizer was applied as subplot treatments at rates of zero, 30 or 60 kilograms per hectare. The trees were cut back one week before the maize was planted and all prunings applied to adjacent alleys.

Dry foliage yields from the hedgerows and total nitrogen equivalent are presented in Table 8. At one year after planting, *Calliandra calothyrsus* produced the greatest foliage dry matter yield—4.69 tonnes per hectare from two prunings, with a total nitrogen equivalent of 140.7 kilograms per hectare. The smallest biomass yield was obtained from *Acacia auriculiformis*.

Average maize yields, as affected by hedgerow species and fertilizer application, are shown in Table 9. Although calliandra produced the highest biomass, leucaena mulch produced the greatest crop yield. Without fertilizer, mulch from the different hedgerow species increased maize yields by 31 to 88% over controls.

Researchers also attempted to assess the economic viability of these alternatives. At this initial stage, only leucaena mulching, with or without fertilizer, appeared to be an attractive alternative to fertilizer use alone.

A third experiment was initiated in April 1989 to compare the efficiency of the standard hedgerow-intercropping arrangement (4-metre alleys between single rows of trees) with alternative arrangements. These involved grouping the hedges together into blocks.

The fourth hedgerow-intercropping experiment is linked to work conducted under a National Cereals and Extension Project to test the productivity of improved maize varieties. The objective is to assess fertilizer requirements for improved maize under hedgerow intercropping. Maize was inter-

Table 8. Foliage dry matter yields (tonnes per hectare) and total nitrogen equivalent (kilograms per hectare) of four multipurpose-tree species interplanted with maize at Yaounde, Cameroon, one year after establishment. The tree plant density was 10,000 per hectare.

Species	First Pruning Yield	First Pruning Nitrogen Equivalent	Second Pruning Yield	Second Pruning Nitrogen Equivalent	Total Yield	Total Nitrogen Equivalent
Calliandra calothyrsus	4.11	123.3	0.58	17.4	4.69	140.7
Leucaena leucocephala	3.23	93.7	0.55	15.9	3.78	109.6
Gliricidia sepium	1.92	53.8	0.38	10.6	2.30	64.4
Acacia auriculiformis	1.52	41.0	0.04	1.1	1.56	42.1
Coefficient of variation (%)	9.18	–	23.13	–	–	–
Least significant diference (p = 0.05)	0.49	–	0.18	–	–	–

planted with three hedgerow species, *Leucaena leucocephala, Gliricidia sepium* and *Cajanus cajan*, with the addition of zero, 30 or 60 kilograms of nitrogen per hectare. This experiment is being conducted under researcher management on six farms near Yaounde. In addition to the specific objectives, this work is generating useful information on the special problems and opportunities associated with on-farm agroforestry research.

An experiment is also in progress to assess a rotational hedgerow-intercropping system with a livestock component. This work involves a third research partner, the Cameroon Government's Institute of Animal Research (IRZ). Begun in 1988 on station at Yaounde, this work tests the effects of *Leucaena leucocephala* and *Gliricidia sepium* interplanted with maize and other crops for two years and then left as fallow for two years. During the fallow period, all prunings are fed to sheep and all manure returned to the plot.

Two improved-fallow experiments were initiated in 1989 at Yaounde, one on station and one on farm. Fallow periods will range from one season to three years, using *Cajanus cajan, Desmodium distortum, Desmodium discolour* and *Crotalaria anagyroides*. A similar experiment will be conducted at Ebolowa.

Experience in 1989 underlined the difficulties associated with measuring the biomass of different tree components in the field. For this reason, work has started aimed at developing a quick method for assessing tree biomass. This involves entering data on stem diameter, number of main branches, number of resprouting branches after coppicing and biomass yield of foliage and woody components in a regression model. Data for the model will be collected from *Paraserianthes falcataria, Calliandra calothyrsus* and *Leucaena leucocephala* at Yaounde and Ebolowa.

Turning to training activities, the IRA/ICRAF team conducted a national ag-

Table 9. Maize grain yields (tonnes per hectare) as affected by species of intercropped tree used for mulch and level of nitrogen fertilizer applied at Yaounde, Cameroon. The maize planting density was 40,000 per hectare.

Species Providing Mulch	Fertilizer Level (kg/ha) 0	30	60	Average
Control (no trees)	2.18	3.00	3.22	2.80
Calliandra calothyrsus	3.45	3.60	4.08	3.71
Leucaena leucocephala	4.11	4.37	4.53	4.34
Gliricidia sepium	2.85	3.87	4.43	3.71
Acacia auriculiformis	3.16	3.75	4.23	3.71
Average	3.15	3.72	4.10	–

	Coefficient of Variance (%)	Least Signficant Difference (p = 0.05)
Between fertilizer levels	23.33	0.99
Between tree species	8.04	0.27
Between fertilizer levels for same tree species	8.04	0.59

roforestry training workshop at Yaounde from 20 to 25 November 1989. There were 20 participants sponsored by the project and 5 self-sponsored participants. Support was provided by IDRC. The programme included lectures and field visits to on-station and on-farm agroforestry research sites around Yaounde.

Under its Research Scholars and Fellows Programme, the project is sponsoring and supervising agroforestry research conducted by six undergraduates from the University Centre of Dschang and one third-cycle doctorate candidate from the University of Yaounde. In addition, the project is already sponsoring one M.Sc. student at the University of Ibadan in Nigeria and arrangements have been made to sponsor a second student.

Ghana

In 1989, ICRAF initiated a collaborative agroforestry research project with the Institute of Renewable Natural Resources (IRNR) of the University of Science and Technology in Kumasi, Ghana. Ghanaian scientists and colleagues from ICRAF conducted a macro diagnosis and design exercise covering the humid zone in the southern part of the country.

This zone is characterized by a low-lying, gently undulating topography, with annual rainfall averaging 1000 millimetres or more. Vegetation consists of thick rainforest, which opens up to savannah towards the north. The soils are forest oxysols and ochrosols, which tend to be well weathered, deep and acidic.

Farmers raise tree crops for cash, food crops and a few livestock. Tree crops include rubber and coconut in the high rainforest, cocoa and coffee in the semi-deciduous rainforest and oilpalm and citrus throughout most of the zone. Food crops are produced on small plots under rotational fallow or intercropped with trees during the first years of tree establishment. The rotational system for food crops generally consists of two to five years of cropping followed by three to eight years of fallow.

The most important constraints on agricultural production are low soil fertility and soil erosion, lack of appropriate technologies to improve yields, and socioeconomic problems, including labour bottlenecks and poor access to markets. Crop yields are reported to be declining, largely due to reduced fallow periods.

The research team recommended hedgerow intercropping, improved fallows and live staking for yams to improve soil fertility and satisfy other needs in plots under food crops. Cocoa production could be improved by intercropping nitrogen-fixing trees on cocoa plots.

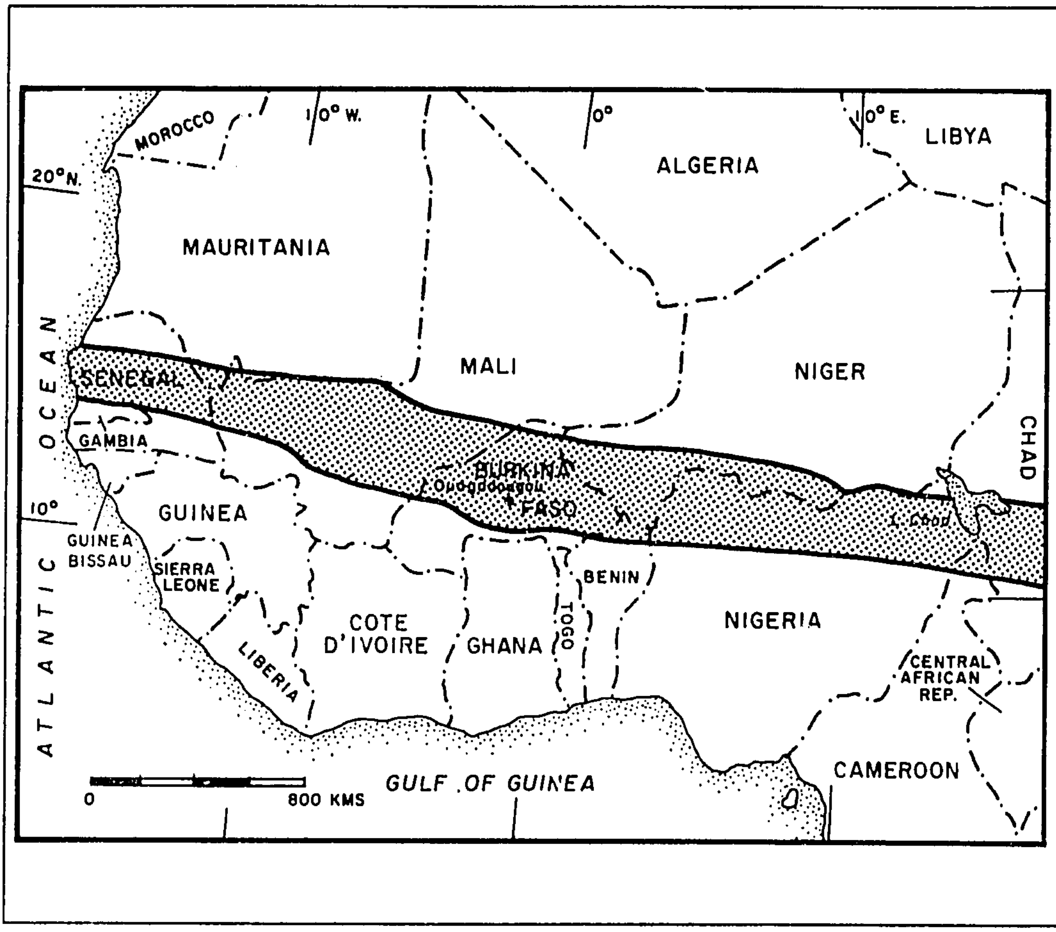
The team also recommended the introduction of fodder crops or other shade-tolerant intercrops on oilpalm and coconut plots. Further recommendations included the intensification and diversification of home gardens using fruit trees.

The next step is to identify a priority land-use system for analysis in greater detail. This should lead to specific proposals for agroforestry research and development activities.

In addition, collaborative work in Ghana will include training courses and workshops to enhance national research capabilities as well as support to improve the agroforestry diploma course offered by the University of Science and Technology.

Livestock owners in Senegal have lopped this old Faidherbia (Acacia) albida *tree to provide dry-season fodder for goats and fuelwood .*

Semi-arid lowlands of West Africa



The AFRENA programme in the Semi-arid Lowlands of West Africa (SALWA) was launched in January 1989 with National Steering Committees and task forces established in the four participating countries—Burkina Faso, Mali, Niger and Senegal. In addition to national ministries and research institutes, ICRAF has been joined by other regional and international organizations participating in the programme. These include the Institut du Sahel, SAFGRAD and ICRISAT. Funding is provided by IFAD.

During the year, ICRAF and national scientists conducted macro diagnosis and design exercises in all four countries. For the purposes of the programme, the semi-arid zone was defined as the area in which the ratio of mean annual precipitation to potential evapotranspiration is between 0.20 and 0.50. Within this zone, 19 land-use systems were identified and described: 3 in Burkina Faso, 5 in Mali, 6 in Niger and 5 in Senegal.

The results of this work were presented at an agroforestry research planning workshop held in December in Ouagadougou, Burkina Faso. Participants selected a priority land-use system in each country, which will serve as the focus for agroforestry research and development activities. These are:

- The agrosilvopastoral system of the northern sudanian zone of Burkina Faso
- The 'parkland' system of croplands with scattered trees in Mali
- The Niger River valley system of Niger
- The groundnut basin system of Senegal.

Rainfed agriculture with mixed cropping is the dominant land-use pattern in all four of these systems. Millet and sorghum are the staple crops and livestock production plays an important role.

In Burkina Faso, research interest focuses on the central part of the northern sudanian zone. This area accounts for over half of the national population and environmental and socioeconomic problems are severe. Farmers traditionally protect trees in their croplands and plant trees around their houses and there is a high potential for increased adoption of agroforestry technologies.

The 'parkland' system is the dominant form of land use in the most densely populated areas of Mali, accounting for about 10% of land in the country and 35% of the national population. This was selected as a target land-use system for agroforestry research because of its importance in terms of food production and because of the environmental problems already apparent as a result of pressure on land.

Millet and sorghum are the staple food crops and cotton and groundnut are grown for cash. These are intercropped in areas where cultivation is by hand and planted in pure stand where animal traction is used. Livestock are important, particularly to provide draught power, and manure is applied to some fields. Farmers grow trees scattered in their croplands, giving a 'parkland' appearance from which the system derives its name. The most important species are *Faidherbia (Acacia) albida, Butyrospermum paradoxum, Adansonia digitata, Borassus aethiopum* and *Parkia biglobosa.*

The Niger River valley in Niger is a complex land-use system including irrigated rice fields near the river, terraces with food-crop plots and pastures, and cowpea and millet fields further away. This diversity provides an opportunity to test agroforestry technologies in a variety of settings. In addition, marketing opportunities are good, as the area surrounds the capital city of Niamey. The introduction of agroforestry into this land-use system should help address four of Niger's main national-development goals: self-sufficiency in food production; environmental protection; improved wood production; and the development of intensive livestock production.

The groundnut basin system of Senegal covers the major food-production zone of the country, accounting for one-third of the agricultural land and nearly two-thirds of the population. Increasing pressure on land is leading to severe degradation of the natural-resource base. The staple food crop is millet, the main cash crop is groundnut and livestock are also important.

In each of these priority land-use systems, the next step in the research programme will be to conduct more detailed micro diagnosis and design studies. Where agricultural practices and problems are similar, complementary research programmes will be designed, focusing on agroforestry technologies that might usefully be introduced in more than one country. To facilitate collaborative research across national boundaries, participants in the December planning workshop set up a Regional Steering Committee, comprising the chairpersons of the four National Steering Committees and representatives of international and regional organizations.

In preparation for the micro diagnosis and design exercises, participating scientists will attend a methodology training course at ICRAF headquarters in January 1990. Following the diagnosis and design and the prerequisite germplasm acquisition and nursery work, network participants expect to initiate field experiments in the middle of 1991.

In 1989, ICRAF and ICRISAT also launched discussions on a special research project in the SALWA region, aimed at the improvement of selected multipurpose trees. Beginning in 1990, an ICRAF scientist will conduct this work, based at ICRISAT's Sahelian Centre in Niger.

Alley farming network for tropical Africa

AFNETA—the Alley Farming Network for Tropical Africa—was launched in 1986 by IITA and ILCA. One overall objective is to promote, support and coordinate research on alley farming (referred to as *hedgerow intercropping* in most ICRAF publications) by national institutions in tropical Africa. A further objective is to promote the on-farm testing, use and extension of alley farming across diverse environments. ICRAF was invited to join IITA and ILCA in drawing up a project document and attracting donor support for the network. A Steering Committee was formed, comprising eight national members plus representatives from the three international centres.

In 1988, the core network proposal was approved for funding by CIDA, with IDRC acting as executing agency. The network came into full operation in February 1989, when the Coordination Unit was established at IITA headquarters in Ibadan, Nigeria.

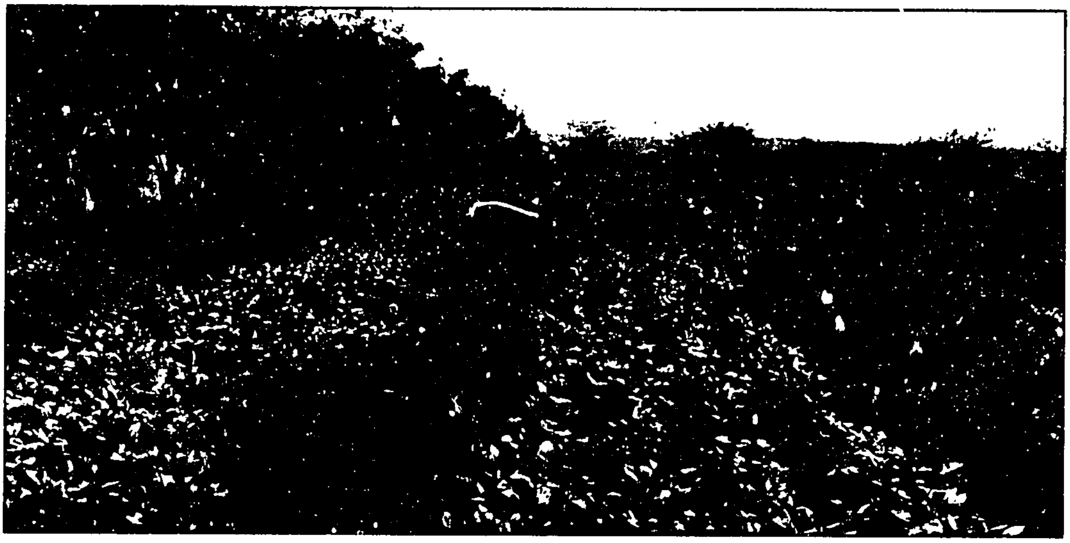
National institutions within tropical Africa were invited to submit proposals for alley-farming research, and in 1989 these were reviewed, revised and synthesized into a single project proposal for submission to IFAD for funding. After further revisions and adjustments, IFAD approved the project and research activities will start up in 1990.

Altogether, 58 alley-farming experiments were approved for funding, submitted by 28 national institutions in 17 countries. Research is grouped in four areas:

- Multipurpose-tree screening and evaluation
- Alley-farming management
- On-farm alley-farming research and development
- Livestock integration in alley farming.

One of ICRAF's roles has been to contribute support and advice to the AFNETA Steering Committee. The second meeting of the Steering Committee took place at ICRAF headquarters in May 1989, and the current chairperson joined ICRAF during the year on sabbatical leave from the University of Science and Technology at Kumasi, Ghana.

ICRAF has also played an active role in the review of national project proposals for alley-farming research. In addition, ICRAF staff members made a major contribution to the first AFNETA training course on alley-farming research methodologies. This was held at IITA from 7 to 18 August 1989. Conducted in English and French, the course attracted 32 participants from 19 countries.



Leucaena hedgerows intercropped with cowpea in an alley-farming experiment at ICRAF's field station, Machakos, Kenya.

