INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY
Annual Report 1990

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Cover: Traditional home garden in Ha Tuyen Province, Vietnam.

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Director-General's Introduction

There is an unwritten, but generally accepted, convention that annual reports are presented as if they were written right at the end of the year they cover. Following this convention, anything that happens between the end of the year and the time when you actually write the report is treated as a likely event in the future.

Since this is my last introduction to an ICRAF annual report, I shall take the liberty of breaking this rule—I shall not disguise the fact that I am writing this introduction in late July 1991, a few weeks before I leave my position as ICRAF's Director-General after 10 years in the job.

Let me start by highlighting some of the major events of 1990. Perhaps the most important of these was the preparation and approval of a 10-year strategy. Beginning in early 1990, staff members, management, the Board of Trustees and representatives from collaborating institutions and donor organizations were all involved in an intense participatory process leading to the formulation of a long-term strategy for ICRAF.

This was set out in the document *ICRAF: Strategy to the Year 2000*. The strategy has provided the basis for developing a programme of work for the 1990s, which, in turn, has led to a substantial restructuring exercise. The strategy also provided the basis for the discussions that led—in 1991—to ICRAF's entry into the Consultative Group on International Agricultural Research (CGIAR).

ICRAF's goal is to help land users achieve higher productivity, sustainability and diversity of output through agroforestry. To fulfil this goal, ICRAF will pursue a three-pronged strategy that will include:

- Strengthening national capacities to conduct agroforestry research

Photo: A Njenga

ICRAF's Director-General, Dr Björn O. Lundgren, discusses the role of multipurpose trees in agroforestry systems at the field station in Machakos, Kenya.

- Collaborating with national and other institutions in applied research to develop agroforestry technologies for well-identified ecological zones and land-use systems
- Conducting strategic research on selected topics of importance at a global or regional level.

ICRAF's new structure was introduced on 1 July 1990. The former Research Development Division merged with the research programmes of the former Collaborative Programmes Division to create a new Research Division under the leadership of Dr Peter Cooper. At the same time, the former Information and Communications Division merged with the training and education programmes of the Collaborative Programmes Division to create a new Training and Information Division under the leadership of Dr Ester Zulberti. Mr Bruce Scott, previously Director of the Collaborative Programmes Division, was appointed Senior Director with responsibility for overall programme coordination. Each division, including Finance and Administration, was divided into programmes or units, and coordinators for these were appointed or recruitment started.

In the second half of 1990, attention focused on intensive programme planning within the new framework. This included, for the first time, a three-week programme review and planning meeting in late September, which involved all ICRAF professional staff. The meeting was highly productive, with intense interaction among staff members, and there are plans to repeat it in 1991.

The 10 long-standing donors to ICRAF's core budget maintained or increased their contributions in 1990, and three new donors—Australia, Belgium and Japan—added their support during the year. Unrestricted core contributions rose by 37%—from US$2.96 million in 1989 to US$4.05 million in 1990. Expenditures, drawing on core funds and restricted project grants, rose by 14%—from US$7.49 million to US$8.53 million. The significant increase in core funds, accompanied by a more modest increase in expenditure, gave ICRAF a welcome opportunity to write off most of a residual deficit that was incurred in 1988.

Clearly, considerable time and resources in 1990 were spent on finalizing the strategy, restructuring the programmes and planning for the decade ahead. Given the magnitude of this effort, the productivity of ICRAF staff over the year—in research, training and other areas—was remarkable. The length of this annual report—120 pages compared to 100 pages for 1989—reflects a significantly increased level of research outputs, particularly from the Agroforestry Research Networks for Africa programmes—the AFRENAs.

Let me highlight a few of the more noteworthy results from 1990. We have always claimed that some agroforestry technologies, using suitable multipurpose trees under appropriate management, have the potential to alleviate problems of soil erosion and declining soil fertility in tropical land-use systems. There is now a growing body of evidence from collaborative programmes within the AFRENA framework, from experiments at ICRAF's field station at Machakos, Kenya, and from the work of other organizations to substantiate this claim.