South Asia

India launched an agroforestry research programme more than 30 years ago and was the first country in the world to create a national institute for agroforestry research—the National Research Centre for Agroforestry, located at Jhansi, in Uttar Pradesh State. India's agroforestry research network includes more than 31 sites, headed by the All-India Coordinated Research Project on Agroforestry. Through the years, ICRAF has participated in several diagnosis and design exercises in India and has provided training and information support. Funding has been provided by the Ford Foundation.

In 1989, ICRAF scientists helped conduct a micro diagnosis and design exercise focusing on land-use systems near the National Research Centre for Agroforestry at Jhansi, where the Indian Council of Agricultural Research (ICAR) plans to establish an agroforestry research and development project. The study area includes three villages in a watershed of 2,163 hectares in India's semi-arid zone. Temperatures reach as high as 47.8°C and annual rainfall ranges from 800 to 1100 millimetres. The landscape is undulating with variable soils.

Farms tend to be small. The average area under cultivation is about two hectares, with roughly half under irrigation. Many households own less than one hectare, indicating that their principal source of livelihood is wage employment. Farmers grow a wide variety of crops, usually in pure stand.

Individually and communally owned wastelands are used for grazing and gathering fuelwood, but productivity in these areas is extremely low. Livestock fodder, fuelwood and building materials are in short supply and households report a lack of opportunities to earn cash.

Several agroforestry technologies were proposed to meet the needs of different groups of land users. To develop technology recommendations for farmers, the study team prepared detailed designs for 14 experiments, to be conducted on station and on farm, as well as a programme of on-farm demonstrations.

These experiments include multipurpose-tree screening and management trials for home gardens, boundary planting, improved pastures, hedgerow intercropping, fruit trees in cropland, woodlots and fodder banks. They were initiated in the 1989/90 cropping season. IDRC has approved support for this research project, including some support for ICRAF's continued collaboration with the National Research Centre for Agroforestry.

ICRAF published a full report of this micro diagnosis and design study in August 1989. Copies are available on request.

Other activities in India during the year focused on institution building. In January, ICRAF undertook a survey of nine agroforestry institutions to assess the agroforestry literature available in their libraries and to arrange for them to receive ICRAF publications and other information services as needed, including support for journal subscriptions. Full sets of ICRAF publications were distributed to 7 centres within ICAR, and another 25 institutions in India received smaller sets of key documents. There are plans to build up the information and documentation capability of the National Research Centre for Agroforestry.

In Bangladesh, ICRAF is collaborating with the National Agroforestry Task Force under the aegis of the Bangladesh Agricultural Research Council (BARC). In 1989, an ICRAF specialist visited Bangladesh to help identify agroforestry information needs and build up the capacity of BARC's Agricultural Information Centre to provide information on agroforestry to researchers around the country. ICRAF will be involved in diagnosis and design exercises in Bangladesh in 1990.

Strategic research and methodology development

Strategic research and methodology development at ICRAF are organized within a framework of three interlinked programmes: research on the role and potential of agroforestry and multipurpose trees; on-station field experimentation; and on-farm research and extension. In 1989, these programmes included some 35 projects. Work completed or in progress resulted in a substantial publication output during the year, as listed in Table 10. A more detailed list of publications is given in a separate section of this report. Two new research activities started up or were considerably expanded during the year, focusing on the multipurpose-tree germplasm improvement and on-farm research.

The role and potential of agroforestry and multipurpose trees

The aim of ICRAF's programme on the role and potential of agroforestry and multipurpose trees is to analyse and synthesize knowledge of agroforestry systems and their components, especially multipurpose trees. Projects in 1989 included reviews, workshops, case studies and the continued development of databases as tools and sources of information for scientists and others working in the field of agroforestry. The most important of these activities will be described.

The potential of agroforestry for soil conservation

A major review of agroforestry for soil conservation, begun in 1986, was completed in 1989. Based on the recognition that soil conservation is potentially the most important service function of agroforestry, the purpose of this review was to establish the magnitude of this potential role and to identify the research required to realize it. Information was collected from the field and from research institutions in several countries. This work benefited from collaboration with the Tropical Soil Biology and Fertility Programme and the Commonwealth Science Council's Programme on Amelioration of Soil by Trees. By the end of 1989, results had been published in 14 journal articles and 6 others were in press.

These results were also brought together in a book, *Agroforestry for soil conservation*, by A. Young, copublished in 1989 by ICRAF and CAB International (CABI) in the UK. In this study, soil conservation is interpreted to mean the maintenance of soil fertility, with erosion control as one necessary, but by no means sufficient, condition. The discussion begins with the nature of soil conservation, agroforestry and sustaina-

Table 10. Major publications in 1989 based on ICRAF strategic research.

- *Agroforestry systems in the tropics* (P.K. Nair, ed.)
- *Agroforestry for soil conservation* (A. Young)
- *Technology monitoring and evaluation in agroforestry projects* (E.U. Müller and S.J. Scherr, comps.)
- *Viewpoints and issues on agroforestry and sustainability* (P.A. Huxley, comp.)
- *Final report of development of agroforestry research methodology aimed at* simplifying the study of potential tree/crop mixtures (P.A. Huxley, A. Pinney and D. Gatama)
- *Meteorology and agroforestry* (W.E. Reifsnyder and T.O. Darnhofer, eds.)
- *Proceedings of an ICRAF mini-workshop on experimental design* (J.H. Roger, ed.)
- *Multipurpose trees: selection and testing for agroforestry* (P.A. Huxley and S.B. Westley, eds.)

bility, followed by a review of the evidence for the potential of agroforestry to control runoff and soil erosion. The next section covers the potential role of agroforestry in the maintenance of soil fertility including the processes by which trees affect soils, the capacity of agroforestry to maintain soil organic matter and improve nutrient cycling, the role of roots, and the tree species and agroforestry technologies particularly suited to enhance soil fertility.

A computer-based tool to assist research on soils and agroforestry was released by ICRAF in 1987—Version 1 of SCUAF, a computer model of soil changes under agroforestry. Programming for Version 2 was completed in 1989 and the handbook will be ready for release in 1990. SCUAF is designed to estimate the effects on soils of specified agroforestry systems within given environments. Version 1 covered erosion and soil organic matter; Version 2 adds nitrogen cycling, improvements to the specification of agroforestry systems and the user interface, and an automatic graph-plotting facility using Lotus 1-2-3.

Version 1 of this model is already being used by a number of national research organizations, particularly in Africa. It is useful at the design stage of agroforestry experimentation to predict the likely effects on soil of different land-use practices and to indicate what data will be required in order to estimate soil changes once the experiment is in progress. At further stages of experimentation, SCUAF can be used to investigate what different outcomes might be expected under alternative management strategies and to extrapolate results over longer time periods, thereby exploring the long-term sustainability effects of alternative land-use systems. The model has also proven useful in training for agroforestry research.

Multipurpose tree and shrub database

ICRAF initiated a project in 1983 aimed at compiling a global inventory of multipurpose trees and shrubs (MPTS). This has led to the development of a database containing as complete information as possible on a wide variety of multipurpose tree and shrub species from the tropics and subtropics. The project is financed by the Ministry of Economic Cooperation (BMZ) of the Federal Republic of Germany through the German Agency for Technical Cooperation (GTZ).

Information is being gathered from researchers and field workers who have direct experience with different tree species. Using a questionnaire, these specialists provide information on species nomenclature and occurrence, climatic data, soil characteristics, plant morphology and reproduction, cultivation problems, environmental requirements and observed uses, including tree products and services. In addition, information is collected from scientific literature representing a variety of sources, including unpublished theses and project reports that are not widely available.

One important use of this database is to help field workers with the preselection of species for agroforestry projects and experiments. This preselection is based on the computerized matching of the biophysical requirements and desired uses of multipurpose trees with site characteristics and project objectives.

Results are shortlists of candidate species and species profiles that facilitate further research and testing work on the trees most likely to succeed in a given environment, technology and land-use system. So far, more than 350 requests for this kind of assistance have been answered, providing relevant information on multipurpose trees and shrubs to researchers and development projects alike.

By the end of 1989, the database contained 2043 descriptions, covering 1033 species. Work during the year led to improvements in the software intended to make the database more accessible to a variety of users. These users include researchers, field staff, universities and organizations responsible for the implementation of agroforestry projects.

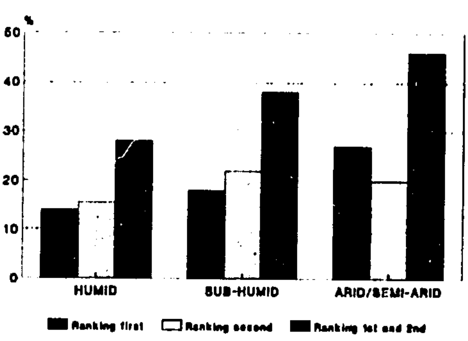
Figure 2 gives one example of the kind of information that can be compiled from the database. The histogram is based on the responses of researchers and field workers in different regions of the tropics.

The multipurpose tree and shrub database should be ready for wider distribution towards the end of 1990. It can be operated on any IBM-compatible computer with a hard disk and a minimum of 12 megabytes of available disk space.

Genetic improvement of selected multipurpose trees

ICRAF launched a project in 1988 on the genetic improvement of multipurpose trees, focusing initially on *Sesbania sesban*, *Grevillea robusta*, *Calliandra calothyrsus*, *Leucaena leucocephala*, *Leucaena diversifolia* and *Markhamia lutea*. Major activities in 1989 included the establishment of a tree nursery and laboratory at the AFRENA site in Maseno, Kenya, and the first mass selection of superior phenotypes of *Sesbania sesban*.

Figure 2. Comparative importance of browse in three regions of the tropics. Ranking expressed as percentage of total number of reports in ICRAF's MPTS database.



Work in 1990 will include establishment of a first-generation seed orchard and open-pollinated progeny trials at various sites in Kenya and Uganda. Staff members involved in this project are working closely with the Eastern and Central Africa AFRENA programme in the design and implementation of experiments involving multipurpose trees. Project staff also facilitate the exchange and supply of tree germplasm to all AFRENA programmes.

Training in genetic improvement research is another important component of this project. Together with staff of the International Board for Plant Genetic Resources (IBPGR) and the National Museums of Kenya, project staff conducted a training course in May 1989 on multipurpose-tree germplasm collection and documentation. Fourteen participants attended from Kenya, Uganda, Somalia and Rwanda.

Through a collaborative agreement with the Australian Centre for International Agricultural Research (ACIAR) and the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia, this project contributed to ICRAF's publication in 1989 of an annotated bibliography on *Grevillea robusta*, containing 224 entries. Through the AFRENA programmes, ICRAF is helping to coordinate provenance documentation, seed collection and trials on this species in several African countries.

Work on the genetic improvement of multipurpose trees will become a major area of concentration at ICRAF, building on previous work and linking with the AFRENA programmes and collaborating institutions specializing in tree germplasm development.

Agroforestry alternatives to shifting cultivation

Increasing pressure on land and forest resources is rapidly leading to destruction of forested areas in many parts of the humid and subhumid tropics. If uncontrolled, this process poses a threat to the long-term stability and productivity of the environment. It also threatens the welfare and economic development of local populations and the political and socioeconomic dynamics of entire regions. Shifting cultivators are traditionally important forest users whose activities are often considered to contribute to forest degradation.

ICRAF agreed with SIDA to conduct a study in Laos and in the region of the Vinh Phu Pulp and Paper Mill in Vietnam focusing on the potential of agroforestry systems as alternatives to shifting cultivation. A two-year project, initiated in 1987, was concluded in 1989 with the preparation of reports on the two study areas.

The study in Vietnam indicated that migration to the area around the SIDA-sponsored paper mill had created a shortage of lowlands suitable for rice cultivation and forced farmers to crop the slopes of hills, on a permanent as well as a shifting basis. This was in conflict with the objective of the paper mill to expand forest plantations in the area. The study recommended agroforestry technologies to increase and maintain the productivity of land already under cultivation, thus reducing the pressure to clear forested slopes.

Results from the study in Laos also indicated that increasing pressure on land—leading to permanent as well as shifting cultivation in forested areas—was a major cause of environmental degradation, and not shifting cultivation *per se*. Many households in Laos combine permanent rice cultivation in lowlands with short fallows or shifting cultivation on uplands. The need to expand upland cultivation could be alleviated by improving the productivity of the permanent cultivation systems in the lowlands. To achieve this objective, various agroforestry technologies were suggested.

Socioeconomic aspects of agroforestry and multipurpose trees

Work in progress on the socioeconomic aspects of agroforestry and multipurpose trees is summarized in Table 11. One major accomplishment in 1989 was the completion of a review of socioeconomic considerations associated with the selection of tree species for agroforestry and related projects. The report will appear in 1990 as a joint publication of ICRAF and the Food and Ag-

Table 11. Socioeconomic work completed or in progress at ICRAF in 1989.

Farmers' Use and Adoption of Agroforestry

- Study on the 'Socioeconomic attributes of trees and tree-planting practices' (completed)
- Keynote address delivered at the University of Edinburgh, UK, Centennial Conference on Agroforestry: 'Social, economic and political aspects of agroforestry' (completed)
- Participation in a study conducted by the Oxford Forestry Institute, UK, on factors affecting agroforestry adoption in Eastern and Southern Africa (in progress)

Agroforestry Extension

- Methods for evaluating the effectiveness of participatory agroforestry extension programmes in pastoral systems (in progress)
- Information system for CARE agroforestry extension project (completed)
- International literature review on extension methods for agroforestry (in progress)
- Annotated bibliography on 'Economic analyses of agroforestry systems' (in progress)
- Review of methods used for on-farm economic evaluation of agroforestry technologies (in progress)

riculture Organization of the United Nations (FAO).

The central question addressed in the review is 'What socioeconomic factors need to be taken into account when selecting tree species for different users and circumstances?' Defining first what is meant by the 'socioeconomic attributes of trees', the paper goes on to elucidate the various ways in which trees may be well or ill suited to particular socioeconomic settings. The question of species choice is embedded in a series of interrelated decisions about tree-growing technologies that need to be considered in light of their social consequences. The design of a tree-growing technology links the socioeconomic characteristics of tree users with the biological attributes of trees.

The study then explores the range of tree-growing options, giving a synthesis of tree uses, tree-planting arrangements, landscape niches for trees and tree-management possibilities. Finally, it considers how small-scale processing enterprises may provide viable opportunities for participation in tree production by the landless and other disadvantaged groups. It concludes with practical guidelines designed to help field workers match technologies to the needs and opportunities of users and then match tree species to the selected technologies.

Field experimentation

The objectives of ICRAF's strategic research and methodology development in the area of field experimentation are to provide

Table 12. Demonstrations and trials in progress during 1989 at ICRAF's Machakos Field Station.

- Multipurpose tree and shrub collection (65 species)
- Intercropping with multipurpose trees
- Windbreak demonstration
- Live fences
- Soil-conservation demonstrations and trials
- Demonstration of a Y-shaped (120°) layout with *Cassia siamea* and maize
- Demonstration of guava (*Psidium guajava*) hedgerows with annual crops
- Y-shaped (120°) layout with *Cassia siamea* and *Ricinus communis* (live and inert fences)
- Single-tree environment interaction study
- Evaluation of prototype hedgerow-intercropping systems
- Comparison of hedgerow intercropping and green-leaf manuring
- *Sesbania* species evaluation trials in short-rotation fallow systems
- *Grevillea robusta* at 45° angles
- Rotational hedgerow intercropping
- Parallel-row systematic design with *Grevillea robusta*
- Nelder fan systematic design
- Modified Chetty systematic design
- Site utilization study
- Repellents against browsing experiment
- Sunken planting trial
- Hedge-alley-hedge-alley (HAHA) experimental design
- *Gliricidia sepium* provenances evaluation trial
- Tree/crop competition for above- and below-ground resources
- Agroforestry potential of pigeonpea (*Cajanus cajan*)
- Comparison of annual versus perennial legumes for soil improvement

support and advice on efficient experimental designs, to develop and evaluate assessment methodologies and to prepare tools for data analysis. An integral part of this programme is strategic research on the processes involved in agroforestry—particularly on tree/crop interactions.

Experimental work is based primarily at ICRAF's field station at Machakos, Kenya. The Kenya Government provided the 40-hectare site in 1981, located 70 kilometres southeast of Nairobi at an altitude of 1600 metres. The climate is transitional between dry subhumid and semi-arid, with annual rainfall averaging 700 millimetres.

Most of the station consists of sloping land. Soils are predominantly haplic lixisols (FAO 1988 classification) but the site is highly variable, which is a positive feature since one aim of work at Machakos is to provide advice on experimental issues to collaborating scientists, many of whom encounter similar problems.

Originally, the field station was used primarily for agroforestry demonstrations and also for observational studies. Recently, more formal strategic research has been initiated at the site, aimed at developing a better understanding of the underlying processes associated with agroforestry. This understanding is an essential prerequisite for the correct interpretation of results from field trials, such as those in progress under the AFRENA programmes.

Strategic research is still at a preliminary stage, focusing primarily on studies of tree/crop interactions using simple measurement methods. Demonstrations and trials in progress at Machakos during 1989 are listed in Table 12. The most important of these will be discussed.

Above- and below-ground interactions at the tree/crop interface

By definition, all agroforestry systems involve interactions between trees and crops. A better understanding of these interactions should make it possible to design agroforestry systems that maximize positive effects and minimize negative ones. Thus, a major research effort at ICRAF, initiated in 1984, has concentrated on detailed investigations of the tree/crop interface. This work was completed in 1989, accompanied by a final report and summary document. Additional publications will follow, giving results in detail.

As reported in *Agroforestry Abstracts* (P.A. Huxley et al., 1989), the objectives of the study were:

- To explore and examine the biophysical characteristics of selected managed woody/nonwoody plant associations in order to understand the needs of tree/crop interface research and to help set feasible and well-focused goals for field experimentation
- To suggest suitable and cost-effective field designs, assessment methodologies and data-analysis procedures for tree/crop interface experiments
- To elucidate appropriate research procedures for the study of woody/nonwoody plant associations in a broad context, including the identification of potential sources of error.

Four basic designs were used for these studies: a Y-shaped (120°) layout of trees with contiguous cropping in parallel rows; separate hedges orientated along four compass directions, randomly dispersed and replicated, and cropped similarly; parallel rows of trees with spacing between rows varying systematically; and grid layouts surrounding single trees. The principal observations were crop harvests, measured row by row away from the tree/crop interfaces, tree heights, collar diameters, biomass yields and measurements of rainfall and soil water status.

Cassia siamea and *Grevillea robusta* were used for the tree components and maize was the principal test crop, with additional observations on castor bean (*Ricinus communis*). An inert fence the same height as a cassia hedge (1 metre) was used in one of the trials to separate the effects of above-ground and below-ground competition.

Throughout the studies, a major goal was to understand not simply *what* to measure, but *how* to measure it most cost-effectively. In several instances, this required over-sampling in order to be certain that results from abbreviated data sets truly reflected the results obtained from more complete information. For example, simple measurements of tree height and stem girth at the collar can describe the growth of the woody component, but measurement of maize plant height does not adequately reflect tree/crop interface effects on yields. Rather, this requires measurement of air-dried cob weights or seeds.

Differences in tree and crop performance were often considerable, even within small plots, indicating the importance of highly localized factors and raising questions concerning the extrapolation of experimental results from routine field plot studies. Results also varied with seasons of above- or below-average rainfall, and according to the orientation of tree rows.

Rainfall and soil water. Using standard 12-centimetre rain gauges, upwind rainfall peaks and downwind rainfall shadows were observed at tree/crop interfaces, but only over short distances. Soil water status was measured using an array of gypsum resistance blocks to record seasonal changes as crude wetting and drying profiles. Results in different situations, as shown in Figure 3, demonstrated the value of this method in helping to interpret yield profiles.

A comparison of maize yields in rows at different distances from a cassia hedge and an inert fence showed that severe competition was restricted to the crop row closest to the hedge or fence. Effects on larger areas of the crop may be due to competition for below-ground resources. As shown in Figure 4, these were evident during a dry season when moisture may have been limiting.

Root systems. At the end of 1988, scientists carried out root excavation on a transect across a cassia hedgerow and adjoining maize crop. The trench wall was smoothed and the cut ends of roots were exposed by water spray. Roots in different size categories were then marked on plastic sheets or counted using a wire grid, as shown in

Figure 3. A sample wetting and drying profile for a plot with a Grevillea robusta *hedge and maize on either side.*

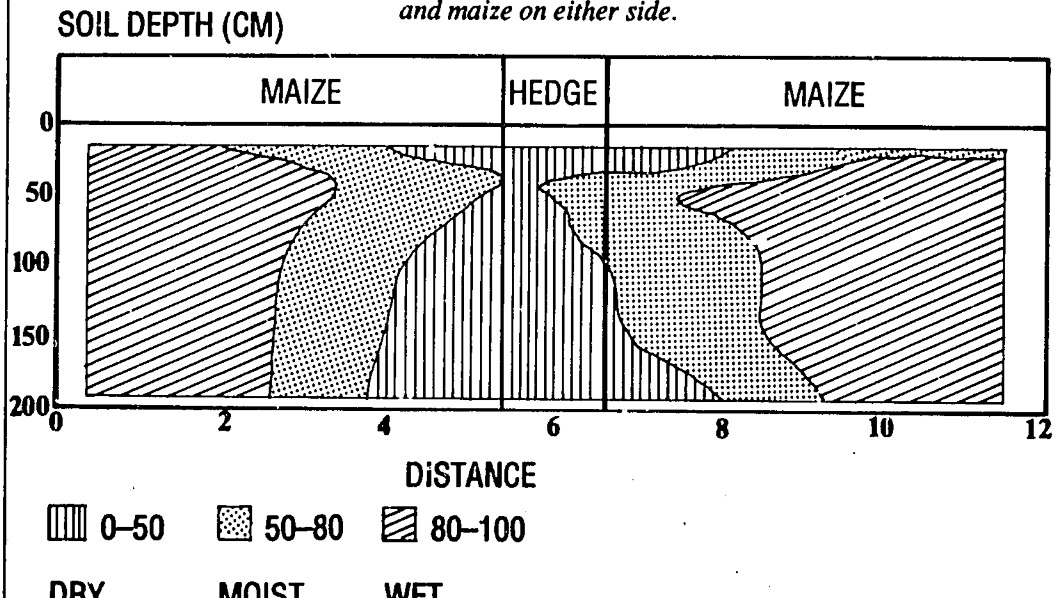


Figure 5. Using this technique, roots of a four-year-old cassia tree were found to penetrate more than 50 centimetres into weathered rock without soil and to extend at least 10 metres out and 2 metres deep. ICRAF staff are now examining graphic methods of depicting root systems, as exemplified in Figure 6. This involves comparing two different approaches for the computerized presentation of large amounts of root data.

ICRAF launched two new studies in 1989 to provide additional information on below-ground tree/crop interactions. The first involved a hedgerow-intercropping system with leucaena, cassia and gliricidia and focused on studying the development of root systems by periodic destructive sampling. The second was initiated to provide quantitative estimates of above- and below-ground interactions of leucaena and maize. The experiment was designed so that the effects of light, moisture and nutrient competition could be distinguished.

Orientation. Because the orientation of hedgerows might have an important effect on adjacent crops, orientation was considered separately in ICRAF's tree/crop interface experiments at Machakos. Results from all trials indicated that orientation was not a major factor in influencing tree or crop growth. However, whether trees were allowed to grow normally or pruned as hedges, adjacent crops showed some small benefits from shelter provided during the period of early growth.

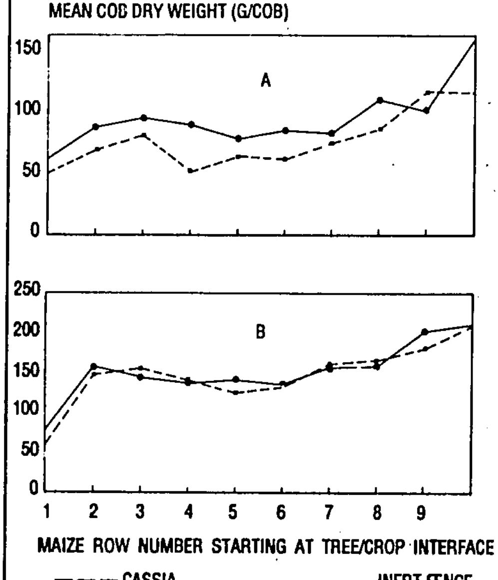
Slope. Slope can influence crop growth because of associated changes in soil fertility and soil moisture. In a tree/crop interface experiment at Machakos conducted on a 14% slope, annual crops in alleys between parallel rows of *Grevillea robusta* showed an asymmetrical growth pattern, with growth on the upper side of the alley much better than growth at the same distance from the hedgerow on the lower side of the alley. This asymmetrical growth pattern was more pronounced on plots with wide alleys.

One possible explanation involves the redistribution of nutrients within the plot, with the grevillea hedgerow acting as a barrier. The top of the alley may be protected from erosive water flow by the hedgerow close above it. Such an effect suggests the importance of careful selection of alley width, tree species and crop management when designing agroforestry systems on sloping land. In experiments, larger borders should be provided on the upslope side of plots than on the downslope side.

Short- and long-term fertility effects of trees. The short-term fertility effects of trees are associated with decomposition of leaf litter, while long-term effects are related to root decomposition and improvements in soil physical properties. These effects have not been properly quantified, but some evidence is available of their importance.

For example, in a tree/crop interface experiment at Machakos, *Cassia siamea* trees were grown on replicated plots for four

Figure 4. Mean cob dry weight of maize adjacent to a cassia hedge and an inert fence in a drier (A) and a wetter (B) season.



years while the adjoining plots were kept under crops. The same fertilizer regime was applied to all plots throughout the period. When the trees were felled, all woody material was removed from the site, including the stumps. Maize was then planted over the whole area. Although soil analyses on the two sets of plots did not reveal any consistent differences, subsequently a maize crop was considerably better on land previously under the trees, as shown in Figure 7. This improvement in maize yield even extended out a short distance into the interface area with adjacent plots previously under crops.

In another study at Machakos, both annual crops and newly planted leucaena hedges showed superior growth on land occupied during the previous four years by hedges of leucaena, cassia and gliricidia, compared with adjacent areas previously under crops. The improvement in growth was confined to 1-metre-wide strips occupied by the previous hedges, although roots from these hedges had extended over a broader area of 2 to 3 metres.

In these instances, the beneficial effects were of a short-term nature and could have been due to several possible causes. These might include the decomposition of leaf litter, fine tree roots, reduced export of nutrients during the period under trees or soil disturbance during tree removal.

An important question is to what extent are woody perennials more valuable in improving soil fertility on a long-term basis than the more commonly grown annual legumes. Thus, another trial was established in 1989 comparing the soil-fertility effects of a short-season legume (cowpea), a full-season legume (pigeonpea) and a perennial legume (*Gliricidia sepium*). These are being grown in various cropping systems, using maize as a test crop to detect improvements in soil fertility.

Figure 5. Roots of a 4-year-old Cassia siamea *hedge exposed by excavation at ICRAF's Machakos Field Station.*

Mulch, root and barrier effects of trees. Depending on site conditions, woody perennials may improve soil fertility and at the same time help prevent soil erosion. It is difficult to distinguish to what extent these effects can be attributed to above-ground biomass applied as mulch, to root activity or to the barrier effects of trees. Two experiments were initiated at Machakos in 1989 to try to measure these different effects separately.

The first experiment focuses on root interactions and mulch effects. Leucaena and cassia were planted with maize in a hedgerow-intercropping system—where root interactions would be expected; and in blocks—where there would not be root interactions between trees and crops. In both systems, plots were planted with three different ratios of land under trees and crops—25:75, 20:80 and 15:85. In addition, maize was planted in pure stand with different levels of inorganic fertilizer. On the test plots, all trees will be pruned at 60 centimetres above ground and the prunings will be incorporated into the corresponding area of maize.

The second trial, concentrating on the barrier effect, was established on a site with a 14% slope. Four treatments will be monitored on plots surrounded by metal sheets to measure runoff.

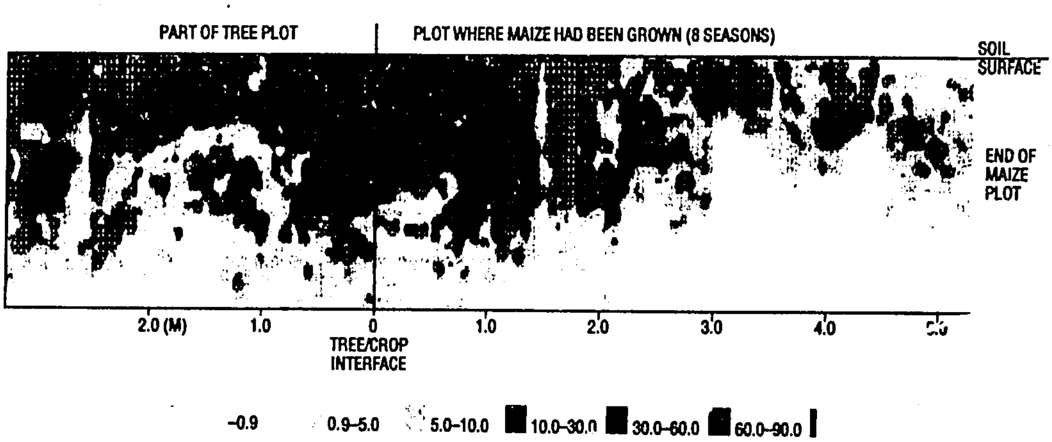
They are:

1. Barrier only—contour-aligned cassia hedgerows 4 metres apart with prunings stacked against the upper sides
2. Barrier plus cover—contour-aligned cassia hedgerows 4 metres apart with prunings spread across cropped alleys
3. Cover only—no hedgerows and the same amount of prunings as in (2) taken from an external tree plot and spread across the whole plot
4. Control—maize only.

Problems of experimental design

Many of the basic principles of scientific research, as applied in agriculture and forestry, are also important in agroforestry. However, the application of these principles to agroforestry research poses several unique problems. These are currently being addressed at

Figure 6. Fine root pattern of a four-year-old Cassia siamea *at a tree/crop interface: vertical section through soil depicted by ICRAF's 'PLOTSURF' computer graphics program.*



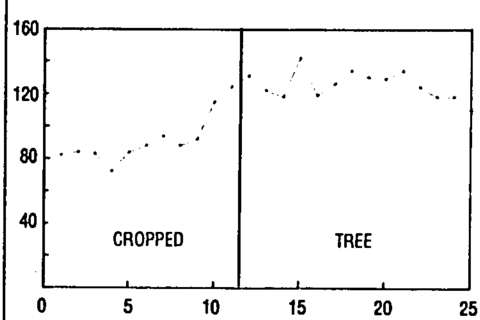
ICRAF. Problem areas include the complexity of agroforestry experiments, the variability of tropical soils, the long duration of many experiments and the limited information available on most multipurpose-tree species.

Some of the more important problems areas and related experiments are shown in Table 13. Work in 1989 included the culmination of the original tree/crop interface studies, preparation of a report on the Mini-workshop on Experimental Design, held in 1988, and detailed consideration of experimental designs for ICRAF's collaborative research programmes.

As an example, the *Gliricidia sepium* provenance evaluation trial currently in progress at Machakos illustrates several of the problems listed in Table 13 and possible approaches to solving them. The Oxford Forestry Institute (UK) provided seed for this trial as part of a multilocational study, aimed at evaluating 16 provenances of *Gliricidia sepium* collected in Central America. The suggested design was a 4 x 4 balanced lattice with five replications, each spread over four homogeneous blocks of four plots.

The first problem was to identify reasonably homogeneous blocks, so that any differences observed between provenances might be attributed to the germplasm and not simply to variations in the site. The site available for this trial was an area of 0.6 hectare, highly variable in terms of soil depth, texture and slope. There was considerable erosion plus two termite mounds and evidence of earlier mounds on the site. Thus the site posed several problems in terms of design and physical layout of the experiment.

Figure 7. Residual effect of four years of Cassia siamea *(right) or maize (left) on maize yield (air dried weight: grams per cob).*



Agroforestry experiments in tropical countries are often conducted on such sites due to scarcity of land. For this reason, the *Gliricidia sepium* trial has been used to demonstrate how agroforestry experiments might be conducted on such sites and how problems of site heterogeneity might be overcome.

To begin with, erosion was controlled by establishing contour grass lines of *Panicum coloratum* in the second half of 1987. Then homogeneous areas for locating blocks were identified by growing uniform crops of beans in the first half of 1988 followed by maize in the second half of the year. Over the whole site, crop growth varied enormously—from patches of several square metres with absolutely no crop to regions with substantial yields. The crops were harvested in grids of 4.5 x 4.5 metres within areas that appeared homogeneous, and yields were measured as a means of establishing block homogeneity.

Suspecting that homogeneity in terms of crop yield might not fully indicate homogeneous conditions for tree growth, scientists went on to assess soil depth by auguring cores at the corners of the grids. Both crop-yield and soil-depth data were then used to demarcate the experimental blocks. This exercise led to the identification of only 12 possible blocks, thus restricting the trial to three replications of the 4 x 4 lattice.

Meanwhile in the nursery, the seed from one provenance did not germinate at all and quite a few others produced only 20 to 25 seedlings. Thus, only 15 provenances (rather than 16) were planted out in three replicates (rather than five). This meant that in each replication one block had three rather than four plots, resulting in an unbalanced design. It was also necessary to reduce plot size from 4.5 x 4.5 metres with nine trees on each plot to 3.0 x 4.5 metres with six trees.

The provenances in each block were placed next to each other with constant spacing on the assumption that differences between provenance, and thus effects on neighbours, were unlikely to be large. Effects on neighbouring provenances will also be reduced because all trees will be cut to a height of 50 centimetres after two or three seasons to assess their coppicing ability. Only the provenances located at the edges of the experimental area were given an extra guard row of three trees.

The trees were planted in April 1989. By the end of the year, preliminary data indicated that blocking had been effective in controlling variability associated with the site.

Data management in agroforestry experiments

Work at ICRAF's Machakos field station has shown the importance of rigorous recording and storage of experimental data. Agroforestry experiments usually include observations on several separate components, with measurements made over several seasons and at different intervals. The tree/crop interface studies in particular indicated a need for a highly flexible database to accommodate complex, interrelated experimental data. At the 1988 Mini-workshop on Experimental Design, ICRAF scientists drew up an outline for such a database system, based on earlier work and in collaboration with colleagues from CSIRO. The database system developed at ICRAF is called *Datachain*, indicating that it bridges the gap between the collection of field data and analysis using existing software packages.

Datachain is a microcomputer program to help collect and check field experimental data prior to analysis with standard statistical and graphics packages. It is designed to document an experiment, help lay out the treatments and organize the collection of data from different sources. It provides forms for data collection and accepts data and information characterizing the experiment either by keyboard entry or by electronic transfer from a Psion Organizer. It also includes facilities for checking field data and has the capacity to archive and merge data before transferring them to the powerful statistical package GENSTAT 5 for analysis.

Following the development of a prototype in 1988, Version 1.1 was released to users outside ICRAF in 1989 at a nominal cost. By the end of the year, there were 70 licensed users in more than 25 countries.

Table 13. Some problem areas in agroforestry experimental design and analysis and related experiments in progress at ICRAF's Machakos Field Station.

Problem Areas	Experiments
• Suitable plot size and arrangement	*Gliricidia sepium* provenance evaluation trial
• Allocation of treatments to plots	Hedge-alley-hedge-alley (HAHA) experimental design
• Edge effects and guard areas	Tree/crop competition for above-ground and below-ground resources
• Orientation effects	*Grevillea robusta* trial at 45° angles
• Extreme trait ranges	Systematic designs (parallel row, Nelder fan and modified Chetty design)

Training courses have been held on the use of Datachain, both for ICRAF headquarters staff and for collaborating scientists in the Southern, Eastern and Central Africa AFRENA programmes.

Agroforestry technologies for soil conservation

Agroforestry appears to have considerable potential for the control of runoff and soil erosion. This potential role has been the subject of a demonstration at the field station since 1984 and has been explored in more detail through field trials initiated in 1988. Nine interlinked trials and demonstrations have been established on land sloping at 14%. These include comparisons of single versus multiple-row hedgerows; comparisons of hedgerows at different spacings; comparisons of cover versus barrier effects; demonstrations of the soil-conservation effects of trees on grass strips, trees on bench terraces and trees with bank-over-ditch structures (referred to as *fanya juu* in Kenya); an assessment of the effects of contour-aligned hedgerow intercropping; and a methods trial testing different plot sizes and techniques for runoff collection.