For example, experiments at two sites in Zambia indicated that a one-year improved fallow of the nitrogen-fixing shrub *Sesbania sesban* can produce more than 20 t/ha (dry wt) of fuelwood and double the productivity of subsequent maize crops. In Cameroon, when one-year improved fallows were introduced using four multipurpose-tree species, maize yields were 15 to 100% higher than yields after natural fallow.

ICRAF has been testing and demonstrating the soil-conservation potential of agroforestry technologies at the Machakos field station since 1984. By 1990, hedgerow intercropping aligned on contours had led to the formation of microterraces, stabilized by tree roots and stems. During a storm in April, 50 mm of rain fell in one hour on a hillside sloping at 14%. Soil erosion on the agroforestry plots ranged from 0.2 to 5.0 t/ha, while erosion on control plots was 34 t/ha or higher.

Partially as a result of encouraging experimental results, ICRAF expanded on-farm activities in 1990, beginning with an international workshop in February to discuss tools and methods for on-farm research. Field studies are now in progress at sites in Cameroon, Kenya, Malawi, Rwanda and Uganda. Participants in the workshop gave an indication of just how multidisciplinary agroforestry is: there were 69 specialists representing 17 different areas of specialization.

Also in 1990, planning began for an important strategic research programme. The focus will be on multipurpose trees and how they increase the efficiency of nutrient cycling in soils and help maintain soil fertility.

Other highlights of the year included work on multipurpose-tree improvement, centred at the Maseno Agroforestry Research Centre in western Kenya. Five species have been selected of special potential for East and Central Africa, and researchers travelled around Kenya to collect seed from hundreds of superior trees of these species. This germplasm will provide the basis for future tree-improvement work.

ICRAF sponsored an international workshop in August to formulate a comprehensive research agenda on *Grevillea robusta*, one of the most promising multipurpose trees for the highlands of East Africa. Finally, work on multipurpose-tree improvement expanded in 1990 to the humid lowlands of West Africa, with collaborative research at two field sites in southern Nigeria.

There has been steady progress—and exciting results—from the on-going AFRENA programmes in the highlands of East and Central Africa, the upland plateau of Southern African, and the humid zone of Cameroon. Another important achievement in 1990 was the successful launching of the AFRENA programme for the Semi-Arid Lowlands of West Africa (SALWA).

This programme links national agriculture, forestry and livestock research institutes in Burkina Faso, Mali, Niger and Senegal with regional and international research centres in a concerted effort to develop agroforestry technologies for the Sudano-Sahelian zone. Collaborative agreements were reached in each country and diagnostic surveys and research-planning exercises were concluded. A regional coordinator took up leadership of the project, with headquarters in Ouagadougou, Burkina Faso.

Achievements in the Training and Information Division were no less impressive during the year. ICRAF's annual introductory course on agroforestry research for development attracted a record number of applicants—332 applicants for 40 places. The library maintained its position as a leading agroforestry information centre, increasing its total holding of books and articles from 16,000 in 1989 to nearly 20,000 at the end of 1990.

A dramatic sign of the growing interest in ICRAF's work is the fact that publications sales more than doubled from 1989 to 1990. About 150 readers write in every month to order copies of ICRAF publications, and an equal number of new readers ask to receive ICRAF's quarterly magazine, *Agroforestry Today*, which is distributed free.

The major concern of ICRAF's management and Board of Trustees during 1990 was the issue of whether ICRAF would be invited to join the CGIAR and on what conditions. After lengthy and animated discussions, a 'conditional' invitation was issued after International Centres Week in October. This was followed, in May 1991, by a final invitation, which was subsequently accepted.

A new era is beginning, and it is appropriate that ICRAF will have a new Director-General. At this point, I would like to take the opportunity to summarize, very briefly, some of the developments that have taken place over the 10 years during which I have been associated with ICRAF.