Most plots are cropped twice a year alternately with maize and cowpea. Observations include: natural terrace formation; runoff and erosion; soil analysis of plots and of eroded sediment; soil cover by hedge, crop and mulch; soil water in transects across hedgerows; infiltration; tree height and biomass (in the demonstration of trees on grass strips); biomass of hedgerow prunings; and crop yield.

Results obtained at the end of 1989 were presented to the Sixth International Soil Conservation Conference, held in November in Addis Ababa, Ethiopia. In the plots with trees in grass strips, *Grevillea robusta* required protection from grass competition for good establishment, but then reached heights of over 5 metres in four years. Six species of fruit tree planted in the ditches of bank-over-ditch structures showed good growth and fruiting, indicating that this might be a promising technique for fruit-tree production in dry areas.

In the hedgerow-intercropping trial on sloping land, *Leucaena leucocephala* and *Cassia siamea* both formed effective barriers, but leucaena decayed too rapidly to provide an adequate mulch cover. No general guidelines exist for spacing hedge-

In a trial at ICRAF's Machakos field station, contour-aligned hedgerow intercropping was used successfully to control runoff and soil loss.

rows on slopes, but intervals of 4 metres on a 14% slope, chosen when this experiment was established in 1984, appeared to be effective. The hedgerows led to the formation of micro-terraces, with risers stabilized by the tree roots.

Crop yields were high on these experimental plots in 1989, averaging 2800 kilograms per hectare for maize and 900 kilograms for cowpeas. As yet, no significant yield differences have been observed among the different treatments per unit area under crops.

An important aspect of this work has been the assessment of different methods for measuring soil erosion. Standardized methods are available for measuring runoff and soil loss on agricultural plots, but not for agroforestry systems that usually require larger plots. Thus a trial was established in 1989 on hedgerow-intercropping plots with four-year-old leucaena barrier hedgerows and on adjacent control plots without any soil-conservation measures.

One objective is to compare the accuracy of erosion measurements from 2 x 20-metre, 5 x 20-metre and 10 x 40-metre plots. Clearly, erosion experiments on small plots will be more cost-effective if results are sufficiently accurate.

The second aim is to compare the accuracy of measurements taken from conventional sediment-collection troughs and from smaller Gerlach troughs. Again, the Gerlach troughs are less expensive and can be sited more easily at different locations within a plot, so it will be useful to learn whether they can provide sufficiently accurate measurements of soil erosion. Observations in this unreplicated trial include runoff, soil loss, soil nutrient loss, crop yields and terrace formation.

Technology trials for tree establishment

Three trials were completed or in progress at Machakos in 1989, designed to test improved methods for tree establishment in dry areas. One trial compared standard planting techniques on level ground with open-pit sunken planting. This work began in 1984, and early results showed a positive effect for sunken-pit planting in terms of height growth and dry-matter yield of *Acacia mellifera*.

Beginning in 1987, the experiment was repeated with *Leucaena leucocephala* and again results showed better growth and significantly higher survival rates with sunken-pit planting. Several parameters were monitored in 1989, including shoot growth, plant survival and condition, pest attacks, flowering, fruit-setting and silting up of the open pits. Results were affected by higher than average rainfall throughout the year. In December, root-excavation work was initiated in order to establish any effects on root development and to assess above- and below-ground biomass distribution. Results will be published in 1990.

A second trial, initiated in 1985, focused on methods for tree establishment during the dry season when labour is not taken up with crop production. Three species were planted—*Grevillea robusta, Casuarina equisetifolia* and *Mangifera indica*—with supplementary watering ranging from 1.0 to 2.5 litres per seedling. The seedlings were watered initially once every two weeks and later once a week, either on the surface or at 40 centimetres below the surface through a plastic tube inserted into the ground near the tree base. Below-surface watering was designed to reduce potential water loss through evaporation.

In spite of very little rain, all the seedlings established successfully. These results suggest that trees can be established in semi-arid areas during the dry season with as little as 1.0 litre of supplementary water every one or two weeks. Most farmers can manage this level of watering for a few trees, for example for fruit, timber or fuelwood trees in a home garden.

The third study tested the effectiveness of various natural repellents in protecting seedlings of *Leucaena leucocephala* from damage by browsing goats. Tree seedlings were exposed to approximately three times the normal browsing pressure for this type of environment. Results in 1988 showed that seedlings protected with clipped sheep's wool or kapok seed fibre suffered markedly less browsing damage than seedlings with other treatments or controls. In 1989, 40 leucaena seedlings were treated with crushed seeds of *Datura stramonium* as a repellent agent, mixed with castor oil and acacia gum acting as adhesives. The treatment clearly delayed and reduced initial browsing but proved ineffective after one week's exposure, indicating that this mixture is inferior as a repellent to sheep's wool or kapok fibre.

Further tests of natural repellents are in progress. The final results will be published in 1990.

Prototype testing

An earlier hedgerow-intercropping trial on station, which was designed to test different species, spacings and pruning heights, was removed in 1989 and replaced with a prototype trial testing one species (*Leucaena leucocephala*), one spacing and one pruning height. Hedgerows were basically laid out at 5.4-metre intervals, although spacing varied somewhat because the trial was on sloping land and the hedgerows were aligned on the contour.

Four systems are being tested, two with hedgerow intercropping and two with annual crops only, with and without fertilizer at a moderate level. In one of the hedgerow-intercropping systems, the prunings are used as mulch for soil fertility improvement, and in the other they are fed to livestock and the manure returned to the soil.

This experiment was established on plots of 300 to 600 square metres, which are large enough to allow the evaluation of labour requirements and the economic impact of the systems being tested. Although this trial has sufficient replication for a formal statistical analysis, it was established on a heterogeneous site and its main purpose is to serve as a demonstration prototype trial, with a flexible approach to plot orientation and size.

Demonstrations

Multipurpose trees with agroforestry potential, established on the field station through the years, now form a collection of 65 species including 15 provenances of *Gliricidia sepium*, 10 provenances of *Leucaena leucocephala* and 10 genotypes of *Cajanus cajan*. Six species were planted in large plots of about 100 trees; the others were planted in small plots of 3 to 15 trees each. They demonstrate the potential of multipurpose trees to provide different products—such as fodder, fuelwood and poles—and also show management aspects and the potential of combining trees and crops.

Results from eight years' work have led to the selection of four species that can be relied upon for good establishment and growth under conditions at Machakos. These are *Leucaena leucocephala, Cassia siamea, Grevillea robusta* and *Gliricidia sepium*. In addition, *Faidherbia (Acacia) albida, Prosopis juliflora, Sesbania sesban* and *Sesbania macrantha* appear generally well adapted to the environment, although not entirely without problems.

The larger tree plots and some of the smaller plots have been cropped regularly with maize and beans. These plots have demonstrated that some tree and crop species can be combined to produce reasonable yields of food plus tree products. However, careful attention must be paid to species selection and management.

A home garden demonstration with fruit trees has been set up on about 500 square metres of land in a previously unused corner of the station. Fruit species include banana, mango, custard apple, loquat, white zapota, fig, guava and strawberry guava. These trees were given supplementary water in the early phase of growth. All are now fruiting after four to five years, and the space between them is used to grow vegetables. This area demonstrates an intensive form of land use with modest inputs capable of producing high-value products.

On-farm research and extension

On-farm research and extension is perceived at ICRAF as an essential component of the agroforestry technology development process. The objectives of this programme are to:

- Study farmers' agroforestry systems, multipurpose trees, land-use problems and interventions in order to improve research planning and analysis
- Work with farmers to improve existing agroforestry technologies and test such improvements
- Design, test and adapt, together with farmers, new agroforestry technologies resulting from on-station experimentation
- Monitor and evaluate adoption and modification by farmers and the impact of agroforestry technologies.

Special-project funding for expanding this programme was provided in 1989 by the Australian International Development Assistance Bureau (AIDAB), the Ford Foundation, the Rockefeller Foundation and secondments from the Governments of Sweden and The Netherlands.

Review of current methods for project monitoring and evaluation

A major activity of ICRAF's on-farm research programme, initiated in 1988 and completed in 1989, was a worldwide review of agroforestry extension and on-farm research projects to identify the methods being used for technology monitoring and evaluation. The review focused on methods for planning agroforestry interventions, evaluating the performance of agroforestry technologies and assessing the adoption and impact of agroforestry. Information on agroforestry monitoring and evaluation was collected from 108 projects and from material in the ICRAF library. This was compiled in an annotated bibliography and published in 1989.

Of the 108 projects surveyed, 42% reported technology-planning activities, some based on the diagnosis and design methodology or related approaches and many using formal surveys; 88% reported technology-evaluation activities consisting of formal trials on research plots or farms or various types of follow-up studies with participating farmers; 45% reported impact-evaluation activities, mainly focusing on tree growing and the extent of agroforestry practices rather than on availability of tree products or socioeconomic benefits.

Several technical articles have been prepared from the material collected, summarizing the lessons to be learned from project experience. Generally speaking, those planning agroforestry projects need to pay greater attention to the analysis of existing agroforestry systems and the identification of opportunities for improvement. At the planning stage, there needs to be less concentration on formal surveys and more focus on soliciting farmer input into the selection of technology priorities and designs and on identifying economic opportunities for agroforestry.

There is also an urgent need to develop more practical methods for evaluating technology performance on farms, including analysis of yields and economic returns, and these must be standardized so that results can be compared across projects. The results shown in Table 14 suggest the need for more attention to assessment of the performance of systems as a whole, rather than of the tree component alone.

Projects also need to be formulated with specified, measurable expected impacts. Impact evaluation can then serve as a valuable tool to guide project management as well as a useful source of information on which to base future project design. Both quantitative and qualitative information are needed in order to document and interpret changes in agroforestry practices and their effects on participating households. In this context, 'adoption' needs to be carefully defined, and the methods used to measure adoption stated explicitly.

The ICRAF review demonstrated that both government and nongovernment agroforestry extension projects are actively involved in technology design and evaluation. Although formal agroforestry research programmes are likely to expand, the role of extension projects in adaptive research will remain extremely important. At the same time, project managers need better methods to select and refine extension recommendations. This situation offers a particularly promising opportunity for collaboration between the development and research communities.

Review of methods for on-farm research

Another activity in 1989 was a review of methods for on-farm multipurpose-tree experimentation and evaluation. ICRAF scientists reviewed a number of key areas in on-farm research methodology for agroforestry and prepared papers that will be published in 1990. These cover the following topics:

Table 14. Variables assessed in technology evaluation by 92 agroforestry projects.

Variable	Number of Projects
Multipurpose-tree performance	67
Tree survival/mortality	50
Tree growth rates	36
Farmer species preferences	17
Site adaptability of trees	8
Condition of planted trees	8
Pest/disease problems	5
Species suitability for specific purposes	5
Tree seed characteristics	3
Growth characteristics of planted trees	3
Indigenous tree growth	1
Multipurpose-tree arrangements/management	38
Multipurpose-tree management and utilization	26
Multipurpose-tree spacing/configurations	19
Planting methods/materials	8
Location of multipurpose trees on-farm	5
Technology performance	71
Yields from crop component	27
Technical evaluation of technologies (variables not specified)	25
Farmer evaluation of technologies	21
Soil fertility/erosion	21
Yields from tree component	18
Economic costs and/or benefits	12
Labour requirements	6
Yields from fodder component	5
Tree/crop compatibility	3

Source: S.J. Scherr and E.U. Müller (in press), Evaluating agroforestry interventions in extension projects, *Agroforestry Systems*.

- Methodological problems in on-farm agroforestry research
- Methods for assessing crop yields in on-farm agroforestry experiments
- Methods for assessing multipurpose-tree yields in linear agroforestry arrangements on farms
- Use of ecological methods in designing on-farm experiments
- Application of tree/crop interface research to on-farm experiments
- Social psychology of researcher/farmer interactions in on-farm research
- Alternative statistical approaches for the design of on-farm technology trials
- Methods for participatory on-farm research in agropastoral systems
- Methods for surveying multipurpose-trees and agroforestry technologies on farm.

Research at the Machakos field station, particularly the tree/crop interface studies, has provided much useful information—for example, on edge effects and tree rooting patterns—to help understand what happens in farmers' fields. This work is of direct relevance to the design of on-farm experiments. A demonstration of a 'farmer's field' at Machakos helps explain these ideas to visitors.

Work in 1989 included the establishment of a database of scientists involved in on-farm agroforestry research and a survey of current on-farm research activities in Eastern, Central and Southern Africa. It will culminate in an international workshop on 'Methods for Participatory On-farm Agroforestry Research' in February 1990.

Survey on agroforestry adoption and impact

In 1989, ICRAF helped CARE-International to design, implement and analyse a survey on the adoption and impact of agroforestry technologies under Kenya's Agroforestry Extension Project. This project was initiated in 1984 in Siaya District, western Kenya, and was extended to South Nyanza District in 1985. The objective of the survey was to obtain information on diffusion and adoption of agroforestry technologies under the project and on the impact of these technologies on farmers and other land users in terms of household supplies of key agroforestry products and services. This information was important to assist CARE's own project-evaluation activities and the study also served to develop research methods for evaluating agroforestry adoption and impact in general. An extra benefit was the identification of key aspects of agroforestry adoption relevant to ICRAF's AFRENA programmes.

The project offered a valuable research site for ICRAF, covering a variety of ecological zones with annual rainfall ranging from 800 to 2000 millimetres and population densities ranging from 100 to 300 people per square kilometre. By mid-1989, the project was working directly with more than 3000 individual farmers through 280 women's groups as well as 300 primary schools. The project also promoted an unusually wide range of tree species and agroforestry technologies.

ICRAF researchers and CARE extension staff developed a three-part questionnaire that was used in interviews with 336 farmers. The first part related to household and farm characteristics and extension contacts. The second part was a detailed census of all trees grown and managed on farms, distinguishing those established before and after farmers joined the project. Data were collected on species, method of establishment, farm niche, tree numbers and density, uses, management and effects on adjacent crops.

The third part of the questionnaire asked farmers to rank the role of trees planted on their farms in supplying key products and services to their households relative to the role of naturally growing trees on and off their farms and of purchases. Products and services included fuelwood, building poles, fruit, soil fertility maintenance and soil erosion control.

Survey findings provided interesting insights into agroforestry adoption patterns in

An extension agent and a farmer in Kiambu District, Kenya, discuss how to manage a leucaena hedge for fodder production. The crop in the foreground is sweet potato.

a mixed crop-livestock smallholder system under intense population pressure. Almost all of the farmers had some experience with planting trees. Only half of the trees found in farmers' fields had been established by planting seedlings; another third were wildlings, but a quarter of these had been transplanted by the farmers from other sites. Home compounds were the most important site for tree growing and showed the greatest species diversity. There was also a clear increase in the number of trees planted in cropland, especially in areas of relatively high rainfall and population density.

Altogether, 178 tree species were found on farms covered by the survey, including several little-known local species. Five species accounted for half of all the trees on farms. These were *Eucalyptus* spp., *Markhamia lutea*, *Leucaena leucocephala*, *Cupressus lusitanica* and *Cassia siamea*. Another 22 tree species were widespread, plus the traditional shrub species *Lantana camara*, *Euphorbia tirucalli*, *Agave sisalana* and *Thevetia peruviana*.

There was a striking specificity of tree species for particular uses, farm niches and ecological zones. For instance, only nine species were considered by more than half of farmers to 'grow well together with crops'. These included the indigenous species *Markhamia lutea*, *Sesbania sesban* and *Croton megalocarpus* and the introduced species *Leucaena leucocephala*, *Grevillea robusta*, *Calliandra calothyrsus*, *Samanea saman*, *Persea americana* (avocado) and *Carica papaya* (pawpaw). Five of these species have been chosen for intensive selection work to be undertaken as part of ICRAF's project on the genetic improvement of multipurpose trees.

Although farmers had only been participating in the project for an average of three years, the survey found that the average number of trees and shrubs on farms had doubled, from around 450 to 925, during this period. As summarized in Table 15, there were also clear shifts in the selection of species, plus greater focus on trees in cropland, more tree establishment from seedlings and more trees planted in linear arrangements. There were also notable differences between farmers in the different ecological zones.

Acceptance of *Leucaena leucocephala* was particularly striking. This is now the sixth most important of all woody perennials on farms and the third most important tree in the area. It is used for a wide range of technologies and functions, but most often in hedgerow intercropping for green manure production.

The ranking exercise showed that planted trees on farms are the most important source of fuelwood, poles and fruit for a large proportion of households. Given that benefits from trees planted during the project period are still modest, a high proportion of farmers should become self-sufficient in these products over the next few years. Trees planted on farms were also an important source of cash income, with half of all farmers reporting the sale of building poles and fruit in the previous year and a third reporting the sale of fuelwood. There is still considerable scope for planting additional trees to improve soil fertility and to control erosion.

Farmers expressed the greatest interest in future tree planting to produce building poles, fruit, timber, green manure and shade/ornamentation. When farmers were asked which five tree species they would like to plant next year, 21 species were mentioned by at least 5% of respondents, with leucaena, eucalyptus and markhamia the most popular. These findings suggest the importance in extension programmes of providing a wide range of tree species for different specialized niches and uses.

This survey was conducted in an area where farmers are already familiar with tree husbandry and are supported by a flexible extension programme focused on meeting their expressed needs for tree products and services. Results showed that under these circumstances agroforestry extension activities can have a marked impact on farm households, even over a short period of time.

Technology design and testing

Technology design and testing activities continued in 1989, including the development of a set of recommendations for improving technical extension advice on hedgerow intercropping and tree borders and an economic study on the use of *Markhamia lutea* in various agroforestry technologies, both focusing on Siaya District. In collaboration with the AFRENA programme for Eastern and Central Africa, research proposals were prepared for testing hedgerow-intercropping technologies with farmers and for evaluating farmers' existing hedgerow-intercropping plots in economic terms.

ICRAF's first field project with farmers focused on the introduction and evaluation of new multipurpose trees and agroforestry technologies. It was launched in 1981, in Kathama Location of Machakos District, Kenya. Work at the site will be completed in 1990.

During 1989, the site assistant continued to monitor farmers' agroforestry activities and their experience with 25 introduced tree species. A field survey was also conducted covering changes in the farmers' use, knowledge and management of multipurpose trees under the project.

Also in 1989, ICRAF prepared one training document outlining planning procedures for on-farm agroforestry technology trials and another discussing farmer collaboration in agroforestry research.

Table 15. Changes in agroforestry practices by CARE-assisted farmers in western Kenya, 1984–1989.

Multipurpose-Tree Species Diversification
- Wide adoption of 9 new species
- Accelerated adoption of 12 previously introduced or indigenous species
- 28 popular species account for 89% of all trees on farms
- 150 other species also found

Increase in Trees on Farms
- 33% increase in average length of dense hedge to 386 metres
- 127% increase in average number of trees to 539

Tree Density in Cropland
- 174 metres of dense hedge and 243 trees in average cropped area of 1.3 hectares per farm

Increase in Proportion of Trees Established from Seedlings
- Before joining project 20%; after joining project 71%

Changing Configurations of Trees on Farms

	Before Joining Project	After Joining Project
Scattered planting	37%	18%
Linear border planting	34%	42%
Hedgerow intercropping	<1%	14%
Block planting, mixed intercropping	28%	26%

Source: S.J. Scherr and E. Alitsi (draft), *The development impact of the CARE-Kenya Agroforestry Extension Project: report of the 1989 adoption and impact survey*, Nairobi: CARE International and ICRAF.

Training and education

Training and education activities at ICRAF are closely linked to the collaborative research programme. The underlying philosophy is that agroforestry research and technology development will be more appropriate for local conditions and more lasting if work is planned and executed in close cooperation with national programmes, rather than by ICRAF alone. As a new field, agroforestry has been particularly hampered at the national level by a lack of trained scientists and development workers. Thus, ICRAF places a strong emphasis on agroforestry training and education, conducted in tandem with research.

An important objective of ICRAF's training and education programme is to provide support to ongoing collaborative research, in particular through the AFRENA programmes. In addition, the programme has a global mandate, offering training and research experience in agroforestry to individuals from all over the world. Table 16 shows the major training and education activities of 1989.

Group activities include both general and specialized training courses, technical meetings, workshops and field trips. ICRAF also offers internships and fellowships to individuals to support their participation in the research programmes. More recently, work has expanded to include the development of agroforestry curricula at the diploma, degree and postgraduate levels. Teaching materials are designed in support of all these training and education activities.

In collaboration with the AFRENA programmes, ICRAF's training activities begin with short- and medium-term training on research planning methods, offered to members of national agroforestry task forces. As research programmes reach the implementation stage, training focuses on experimental methods and techniques for field research in agroforestry, plus support for postgraduate education. For example, in the development of the Eastern and Central Africa AFRENA training activities from 1987 to 1989 included: five in-country workshops on different aspects of agroforestry research planning, monitoring and evaluation; individualized, six-month, on-the-job training for leaders of the national task forces; a three-week course on the diagnosis and design methodology; and a study tour. Beginning in 1990, national scientists will also be sponsored for postgraduate education.

In 1989, ICRAF conducted two new courses in response to needs that have become apparent within the AFRENA programmes—one for researchers on statistical analysis and one for field technicians on field experimentation and data collection.

The five-day course on the use of computers and the SAS system for statistical analysis was held in April. Collaborative assistance was provided by the International Centre of Insect Physiology and Ecology (ICIPE). The aim was to help scientists working in the Southern Africa AFRENA in the use of computers for data entry, processing, analysis and retrieval. Participants included eight national scientists from Malawi, Tanzania and Zambia and six ICRAF staff members working in the region.

The three-week training course on field experimentation was conducted at the Machakos field station in October-November, with financial support from IDRC. The 12 participants were field technicians working in the AFRENA programmes for Eastern, Central and Southern Africa.

Instruction was organized in three modules. The first covered soil and climatic parameters including soil sampling and measurement of soil moisture, field capacity, infiltration, hydraulic conductivity, soil erosion and the minimum weather parameters. The second covered the layout of field experiments and the establishment and management of agroforestry trials. This included layout of contour lines, selection of precise positions for plots, discarding of inappropriate parts of the site, positioning of borders and guard areas, physical dimensions of plots, preparation of tree seeds, nursery techniques and tree-planting methods. The third module covered the measurement of trees and crops and data handling. This included phenological observations on trees, tree growth measurements, root sampling, litter collection, crop measurements, drying plant samples, sampling procedures and direct keyboard data entry in the field. The approach was informal, with an emphasis on practical field exercises. The objective was to ensure that measurements made in the field are as accurate as possible and that field staff have a good understanding of the purpose and design of experiments. There are plans to repeat this course in 1990, and the extensive written material prepared for the course is being developed for broader use.

For a global audience, ICRAF has conducted a three-week introductory course every year since 1983 on agroforestry research for development. This course is intended for researchers and planners from developing countries. The goal is to provide the technical background information necessary to plan and implement sound agroforestry research. Financial support has

Table 16. ICRAF training and education activities in 1989.

Activity and Programme	Main Topic	Venue and Duration	Participants
Workshops			
Eastern/Central Africa	Research planning and evaluation	Uganda—6 days	20
Southern Africa	Research planning	Tanzania—2 weeks	20
Humid Lowlands of West Africa	Agroforestry concepts and technologies	Cameroon—5 days	20
Semi-arid Lowlands of West Africa	Research planning	Burkina Faso—4 days	44
Training courses			
Global	Agroforestry research for development	Kenya—3 weeks	37
Eastern/Central and Southern Africa	Field data collection	Kenya—3 weeks	12
Southern Africa	Computers and statistical packages	Kenya—5 days	12
Internships			
Southern Africa	Tree/crop interface	Kenya—3 months	2
Humid West Africa	Multipurpose tree germplasm improvement	Cameroon—3 months	3
Fellowships			
Southern Africa	M.Sc. course work	USA—2.5 year	5
	M.Sc. course work	Canada—2.5 year	1
Humid West Africa	M.Sc. course work	Nigeria—2 years	1
	Ph.D. research	Cameroon—3 years	1
Field trips			
Southern Africa	Field observations	Tanzania—10 days	15
East/Central Africa	Field observations	Uganda—2 days	15

been provided since 1987 by the programme for Direct Support to Training Institutes in Developing Countries (DSO) of the Government of The Netherlands.

In May 1989, 37 scientists attended the course from 24 developing countries in Africa, Latin America and South and East Asia. Instruction was organized in four modules, as follows:

- Introduction to agroforestry
- The diagnosis and design methodology
- Agroforestry technology generation
- Scientific evaluation of agroforestry.

The course consisted of lectures, poster presentations by participants, group work, meetings with ICRAF staff and work on an individual basis—all at ICRAF headquarters in Nairobi. In addition, there was a two-day field exercise that allowed participants to conduct a diagnosis and design survey in western Kenya with assistance from the CARE-International agroforestry project in Siaya District and the Kenya Government's District Agricultural Office at Kisumu.

For the first time in 1989, the course was conducted on a bilingual basis in English and French. During the evaluation exercise, the participants mentioned difficulties in understanding lectures through interpreters and in getting to know each other without a language in common. As a result, future courses will be held in each language alternatively. Otherwise, as in previous years, participants gave the course an excellent rating.

Field trips are another type of training activity, organized by ICRAF on request from national, international and donor organizations. Their purpose is to provide an opportunity for researchers and development specialists to exchange views and to obtain first-hand knowledge of agroforestry systems and practices. In 1989, ICRAF organized 22 field trips with an average duration of 13 days. These included 20 field trips in Kenya and 1 each in Uganda and Tanzania. A total of 133 people participated. ICRAF also helped conduct a training course for AFNETA in collaboration with ILCA and IITA.

A project was launched in 1988 to develop curricula for agroforestry education, particularly at the M.Sc. level. In 1989, ICRAF pursued this objective by reviewing literature on existing agroforestry education programmes and making contacts with universities in Africa and other parts of the world. ICRAF staff members met with senior administrators and teaching staff of 11 universities in Africa to discuss such issues as:

- The status of current agroforestry education at the undergraduate and postgraduate level
- The extent of interest in agroforestry education and research among university students and staff
- The human and physical resources that would be required to establish an M.Sc. programme in agroforestry
- National agroforestry policies and manpower needs.

The information gathered during the year will provide a basis for designing university curricula in agroforestry. In 1989, Makerere University in Uganda extended its B.Sc. programmes in forestry and agriculture to allow for the introduction of additional subjects, including agroforestry. ICRAF staff made a substantial contribution to the development of the new agroforestry course. Three universities were also tentatively identified to initiate M.Sc. courses in agroforestry. These are Moi University in Kenya, Sokoine University of Agriculture in Tanzania and the University of Science and Technology in Ghana.

Information and documentation

During 1989, ICRAF's information and documentation services continued to respond to the needs of agroforestry researchers and others collaborating directly with ICRAF, as well as to the growing need for agroforestry information arising from individuals and institutions involved in development work and research.

A major ongoing task is the identification and acquisition of material on agroforestry for the ICRAF library. With this objective, information staff scrutinize the relevant databases and abstracting journals. These include the AGRICOLA database of the National Agricultural Library of the United States Department of Agriculture (USDA), available at ICRAF on CD-ROM, the International Information System for the Agricultural Sciences and Technology (AGRIS) database coordinated by FAO and the databases maintained by CABI. Nonconventional literature is obtained primarily by exchange with other libraries or through ICRAF staff who visit other institutions in the course of their work.

By the end of 1989, the library contained 5700 books and 10,500 reprints. During the year, 2680 new acquisitions were analysed and entered into ICRAF's computerized library database, bringing the total number of entries to more than 15,000. In order to improve its usefulness, abstracts of articles from the first two volumes of *Agroforestry Systems* were entered in the database. A major exercise was also undertaken to reduce the number of errors. The objective is to prepare ICRAF's library database for distribution to collaborating institutions by the end of 1990.

In response to requests for information on specific topics related to agroforestry, staff members search the library database and provide printouts listing appropriate references. Requests for this service are increasing every year: In 1989, one or more request was received from 391 individuals or institutions in Africa, 49 in Asia and the Pacific, 25 in Latin America, 33 in North America and 43 in Europe. Throughout the year, a total of 825 computer searches were undertaken in response to these requests. About half were for scientists and field workers collaborating with ICRAF through the AFRENA programmes. Using the Selective Dissemination of Information (SDI) service offered through the AFRENAs, 175 collaborating scientists also requested and received full copies of more than 1200 documents identified by database searches.

To help keep scientists apprised of ongoing research that may not have reached the stage of publication, ICRAF maintains a computerized directory of agroforestry researchers around the world. At the end of 1989, this database contained 350 names with addresses and research profiles.

ICRAF produces a bimonthly library accessions list, describing about 450 new references in each issue. This is distributed to 350 libraries and individual researchers on a regular basis. In 1989, an annotated bibliography, *Agroforestry literature: a selected bibliography on subsaharan Africa*, was also prepared by information staff, plus a brochure describing ICRAF's library and information and documentation services. Production of the bibliography was supported by funding from IDRC.

Copies of all ICRAF publications are provided free of charge to 86 selected libraries. These include national agricultural libraries in countries where ICRAF is conducting collaborative research, some of the major agricultural libraries in other parts of the world and the publishers of the major bibliographic databases in the agricultural sciences.

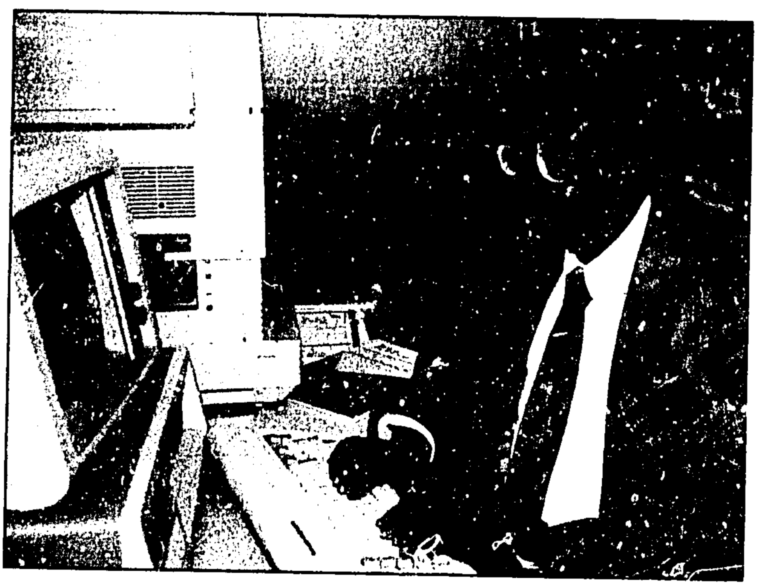
ICRAF continues to emphasize the improvement of information resources available in both English and French. This work is supported in part by the Government of France, including the provision of documentation from the Centre technique forestier tropical (CTFT) and exchanges with the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD). Major efforts are ongoing to develop agroforestry terminology in both languages and to maintain currency in the use of species descriptor terms. As a result, more than 2110 subject descriptor terms are available for use in bibliographic analysis. ICRAF collaborates closely with FAO and CABI in this work, relying on FAO's AGROVOC thesaurus and CABI's CABVOC thesaurus for most agricultural terms and informing these organizations of suggested terminology on agroforestry.

Other collaborative activities include participation as a special information source on agroforestry in the environmental information network, INFOTERRA, of the United Nations Environment Programme (UNEP). ICRAF also participates actively in collaborative information and documentation activities of the CGIAR. Within this group, ICRAF serves as a distribution point for the Micro CDS/ISIS software used for bibliographic database management on microcomputers and is responsible for liaison with developers of the software at the United Nations Educational, Scientific and Cultural Organization (UNESCO). Additional activities in collaboration with the CGIAR include the preparation of a directory of information specialists with experience in training in developing countries and a list of training materials available on information and documentation.

During 1989, information staff travelled to Burkina Faso, Niger, Mali, Senegal, India and Bangladesh to evaluate the agroforestry information needs in these countries, to identify the main agroforestry researchers and development workers and to learn about the information services available. These missions were funded by the Ford Foundation, IFAD and the Government of France. A project was planned, for implementation in late 1990, to help selected institutions in the sahelian region develop their capacity to provide information on agroforestry. Funding will be provided by CIDA.

In Eastern and Southern Africa, ICRAF participates in a network of 14 institutions organized for the exchange of information on agroforestry. ICRAF has also helped establish a Micro CDS/ISIS users' group among libraries and documentation centres in Kenya and played a major role in a workshop on Micro CDS/ISIS conducted in 1989.

Through its leading role in the Nairobi Information Group, ICRAF encourages collaboration between the information services of the many international institutions located in Nairobi, including efforts to develop a unified list of periodicals held in the libraries of these centres. Finally, ICRAF offered a six-week study attachment in 1989 to a library and information science student from Moi University.



A visiting scientist at ICRAF headquarters consults the computerized library database.

Communications

Communications activities at ICRAF include publication, translation, distribution, audiovisual production and services, and public affairs. Work in these areas is planned and implemented largely in support of the research and training programmes. The overall objective is to communicate to a range of audiences the agroforestry information that emanates from ICRAF's own research programme, from the AFRENA programmes and other research collaborators and from a variety of outside sources.

ICRAF staff contribute regularly to the international literature on agroforestry through journal articles, chapters in scholarly books and papers presented at conferences. In 1989, staff members produced more than 100 articles and chapters in a variety of publications, as listed in a separate section of this report.

The major publications produced directly by ICRAF are the quarterly magazine, *Agroforestry Today*, and the annual report. The magazine was launched in 1989 as an improved and expanded replacement for the former *ICRAF Newsletter*. Produced for a broad audience, it serves both a communications and a promotion function. Articles cover the field of agroforestry as a whole, not just activities at ICRAF, and a substantial proportion of the contents originates from outside sources.

Information for audiences concerned more specifically with ICRAF is published in the annual report. This publication was redesigned in 1988, and the effort to improve its content and appearance is ongoing. As results become available from ICRAF's strategic and collaborative research programmes, the annual report is becoming a forum for substantial reports on agroforestry research in different ecological zones.

Beginning in 1988, ICRAF made an important commitment to producing major publications in French as well as in English. This decision was taken in view of the potential role of agroforestry in much of francophone Africa and the valuable contribution of several francophone countries to the AFRENA programme. In 1989, the Communications Unit published French editions of the quarterly magazine, with the title *L'agroforesterie aujourd'hui*, and a French version of the annual report. In addition, the user's manual on ICRAF's diagnosis and design methodology, published in English in 1987, was translated and published in French. Finally, 20 course notes were translated into French for ICRAF's annual international training course on agroforestry research for development.

ICRAF copublishes *Agroforestry Systems* with Kluwer Academic Publishers in The Netherlands, an international scholarly journal with six issues a year. In addition to major participation in the peer review and editorial policy-making functions, ICRAF provides 120 subscriptions of the journal to libraries in developing countries.

ICRAF also copublishes a quarterly abstracting journal, *Agroforestry Abstracts*, with CABI. Contents of the journal are based in part on ICRAF's library accessions list and ICRAF is also responsible for identifying contributors to overview articles. ICRAF provides 500 free subscriptions to key agricultural libraries in developing countries and to collaborating researchers in subsaharan Africa. An additional 150 subscriptions are provided through funding from the Asian Development Bank (ADB) to agricultural libraries in ADB member countries.

ICRAF publishes monographs as research projects are completed, and also conference proceedings and annotated bibliographies on different aspects of agroforestry. In 1989, eight book-length volumes were published independently and one volume was copublished with Kluwer and another with CABI. There is also a regular output of short brochures and factsheets in English and in French. Seven publications were issued in this category in 1989.

The rapid and inexpensive dissemination of research results is achieved through ICRAF's series of Working Papers and AFRENA Reports. These documents are made available for comment and discussion and to inform interested colleagues about work in progress. Many are eventually revised and published in more permanent form. In 1989, ICRAF published three Working Papers and five AFRENA Reports.

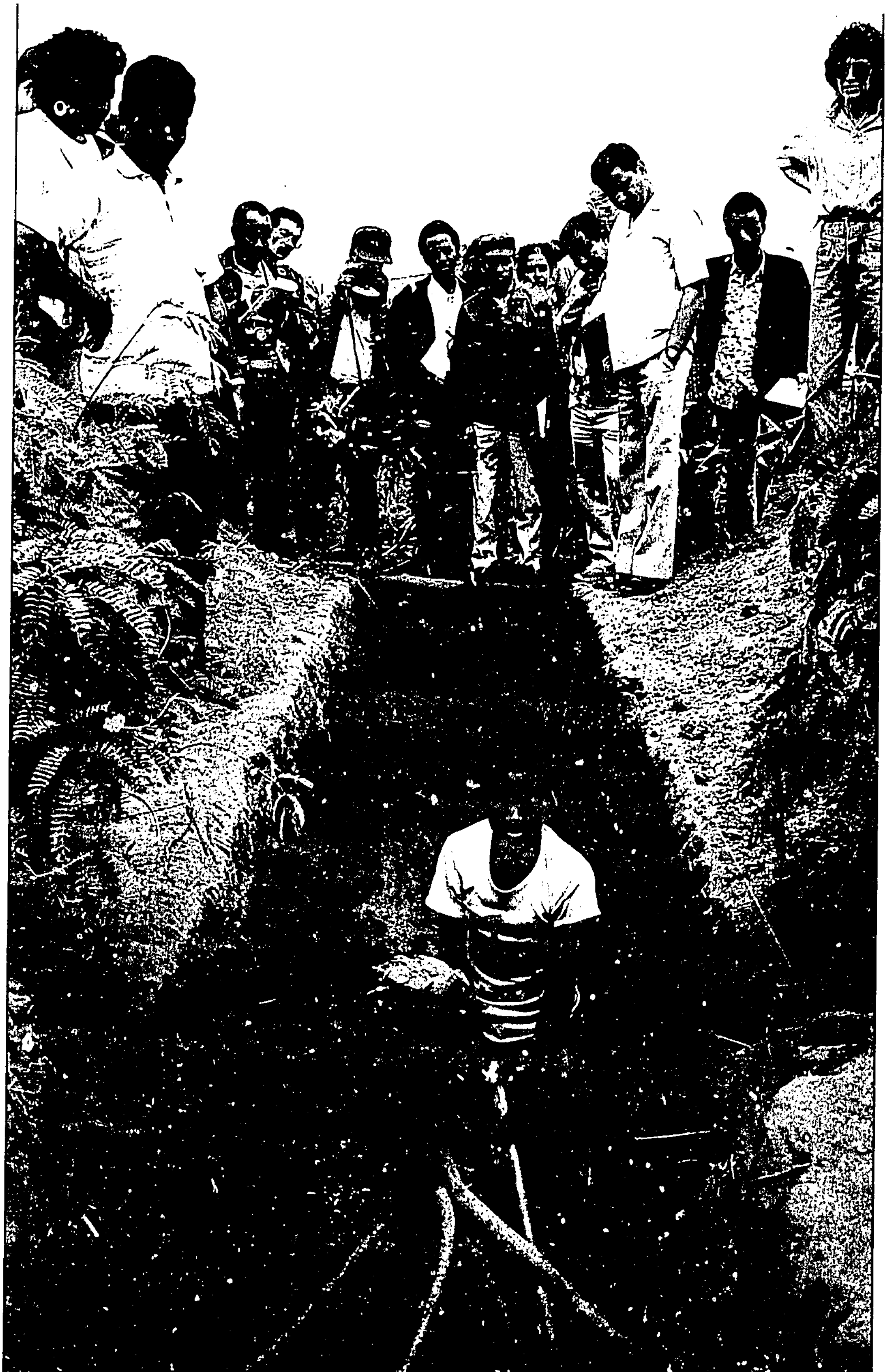
A special audiovisual project funded by SIDA resulted in 1989 in the production of two English-language slide/video presentations for a general audience and one, on the diagnosis and design methodology, for use in conjunction with ICRAF's training courses. The first general presentation, *The promise of agroforestry*, was also produced in French.

ICRAF cooperates with other international agricultural research centres in initiatives to increase public awareness of mutual goals and achievements. Specific ICRAF activities in 1989 included the creation of a media database, with 1131 entries, and a speakers' database, with 88 entries, for the international centres. ICRAF also took a leading role in the development of a strategy and workplan for a global campaign to raise public awareness of the need to support international agricultural research. This activity is sponsored by the CGIAR. In addition, staff members are involved in promotional activities such as interviews with journalists, preparation of press releases and appearances on local radio and television in several countries.

Agroforestry Today is distributed free of charge to nearly 8000 readers around the world. Other publications are distributed to libraries in developing countries free or on exchange and are made available to other readers, usually on a cost-recovery basis.

As resources allow, communications staff provide editing, translating and audiovisual support to other sections of ICRAF and to collaborating institutions. In 1989, support to outside institutions included: training in scientific report writing offered as part of a regional course on experimental data analysis sponsored by the International Maize and Wheat Improvement Centre (CIMMYT); a nine-month training attachment at ICRAF for a graphic art student from the Kenya Polytechnic; and arrangement of a two-month study attachment for a graphic artist sponsored by the United Nations Industrial Development Organization (UNIDO) office in Somalia.

During the year, communications staff provided audiovisual support for nine major conferences, workshops and meetings held at ICRAF; supplied 157 colour slides and black-and-white photographs to collaborating scientists and others wishing to publish or make presentations on agroforestry; and prepared illustrations and layouts and arranged printing and binding for a variety of documents produced by ICRAF staff and associates. In order to provide audiovisual material more efficiently to a growing number of users, a database was created for the ICRAF slide and photograph collections. Out of a total slide collection of more than 6000, 1560 had been entered in the database with full documentation by the end of 1989.



A field worker at ICRAF's Machakos field station demonstrates a root-profile excavation to participants in the May 1989 course on agroforestry research for development.

Conferences and workshops

Conferences and workshops play an important role in the progress of scientific research, bringing together scientists to share ideas and information. The rapid communication afforded by such gatherings is of particular value in agroforestry, due to the wide range of disciplines involved and the speed of research advances. In 1989, ICRAF hosted three international gatherings and published four proceedings volumes.

In February, the International Foundation for Science (IFS) of Sweden joined ICRAF in sponsoring a regional seminar on 'Trees for development in subsaharan Africa'. The seminar was held at ICRAF headquarters in Nairobi. A proceedings volume, including 43 papers, was published by IFS later in the year.

A workshop on 'Perennial *Sesbania* Species in Agroforestry Systems' was held at ICRAF headquarters in March, organized jointly with the Nitrogen Fixing Tree Association (NFTA) and including a two-day field trip to western Kenya. Objectives of the workshop were to assess the present status of research on the botany, natural history, biological nitrogen fixation, genetics and germplasm of perennial *Sesbania* species; to asses the present status of management and utilization of these species in agroforestry systems; and to define priorities, methodologies and responsibilities for collaborative research, development and networking.

Twenty-seven papers were presented in three sessions—on basic biology and germplasm, management and utilization, and regional case study reports. Working groups on biology and germplasm, management for sustainable agriculture, and products and utilization discussed present knowledge and research priorities and responsibilities and made recommendations for development and extension. These recommendations have been published by NFTA in an executive summary. A panel of authors was also assembled during the workshop to draft a practical manual on 'Sesbania production and use'. NFTA is publishing a full proceedings volume.

In November, ICRAF and the International Board for Soil Research and Management (IBSRAM) sponsored a training workshop on Research in Soil Management and Agroforestry, held at ICRAF headquarters. The objectives were to help members of IBSRAM research networks include agroforestry treatments in their experiments, to help ICRAF scientists with soil-management aspects of their research and to consider production of a set of guidelines on soils research in agroforestry.

A total of 47 scientists from 22 countries attended the workshop. The programme consisted of invited papers, a visit to ICRAF's Machakos field station, working group discussions and an open session. Invited papers covered nutrient cycling, erosion control, soil variability, roots and mycorrhiza, soil biology, hypotheses for soil-agroforestry research, and experimental design. There were also reports on research in Costa Rica, Peru, Sri Lanka and various network sites in Africa and Asia. Workshop participants stressed the importance of continuing collaboration between IBSRAM and ICRAF and recommended the publication of a simple descriptive guide to agroforestry technologies plus a set of guidelines on soils research in agroforestry. ICRAF will publish a summary report on the workshop.

Both an executive summary and a proceedings volume from the Second Kenya National Seminar on Agroforestry, held at ICRAF in November 1988, were published in 1989. The full proceedings, *Agroforestry development in Kenya* (A.M. Kilewe, K.M. Kealey and K.K. Kebaara, editors), includes 46 papers, plus plenary addresses and recommendations. This book serves as a reference source on the current status of agroforestry in Kenya, including research, extension, the institutional framework, socioeconomic aspects and training.

A third proceedings volume published in 1989 was *Meteorology and agroforestry* (W.E. Reifsnyder and T.O. Darnhofer, editors), including 50 papers presented at an international workshop held at ICRAF in 1987 and cosponsored with the World Meteorological Organization (WMO) and UNEP. The volume begins with papers on the relationship between the environment and agroforestry and then presents information basic to the understanding of how meteorology and climatology can be used in agroforestry systems.

Specific examples follow of how meteorology and climatology factors have been integrated into agroforestry practice in many countries of the world. Next comes a technical discussion on how the environment can be measured, how experiments can be designed and how they can be analysed to elicit useful information. Finally, the volume concludes with reports on the results of several agroforestry experiments. This work represents the first major contribution to the literature on the agroclimatology of agroforestry and will serve as an important source of information and a starting point for future research.

A fourth set of proceedings published in 1989, *Multipurpose trees: selection and testing for agroforestry* (P.A. Huxley and S.B. Westley, editors), contains nine papers presented at a technical seminar held during ICRAF's tenth anniversary celebrations in November 1987. These papers describe ICRAF's approach to various stages of research on multipurpose trees, with examples from work at ICRAF and in collaborative programmes. They cover the steps required to select and test of woody species for particular biophysical settings, agroforestry technologies and land-use systems. The authors, all staff members or former staff members of ICRAF, are specialists in forestry, agronomy, plant science, agricultural economics and ecological anthropology.

An Indonesian scientist examines the roots of a leucaena hedgerow at ICRAF's Machakos field station during the IBSRAM/ICRAF training workshop.

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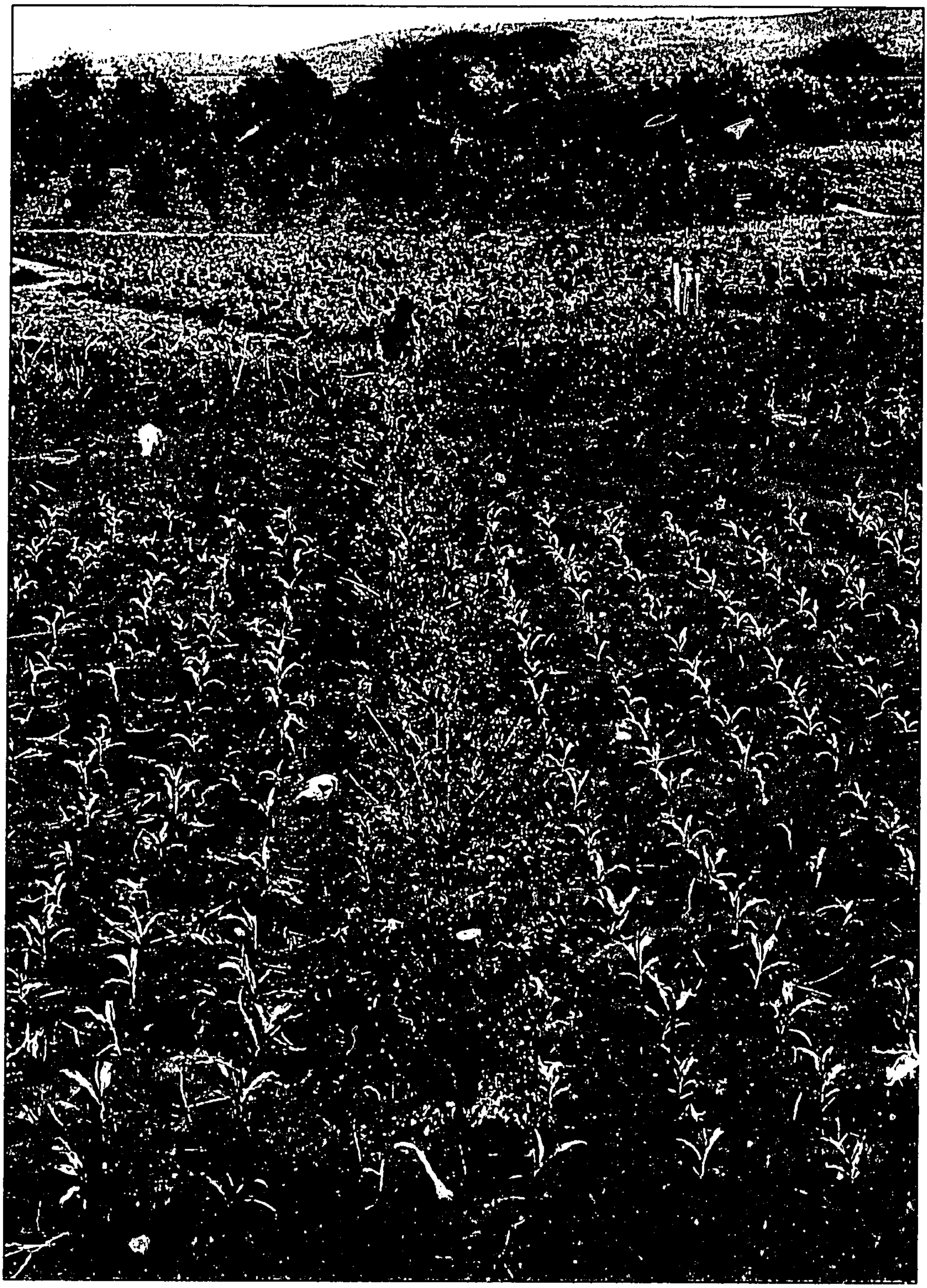

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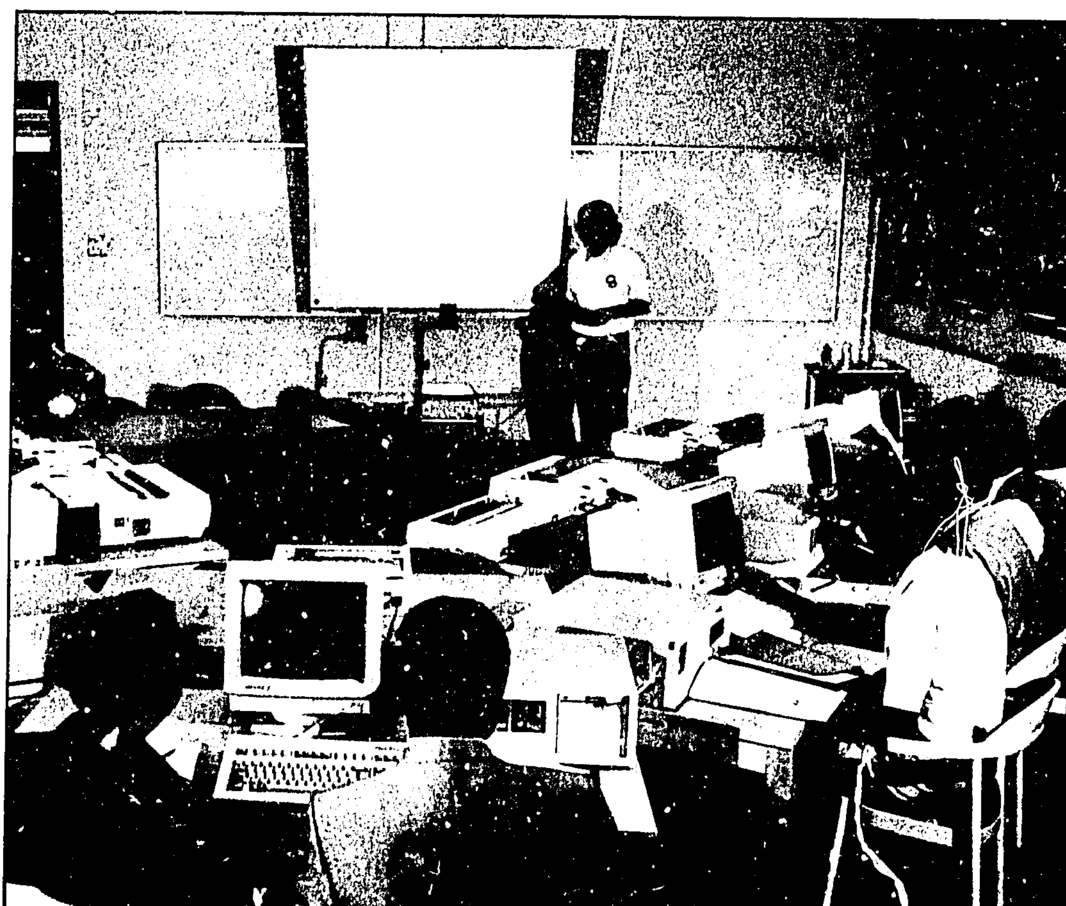
Staff list

Name	Position/Discipline (Nationality)	Date Joined (Date Left)	Duty Station
Office of the Director-General			
Dr B. Lundgren	Director-General (Sweden)	01.09.1981	Nairobi
Mr S. Kanani	Technical Coordinator (Kenya)	13.06.1983	Nairobi
Mr K. Thuo	Protocol Officer (Kenya)	16.09.1985 (30.9.1989)	Nairobi
Mrs F. Mboya	Principal Secretary (Kenya)	22.09.1978	Nairobi
Mrs J. Kasyoki	Secretary (Kenya)	13.02.1989	Nairobi
Finance and Administration			
Mr D.M. Sickelmore	Director, Finance and Administration (UK)	01.01.1986	Nairobi
Mr A. Aghaulor	Head of Finance (Nigeria)	01.08.1989	Nairobi
Mrs V.H. Guerrero	Head/Human Resources Unit (Venezuela)	01.04.1989	Nairobi
Mr G. Maina	Management Accountant (Kenya)	01.10.1989	Nairobi
Mrs N. Sood	Associate Travel and Conference Officer (Kenya)	01.11.1989	Nairobi
Mr P. Waiguru	Computer Specialist I (Kenya)	03.07.1984 (06.8.1989)	Nairobi
Mr J. Akhatika	Cleaner (Kenya)	01.11.1985	Nairobi
Mrs F. Chege	Tea Lady/Cleaner (IUFRO) (Kenya)	01.07.1987	Nairobi
Mrs M.M. de Souza	Personnel Assistant (Kenya)	01.10.1987	Nairobi
Mr L. Gakombe	Cleaner (Kenya)	15.07.1987	Nairobi
Mr E. Gatoru	Assistant Accountant/Projects (Kenya)	01.09.1988	Nairobi
Mr J. Gitau	Mail/Filing Clerk (Kenya)	01.03.1984	Nairobi
Mr B.B. Hware	Photocopy Operator (Kenya)	15.07.1987	Nairobi
Mr T. Ivati	Mechanic (Kenya)	18.07.1981	Nairobi
Mr J. Kagiri	Photocopy Operator (Kenya)	01.10.1985	Nairobi
Mrs D. Kamaan	Receptionist/Telex Operator (Kenya)	29.08.1987	Nairobi
Mr T. Kamundi	Computer Operator (Kenya)	01.08.1988	Nairobi
Mr P. Kang'ethe	Driver (Kenya)	10.06.1987	Nairobi
Mr P. Kanyasya	Assistant Accountant/General Ledgers (Kenya)	15.09.1989	Nairobi
Ms C. Kanyeki	Building Superintendent (Kenya)	17.01.1980	Nairobi
Mr J. Kariuki	Driver (Kenya)	15.07.1987	Nairobi
Mrs B. Kedeng'e	Principal Secretary (Kenya)	17.03.1986	Nairobi
Mr K. King'aru	Transport Superintendent (Kenya)	01.09.1987	Nairobi
Mr M. Kuria	Accounts Clerk/Disbursements (Kenya)	19.09.1983	Nairobi
Mr H. Luvinzu	Cleaner (Kenya)	01.08.1988	Nairobi
Mr A. Makindu	Cashier (Kenya)	01.01.1988	Nairobi
Mr J. Mbugua	Messenger (Kenya)	01.11.1985	Nairobi
Mr D. Michino	Accounts Clerk/Receivables (Kenya)	01.08.1988	Nairobi
Miss I. Moraa	Filing Clerk (Kenya)	01.07.1987	Nairobi
Mr J.M. Muli	Carpenter (Kenya)	01.10.1987	Nairobi
Mr D.M. Musili	Cleaner (Kenya)	05.10.1987	Nairobi

Name	Position/Discipline (Nationality)	Date Joined (Date Left)	Duty Station
Miss M. Mutua	Computer Operator (Kenya)	01.07.1986	Nairobi
Mrs T.K. Ng'ang'a	Secretary (Kenya)	18.08.1986	Nairobi
Miss F. Ngari	Tea Lady/Cleaner (Kenya)	21.06.1983	Nairobi
Mrs G. Ngugi	Receptionist/Telex Operator (Kenya)	29.08.1988	Nairobi
Mr C.D. Nyaga	Messenger (Kenya)	01.12.1987	Nairobi
Mr B. Nyachienga	Driver (Kenya)	01.05.1988	Nairobi
Mrs C. Ochieng'	Assistant Accountant (Kenya)	19.03.1986 (20.7.1989)	Nairobi
Mr A.N. Okello	Electrician (Kenya)	01.11.1987	Nairobi
Mrs M. Oluoch	Accounts Assistant/Payroll (Kenya)	19.09.1983	Nairobi
Mr J.O. Opande	Driver (Kenya)	01.10.1987	Nairobi
Mrs L. Wambua	Procurement Clerk (Kenya)	28.04.1983	Nairobi
Ms L. Wanjau	Receptionist (Kenya)	05.06.1987	Nairobi
Mr H. Wanjohi	Cleaner (Kenya)	01.11.1988	Nariobi
Mr F. Wanyoike	Messenger (Kenya)	01.2.1985	Nairobi
Research Development Division			
Dr P. Huxley	Divisional Director/Horticulture (UK)	04.01.1979	Nairobi
Mr E. Akunda	Research Officer/Crop Physiology (Kenya)	01.01.1986	Nairobi
Mr Bashir Jama	Research Assistant I (Kenya)	01.09.1986	Nairobi
Dr M. Baumer	Senior Scientist/Range Management (France)	01.09.1983	Nairobi
Mr G. Böklin	Research Associate/Agronomy (SIDA) (Sweden)	03.11.1987 (01.11.1989)	Nairobi
Mr P. von Carlowitz	Senior Research Scientist/Forestry (GTZ) (FRG)	26.06.1982	Nairobi
Dr T. Damhofer	Senior Scientist/Agrometeorology (Austria)	15.07.1982	Nairobi
Mr E. Franz	Visiting Scientist/Ecology (USA)	02.08.1989	Nairobi
Mr D. Gatama	Research Assistant (Kenya)	08.07.1985	Nairobi
Mr P. Kiepe	Research Associate/Soil Science (Netherlands)	08.12.1987	Nairobi
Mr M. Lundberg	Research Associate/Anthropology (SIDA) (Sweden)	10.08.19879 (01.9.1989)	Nairobi
Mr P. Muraya	Research Officer/Computer Applications (Kenya)	01.05.1985	Nairobi
Mr P. Oduol	Associate Research Officer/Forestry (Kenya)	01.10.1985	Nairobi
Dr F. Owino	Senior Scientist/Tree Breeding (Kenya)	10.08.1987	Nairobi
Mr B. Owuor	Associate Research Officer/Tree Breeding (Kenya)	01.01.1989	Maseno
Mr A. Pinney	Graduate Fellow (UK)	09.05.1987	Nairobi
Dr J. Raintree	Principal Scientist/ Social Science (USA)	18.12.1980	Nairobi

Name	Position/Discipline (Nationality)	Date Joined (Date Left)	Duty Station
Dr M.R. Rao	Senior Scientist/Experimental Agronomy (India)	01.05.1988	Nairobi
Dr J.H. Roger	Senior Scientist/Biometrics and Statistics (UK)	01.04.1988	Nairobi
Dr S. Scherr	Senior Scientist/Socioeconomics (USA)	01.12.1985	Nairobi
Dr K. Shepherd	Scientist/On-farm Agronomy Rockefeller (UK)	14.12.1989	Nairobi
Mr R. Swinkels	Research Associate/Economics (Netherlands)	12.05.1989	S. Nyanza
Mr D. Wambugu	Associate Research Officer/ Agronomy (Kenya)	01.12.1982	Nairobi
Mr G.V. Wolf	Scientist/Forestry (GTZ) (FRG)	04.11.1986	Nairobi
Dr A. Young	Principal Scientist/Soil Science (UK)	04.01.1983	Nairobi
Mrs K. Gilani	Senior Secretary/GTZ (Kenya)	15.06.1984	Nairobi
Miss H. Gitere	Tea Lady/Cleaner (Kenya)	08.08.1987	Nairobi
Mrs B. Kibe	Principal Secretary (Kenya)	01.06.1981	Nairobi
Mrs T. Lohay	Administrative Assistant (Kenya)	01.06.1985	Nairobi
Mr A. Mageto	Messenger (Kenya)	15.07.1987	Nairobi
Miss S. Muasya	Secretary (Kenya)	26.04.1983	Nairobi
Mrs F. Musau	Senior Secretary (Kenya)	01.09.1987 (31.10.1989)	Nairobi
Mrs J. Muriuki	Secretary (Kenya)	01.01.1989	Nairobi
Miss M. Mwangi	Secretary (Kenya)	01.10.1986	Nairobi
Mrs J.W. Njagi	Secretary (Kenya)	01.01.1989	Nairobi
Mr J. Obande	Field Attendant (Kenya)	01.02.1989	Maseno
Miss M. Ondeng'	Secretary (Kenya)	23.03.1987 (08.01.1989)	Nairobi
Miss R.N. Thuo	Secretary (Kenya)	24.08.1987	Nairobi
Mrs J. Waweru	Secretary (Kenya)	01.03.1980	Nairobi
Mr P. Waweru	Senior Driver (Kenya)	01.01.1979	Nairobi
Field Station—Machakos			
Mr P.M. Kurira	Assistant Research Officer/Farm Manager (Kenya)	01.08.1981	Machakos
Mr M. Mathuva	Associate Research Officer/ Agronomy (Kenya)	01.06.1989	Machakos
Mr P. Ambani	Senior Field Assistant (Kenya)	01.09.1988	Machakos
Mr K. Chondo	Labourer (Kenya)	01.01.1988	Machakos
Mr B. Kamba	Labourer (Kenya)	08.09.1981	Machakos
Mr G. Kiilu	Labourer (Kenya)	15.03.1982	Machakos
Mr G. Kilonzo	Gardener (Kenya)	01.09.1988	Machakos
Mr M. Kioko	Labourer (Kenya)	01.01.1988	Machakos
Mr J. Kyengo	Field Attendant (Kenya)	01.05.1989	Kathama
Mr W. Kyule	Labourer (Kenya)	08.09.1981	Machakos
Mr E. Letaulo	Labourer (Kenya)	01.01.1988	Machakos
Mr J. Malonzah	Labourer (Kenya)	01.07.1988	Machakos

Name	Position/Discipline (Nationality)	Date Joined (Date Left)	Duty Station
Mr P. Mbiti	Field Assistant (Kenya)	08.09.1986	Machakos
Mr Z. Musembi	Labourer (Kenya)	01.07.1988	Machakos
Mr M. Muthoka	Labourer (Kenya)	01.01.1988	Machakos
Mr E. Mutinda	Labourer (Kenya)	08.01.1988	Machakos
Mr P. Mutua	Labourer (Kenya)	20.01.1988	Machakos
Mr L. Mutunga	Labourer (Kenya)	22.01.1988	Machakos
Mr G. Mwasambu	Field Assistant (Kenya)	01.12.1982	Machakos
Mr M. Ndambuki	Labourer (Kenya)	01.01.1988	Machakos
Mr P. Nzioka	Labourer (Kenya)	01.01.1988	Machakos
Mr T.O. Ondieki	Labourer (Kenya)	17.01.1988	Machakos
Collaborative Programmes Division			
Mr R.B. Scott	Divisional Director/International Development (Canada)	01.01.1988	Nairobi
Dr E. Akyeampong	Scientist/Agronomy (Ghana)	01.01.1987	Burundi



ICRAF statistician conducts training session on statistical analysis for scientists working in collaborative field programmes.

Name	Position/Discipline (Nationality)	Date Joined (Date Left)	Duty Station
Dr Amare Getahun	Principal Scientist/Agroforestry (Ethiopia)	01.09.1988	Nairobi
Dr E.O. Asare	Senior Visiting Fellow/Agronomy (SIDA) (Ghana)	19.02.1989	Nairobi
Dr M. Avila	Senior Scientist/Economics (Belize)	13.07.1987	Nairobi
Dr Bahiru Duguma	Scientist/Forestry (Ethiopia)	01.02.1987	Cameroon
Mr J. Beniest	Scientist/Horticulture (Belgium)	16.01.1989	Nairobi
Ms E. von Capeller	Research Associate/Agronomy (Switzerland)	06.11.1989	Cameroon
Dr M. Djimde	Scientist/Animal Science (Mali)	01.05.1985	Nairobi
Mr A. Heineman	Research Associate/Forestry (Netherlands)	07.11.1987	Maseno
Mr D. Hoekstra	Regional Coordinator/Agricultural Economics (Netherlands)	01.03.1982	Nairobi
Dr C. Kamara	Scientist/Soil Science (Sierra Leone)	01.09.1988	Zambia
Miss I. Kamau	Research Officer/Biology (Kenya)	01.09.1984	Nairobi
Dr M. Karachi	Scientist/Agronomy (Kenya)	01.08.1988	Tanzania
Dr F. Kwesiga	Scientist/Forestry (Uganda)	01.04.1985	Zambia
Dr J. Maghembe	Senior Scientist/Forestry (Tanzania)	01.06.1987	Malawi
Dr S. Minae	Scientist/Socioeconomics (Kenya)	01.08.1985	Nairobi
Dr D. Ngugi	Regional Coordinator/Agronomy (Kenya)	01.11.1985	Malawi
Dr A. Niang	Scientist/Forester (Senegal)	15.01.1989	Uganda
Mrs G. Patel	Associate Administrative Officer (Kenya)	26.01.1988	Nairobi
Dr D. Peden	Senior Scientist/Range Management (Canada)	21.04.1989	Uganda
Mr J. Pegorie	Research Associate/Forestry (CTFT) (France)	14.12.1988	Nairobi
Mr H. Prins	Research Associate/Forestry (Netherlands)	01.03.1988	Malawi
Mr H. Thijssen	Associate Expert/Agriculture (Netherlands)	22.07.1988	Nairobi
Dr E. Torquebiau	Scientist/Forest Ecology (France)	09.10.1987	Nairobi
Mr J. Wahome	Research Officer/Animal Science (Kenya)	01.08.1984	Nairobi
Dr E. Zulberti	Coordinator/Training and Education (Argentina)	26.04.1982	Nairobi
Mrs A. Aduol	Secretary (Kenya)	01.09.1986	Nairobi
Miss S. Hirani	Bilingual Secretary (Kenya)	14.07.1985 (31.05.1989)	Nairobi
Mrs J. Kimotho	Secretary (Kenya)	18.09.1986	Nairobi
Mr A. Kirima	Messenger (Kenya)	01.07.1987	Nairobi
Miss T. Knudsen	Principal Secretary (Kenya)	19.02.1983	Nairobi
Mrs J.B. Muga	Secretary (Kenya)	01.01.1988	Nairobi
Miss E. Muhenge	Secretary (Kenya)	01.09.1986	Nairobi
Mrs L. Munge	Cleaner/Tea Lady (Kenya)	01.06.1988	Nairobi

Name	Position/Discipline (Nationality)	Date Joined (Date Left)	Duty Station
Ms C. Muniafu	Bilingual Secretary (Kenya)	01.03.1988	Nairobi
Miss L. Mwandawiro	Bilingual Secretary (Kenya)	01.02.1988	Nairobi
Miss R. Mwangi	Bilingual Secretary (Kenya)	03.08.1989	Nairobi
Mrs E. Mwavua	Senior Secretary (Kenya)	01.09.1987 (31.08.1989)	Nairobi
Mrs S. Okoth	Secretary (Kenya)	01.08.1987	Nairobi
Information and Communications Division			
Mr R.D. Huggan	Divisional Director/Communications (Canada)	01.08.1987	Nairobi
Mr B. Bondole	Associate Information Officer (Zaire)	07.03.1988	Nairobi
Mr G. de Chatelperron	Associate Information Officer (France)	01.07.1988	Nairobi
Ms K. Kealey	Editorial Consultant (Canada)	01.04.1988 (31.03.1989)	Nairobi
Ms K. Kebaara	Assistant Editorial Officer (Kenya)	03.12.1984	Nairobi
Mr R. Labelle	Head/Information and Documentation Unit (Canada)	01.07.1981	Nairobi
Ms A. Leymarie	French Translator/Revisor (France)	01.09.1988	Nairobi
Mrs M. Mbindyo	Associate Administrative Officer (Kenya)	19.09.1988	Nairobi
Mr S. Mburu	Associate Information Officer/ Computer Programmer (Kenya)	01.01.1989	Nairobi
Mrs H. Munyua	Associate Information Officer (Kenya)	01.05.1986	Nairobi
Mr A. Njenga	Assistant Audiovisual Officer (Kenya)	01.02.1988	Nairobi
Ms D.A. Odanga	Assistant Graphic Arts Officer (Kenya)	05.10.1988	Nairobi
Ms Chang Soh Kiak	Senior Visiting Fellow/Audiovisual Producer SIDA (Singapore)	01.02.1989	Nairobi
Ms L. Teemba	Associate Information Officer (Kenya)	01.03.1979	Nairobi
Ms S. Westley	Head/Communications Unit (USA)	01.08.1988	Nairobi
Mrs H. Abdalla	Senior Secretary (Kenya)	01.07.1988	Nairobi
Mrs L. Chege	Secretary (Kenya)	01.01.1985	Nairobi
Mrs E.K. Gimode	Principal Bilingual Secretary (Kenya)	09.11.1987	Nairobi
Ms M. Kanyugo	Production Secretary/English (Kenya)	18.10.1989	Nairobi
Mrs M. Kimenye	Secretary (Kenya)	01.08.1986	Nairobi
Mr S. Maina	Messenger (Kenya)	01.11.1985	Nairobi
Mr A. Mureithi	Library Assistant (Kenya)	01.01.1989	Nairobi
Ms M. Mwangi	Bilingual Secretary (Kenya)	01.11.1988	Nairobi
Mr S. C[illegible]mo	Library Coordinator (Kenya)	25.01.1982	Nairobi
Ms L. Ular	Bilingual Secretary (Kenya)	12.10.1987	Nairobi
Mrs P. Wandhala	Tea Lady/Cleaner (Kenya)	16.11.1985	Nairobi

Financial statements for 1989

CORE FUND—REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31 DECEMBER 1989

	1989 (US$'000)	1988 (US$'000)
Revenue		
Grants	2960	2477
Recharges	1624	929
Sundry income	181	176
	4765	3582
Expenditure		
Personnel costs	3010	2596
Supplies and services	1094	969
Travel	187	202
Purchase of fixed assets	259	368
	4550	4135
Surplus (deficit) of revenue over expenditure for the year before extraordinary item	215	(553)
Extraordinary item	(431)	—
Deficit of revenue over expenditure for the year	(216)	(553)
Statement of accumulated core funds		
Balance as at 1 January	(1119)	(566)
Adjustment due to policy changes	669	669
Balance as at 1 January as restated	(450)	103
Deficit for the year	(216)	(553)
Balance as at 31 December	(666)	(450)

Note: The complete 1989 audited financial statements will be supplied upon request.

BALANCE SHEET AT 31 DECEMBER 1989

	1989 (US$'000)	1988 (US$'000)
Fixed assets	3782	3649
Current assets		
Stocks	42	—
Donor debtors	443	540
Other debtors	639	681
Bank balances and cash	407	174
Total	1531	1395
Current liabilities		
Restricted project funds	1266	1493
Donations received in advance	—	150
Creditors	751	413
	2017	2056
Net current liabilities	(486)	(661)
Net assets	3296	2988
Funded by:		
Capital funds	3782	3649
Core funds	(666)	(450)
Headquarters funds	—	(431)
Long-term loan	180	220
Total	3296	2988

STATEMENT OF CHANGES IN FINANCIAL POSITION FOR THE YEAR ENDED 31 DECEMBER 1989

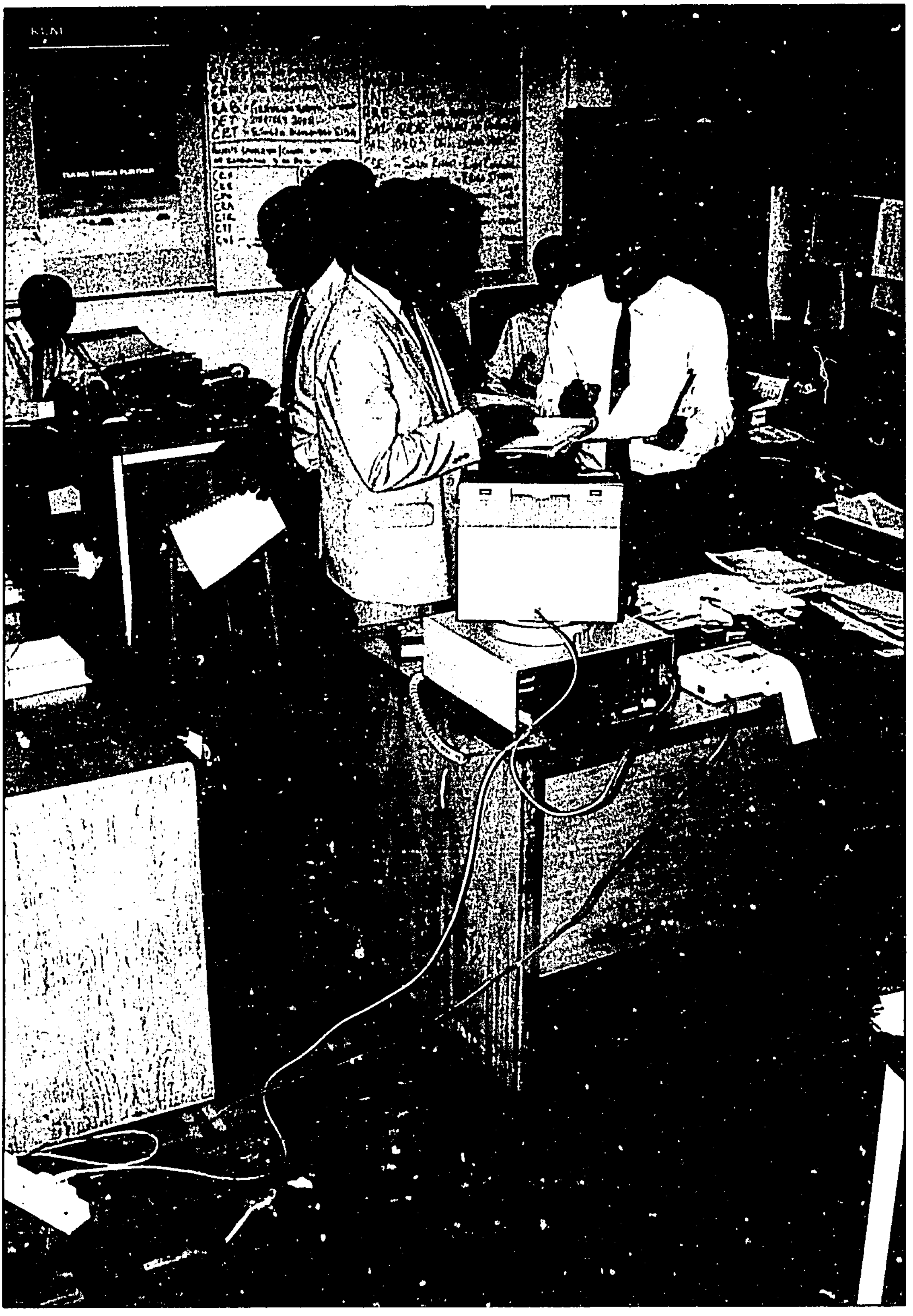
	1989 (US$'000)	1988 (US$'000)
Source of funds		
Deficit of revenue over expenditure	(216)	(553)
Adjustment for items not involving movement of funds:		
Write-off of headquarters fund deficit	431	—
Funds generated from operations	215	(553)
Funds from other sources		
Increase in capital funds	133	606
Increase in restricted project fund	—	492
Increase in donations received in advance	—	150
Decrease in debtors and prepaid expenses	139	—
Increase in creditors	338	—
	825	695
Application of funds		
Increase in fixed assets	133	606
Decrease in long-term loan	40	38
Increase in stocks	42	—
Increase in debtors and prepaid expenses	—	351
Decrease in restricted project fund	227	—
Decrease in donations received in advance	150	—
Decrease in creditors and accrued charges	—	58
	(592)	(1053)
	233	(358)
Changes in net liquid funds		
Increase/(decrease) in cash and bank balances	233	(393)
Decrease in overdraft	—	35
	233	(358)

CORE DONORS FOR 1988 AND 1989

	1989 (US$'000)	1988 (US$'000)
Canada (CIDA)	753	727
World Bank (IBRD)	460	460
Netherlands	357	369
Norway	295	272
Switzerland	251	286
Finland (FINNIDA)	235	—
African Development Bank	200	—
Sweden (SAREC)	198	213
Ford Foundation	150	150
France	61	—
Total	2960	2477

RESTRICTED PROJECT GRANTS FOR 1988 AND 1989

	1989 (US$'000)	1988 (US$'000)
Canada (CIDA)	854	328
United States of America (USAID)	572	1014
Sweden (SIDA)	529	635
International Fund for Agricultural Development (IFAD)	507	—
Rockefeller Foundation	365	—
Ford Foundation	325	—
Swedish Agency for Research Cooperation with Developing Countries (SAREC)	255	298
German Ministry for Economic Cooperation and German Agency for Technical Cooperation (BMZ/GTZ)	238	342
Direct Support to Training Institutes in Developing Countries (DSO)—Government of The Netherlands	220	213
International Development Research Centre (IDRC)	111	65
Australia (AIDAB)	107	—
Switzerland	68	3
France	54	56
The Netherlands	21	—
Nitrogen Fixing Tree Association (NFTA)	16	—
International Foundation for Science (IFS)	15	—
Norwegian Agency for International Development (NORAD)	8	—
Near East Foundation	—	100
Finland (FINNIDA)	—	13
USA/Sweden/Switzerland/Netherlands (Second Kenya National Agroforestry Seminar)	—	77
Total	4265	3144



A view of ICRAF's busy Finance and Administration Division.

ANALYSIS OF RESTRICTED PROJECT FUNDS AT 31 DECEMBER 1989

	Balance at 1.1.1989	Income Received 1989	Income Accrued 1989	Total Available 1989	Personnel Cost	Supplies and Services	Travel	Fixed Assets	Total Expenditure	Balance
Ford Foundation										
Graduate Training	—	61 000	—	61 000	34 500	—	3 640	—	38 140	22 860
India—Bangladesh	—	164 530	—	164 530	3 500	19	734	—	4 253	160 277
Information Management in Agroforestry	69 451	—	—	69 451	29 800	26 686	12 965	—	69 451	0
India—Delhi	22 541	—	—	22 541	7 466	12 081	226	2 768	22 541	0
Rural Development—Sudan	10 063	—	—	10 063	—	10 063	—	—	10 063	0
Research Trainee	—	50 000	—	50 000	12 710	95	2 066	4 020	18 891	31 109
On-Farm Research Workshop	—	24 000	—	24 000	4 800	589	—	—	5 389	18 611
CIDA										
Agroforestry Network in Southern Africa	7 492	—	—	7 492	—	7 492	—	—	7 492	0
Southern Africa AFRENA	91 699	812 572	—	904 271	403 039	240 221	145 419	64 455	853 134	51 137
French Language Development	—	16 515	—	16 515	—	16 515	—	—	16515	0
GTZ										
Tree/Crop Interface	36 043	—	—	36 043	32 133	3 910	—	—	36 043	0
Animals and Agroforestry	94 131	—	—	94 131	83 131	11 000	—	—	94 131	0
MPT Germplasm	97 708	234 027	—	331 735	103 931	66 038	23 452	28 288	221 709	110 026
WMO Workshop	—	—	13 866	13 866	13 252	614	—	—	13 866	0
SIDA										
Agroforestry and Soil Conservation	6 887	—	—	6 887	—	6 887	—	—	6 887	0
Field Station	50 866	236 145	—	287 011	172 160	47 111	2 800	17 673	239 744	47 267
Second Kenya National Seminar on Agroforestry	14 871	—	—	14 871	—	14 871	—	—	14 871	0
Agroforestry and Shifting Cultivation	89 979	—	—	89 979	26 689	47 481	15 809	—	89 979	0
Fellowship—Audiovisual	47 619	47 500	—	95 119	55 509	18 832	1 415	—	75 756	19 363
Fellowship—Curriculum Development	47 619	47 500	—	95 119	55 139	20 522	2 873	—	78 534	16 585
Agroforestry for Development in Kenya	114 811	199 534	—	314 345	127 702	48 628	1 330	—	177 660	136 685
SAREC										
ICRAF/Zambia Agroforestry Research	194 444	183 171	—	377 615	108 263	54 350	20 830	23 405	206 848	170 767
Macro D&D—Ethiopian Highlands	—	47 133	—	47 133	28 300	4 604	14 229	—	47 133	0
USAID										
Eastern and Central Africa AFRENA	341 023	443 560	130 160	914 743	455 402	308 666	78 284	72 391	914 743	0
ICRAF/OSU/IITA MPT Evaluation	80 000	—	—	80 000	699	59	4 725	—	5 483	74 517

ANALYSIS OF RESTRICTED PROJECT FUNDS AT 31 DECEMBER 1989, CONTINUED

	Balance at 1.1.1989	Income Received 1989	Income Accrued 1989	Total Available 1989	Personnel Cost	Supplies and Services	Travel	Fixed Assets	Total Expenditure	Balance
IDRC										
IRA/ICRAF—Cameroon	36 407	36 312	21 162	93 881	30 535	32 089	22 372	8 885	93 881	0
Humid Lowlands—Ghana	—	40 637	6 751	47 388	21 434	2 176	23 778	—	47 388	0
Technician Training Course	—	—	42 735	42 735	10 403	19 001	12 434	897	42 735	0
AIDAB										
Methods for On-Farm AF Research	—	64 552	—	64 552	23 108	13 545	9 858	18 041	64 552	0
Monitoring & Evaluation Review	—	30 719	—	30 719	24 945	5 774	—	—	30 719	0
Grevillea Robusta	—	11 213	—	11 213	—	2 935	8 278	—	11 213	0
Rockefeller Foundation										
On-Farm Research	—	350 000	—	350 000	51 693	55	503	—	52 251	297 749
IFAD										
Semi-Arid Lowlands	507 150	—	—	507 150	222 442	30 566	137 196	9 974	430 178	76 972
Switzerland										
Associate Expe[illegible]—Cameroon	—	39 990	—	39 990	6 645	5	1 065	—	7 715	32 275
Short- and Medium-Term Plan—Rwanda	—	9 568	6 011	15 579	11 300	—	4 279	—	15 [illegible]	0
NORAD										
Agroforestry in Arid Areas	—	—	7 617	7 617	1 101	—	—	6 516	7 617	0
The Netherlands—DSO										
ICRAF/DSO Training Course 1989	—	198 800	16 460	215 260	83 422	52 348	79 490	—	215 260	0
ICRAF/DSO Training Course 1990	—	—	4 765	4 765	4 765	—	—	—	4765	0
OTHERS										
External Programme and Management Review	—	114 178	25 000	139 178	68 960	9 378	60 840	—	139 178	0
IFS/ICRAF Workshop	—	15 394	—	15 394	8 552	6 842	—	—	15 394	0
ICRAF/NFTA Workshop	—	16 431	—	16 431	14 730	—	1 701	—	16 431	0
Consultant—France	31 278	—	38 485	69 763	55 852	9 902	4 009	—	69 763	0
ICRAF/IBSRAM Workshop	—	18 928	—	18 928	—	6 148	12 780	—	18 928	0
Ethiopia National Seminar	8 210	—	—	8 210	1 250	6 960	—	—	8 210	0
TOTAL	1 493 142	4 021 059	313 012	5 827 213	2 399 262	1 165 058	739 380	257 313	4 561 013	1 266 200

List of acronyms

ACIAR Australian Centre for International Agricultural Research (Canberra, Australia)
ADB: Asian Development Bank (Manila, The Philippines)
AFNETA: Alley Farming Network for Tropical Africa (Ibadan, Nigeria)
AFRENA: Agroforestry Research Networks for Africa (coordinated from ICRAF)
AGRICOLA: Database of the National Agricultural Library (USA)
AGRIS: International Information System for the Agricultural Sciences and Technology (Rome, Italy)
AIDAB: Australian International Development Assistance Bureau (Canberra, Australia)
BARC: Bangladesh Agricultural Research Council (Dacca, Bangladesh)
BMZ: Bundesministerium für wirtschaftliche Zusammenarbeit/German Ministry for Economic Cooperation (Bonn, FRG)
CABI: CAB International (Wallingford, U.K.)
CGIAR: Consultative Group on International Agricultural Research (Washington, D.C., USA)
CIDA: Canadian International Development Agency (Hull, Quebec, Canada)
CIMMYT: International Maize and Wheat Improvement Centre (Mexico, D.F., Mexico)
CIRAD: Centre de coopération internationale en recherche agronomique pour le devéloppement
CSIRO: Commonwealth Scientific and Industrial Research Organization (Canberra, Australia)
CTA: Technical Centre for Agricultural and Rural Cooperation (Brussels, Belgium)
CTFT: Centre technique forestier tropical (Nogent-sur-Marne, France)
D&D: Diagnosis and design
DSO: Direct Support to Training Institutes in Developing Countries (The Hague, The Netherlands)
FAO: Food and Agriculture Organization of the United Nations (Rome, Italy)
F/FRED: Forestry/Fuelwood Research and Development, Winrock International (Washington, D.C., USA)
FINNIDA: Finnish International Development Agency (Helsinki, Finland)
FRG: Federal Republic of Germany
GTZ: Gesellschaft für technische Zusammenarbeit/German Agency for Technical Cooperation (Eschborn, FRG)
IAR: Institute of Agricultural Research (Addis Ababa, Ethiopia)
IBPGR: International Board for Plant Genetic Resources (Rome, Italy)
IBRD: International Bank for Reconstruction and Development (World Bank) (Washington, D.C., USA)
IBSRAM: International Board for Soil Research and Management (Bangkhen, Bangkok, Thailand)
ICAR: Indian Council of Agricultural Research (New Delhi, India)
ICIPE: International Centre of Insect Physiology and Ecology (Nairobi, Kenya)
ICRAF: International Council for Research in Agroforestry (Nairobi, Kenya)
ICRISAT: International Crops Research Institute for the Semi-arid Tropics (Hyderabad, India)
IDRC: International Development Research Centre (Ottawa, Canada)
IFAD: International Fund for Agricultural Development (Rome, Italy)
IITA: International Institute of Tropical Agriculture (Ibadan, Nigeria)
ILCA: International Livestock Centre for Africa (Addis Ababa, Ethiopia)
IIMI: International Irrigation Management Institute (Colombo, Sri Lanka)
INSAH: Institut du Sahel (Bamako, Mali)
IRA: Institut de la recherche agronomique (Yaounde, Cameroon)

IRAZ: Institut de recherche agronomique et zootechnique (Gitega, Burundi)
IRNR: Institute of Renewable Natural Resources (Kumasi, Ghana)
IRZ: Institute of Animal Research (Yaounde, Cameroon)
ISAR: Institut des sciences agronomiques du Rwanda (Butare, Rwanda)
ISABU: Institut des sciences agronomiques du Burundi (Bujumbura, Burundi)
IUBS: International Union of Biological Sciences (Paris, France)
IUFRO: International Union of Forestry Research Organizations (Vienna, Austria)
KARI: Kenya Agricultural Research Institute (Nairobi, Kenya)
KEFRI: Kenya Forestry Research Institute (Muguga, Kenya)
KENGO: Kenya Energy and Environment Organizations (Nairobi, Kenya)
MAB: International Coordinating Council of the Programme on Man and the Biosphere, UNESCO (Paris, France)
NFTA: Nitrogen Fixing Tree Association (Waimanolo, Hawaii, USA)
NORAD: Norwegian Agency for International Development (Oslo, Norway)
ODA: Overseas Development Administration (London, UK)
OSU: Oregon State University (Corvallis, Oregon, USA)
SACCAR: Southern Africa Centre for Cooperation in Agricultural Research (Gaborone, Botswana)
SADCC: Southern Africa Development Coordination Committee (Harare, Zimbabwe)
SAFGRAD: Consultative Advisory Committee on Semi-arid Food Grains Research and Development (Lagos, Nigeria)
SALWA: Semi-arid Lowlands of West Africa (AFRENA programme)
SAREC: Swedish Agency for Research Cooperation with Developing Countries (Stockholm, Sweden)
SCUAF: Soil Changes Under Agroforestry
SDI: Selective dissemination of information
SIDA: Swedish International Development Authority (Stockholm, Sweden)
TAC: Technical Advisory Committee, CGIAR (Rome, Italy)
TARO: Tanzania Agricultural Research Organization (Dar es Salaam, Tanzania)
TSBF: Tropical Soil Biology and Fertility programme (Nairobi, Kenya)
UK: United Kingdom
UNEP: United Nations Environment Programme (Nairobi, Kenya)
UNESCO: United Nations Educational, Scientific and Cultural Organization (Paris, France)
USA: United States of America
USAID: United States Agency for International Development (Washington, D.C., USA)
USDA: United States Department of Agriculture (Beltsville, Maryland, USA)
UNIDO: United Nations Industrial Development Organization (Vienna, Austria)
WMO: World Meteorological Organization (Geneva, Switzerland)

Board of Trustees

Members

Meetings during 1989

18th Programme Committee meeting—28 April
11th Executive and Finance meeting—29 April
16th Board of Trustees meeting—3–4 May
12th Executive and Finance meeting (held in London)—25–27 September
19th Programme Committee meeting—24 November

Board decisions in 1989

- Dr J. McWilliam (Australia), Dr G. Holmes (UK) and Dr R. Mupawose (Zimbambwe) were appointed to the Board of Trustees as of May 1989. Dr M. Wessel (The Netherlands) retired as a Trustee after completing two three-year terms.
- The Board amended By-law Number 2 of the Charter to permit the extension of the appointment of the Chairman from the present maximum period of six years for a further maximum period of three years. This clause is only to be invoked in exceptional circumstances.
- The Board appointed Coopers and Lybrand as auditors for the year 1990, replacing the previous firm.
- The Board established an Audit Committee consisting of a Chairman appointed annually by the Chairman of the Board of Trustees and two elected members.
- The Board agreed that the appointment of Divisional Directors should be by the Board acting on the recommendation of the Director-General.
- The Board discussed and approved ICRAF's Programme of Work for 1989 with projections for 1989–90.
- The Board approved the new Personnel Policy document prepared by an external consultant and authorized its introduction on 1 July 1989.
- The Programme and Executive and Finance Committees discussed the outcome of the External Review of ICRAF and responded thereto.

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