The most obvious development has been ICRAF's dramatic growth. This can easily be quantified. In 1981, when I took up the position of Director-General, ICRAF had a total of 17 staff members, with 6 internationally recruited professionals, and an operating budget of about US$800,000. In mid-1991, ICRAF has about 300 staff members, including 45 internationally recruited professionals and 41 other professionals. Operations are based in 14 different countries, and the total operating budget is close to US$15 million.

Three factors, in my judgement, have made this growth possible. For one thing, diverse groups—scientists, development agencies, government policy-makers and the media—have become increasingly aware of agroforestry's exciting potential to address key land-use problems in many areas of the tropics. Although ICRAF has been far from alone in creating this awareness, it is fair to say that we have been regarded as the international focal point for agroforestry research and development. This has undoubtedly contributed to our success in raising funds.

Secondly, ICRAF's scientific colleagues and supporters have been enthusiastic about our approach to agroforestry research. One important aspect has been the careful, logical development of ICRAF's programmes over the years.

In the initial phase, the emphasis was on developing concepts and methods for agroforestry research and on compiling a strong information base. This early work provided the basis for applied field research, beginning in the mid-1980s, through the AFRENA programmes in major ecological zones of Africa. Now, in the 1990s, we will see expanded strategic research and institution-building efforts based on this accumulated experience.

It may have been difficult at times to see the long-term plan underneath ICRAF's myriad ongoing activities. Yet looking at the previous decade as a whole, the logical thread running through the development of ICRAF's programmes is clear. And this approach has paid off in the sense that ICRAF's donors remained loyal during the less-exciting early years and were prepared to put ever increasing funds at our disposal as our work progressed.

Another aspect of ICRAF's approach that has been strongly appreciated is the emphasis on research for development rather than as an end in itself. One of ICRAF's most important contributions has been to bridge the boundaries between conventional academic disciplines and to direct research efforts towards objective problem solving.

A third aspect of ICRAF's approach is an insistence on full partnership with national institutions. ICRAF's work is not based in separate, isolated facilities, but in existing national or regional research stations and laboratories. Here, multidisciplinary teams of national scientists and ICRAF staff members work together closely at every stage of research planning and implementation.

It has been singularly rewarding for me to note just how effectively and genuinely ICRAF has managed to establish working relations with scientists and institutions in 14 countries of Africa. The next challenge for ICRAF will be to establish equally effective relationships in South America and Asia, appropriate for conditions in those regions.

So, in my view, ICRAF's exciting growth over the past decade has been due to a generally increased awareness of agroforestry's potential and to widespread enthusiasm about ICRAF's approach to research for development. The third, and by far the most important, reason for this success has been the people associated with ICRAF—the staff members, the Board of Trustees, donors, collaborating scientists and others.

Of course I may be biased, but I think ICRAF's expanding multidisciplinary team of scientists and other specialists is probably unique. Over the years, this team has produced some remarkably innovative work in agroforestry research, training and information. A sense of unity of purpose and mutual respect across disciplinary, national and cultural boundaries have created a positive, enthusiastic atmosphere that impresses visitors.

Similarly, my experience with the Board of Trustees, both individually and as a group, has been extremely positive and stimulating. The Board took a big risk in 1981 when they appointed such a young and inexperienced person as Director-General. Among the Board members who took that risk were 'old boys' such as Robert Chandler, M.S. Swaminathan and the late John Bene. The support I have received from the Board, and particularly from Howard Steppler and the late Walter Bosshard, has been crucial for ICRAF's progress and consistency in programme direction through the years.

Let me finish by expressing my sincere thanks to all those who have contributed to ICRAF's success over the past 10 years and who have made my work an unsurpassed professional, intellectual and personal experience. The challenges and opportunities ahead for ICRAF are enormous. I wish ICRAF's new Director-General, Dr Pedro Sanchez, the staff and the Board of Trustees all the best in the coming years.

Björn O. Lundgren
Director-General

Agroforestry and Land-use Systems

Smallholder farming system near Maseno in western Kenya. Trees are planted along boundaries, around homes and in woodlots, while naturally occuring trees are maintained in groves and scattered individually in croplands

Studies on how land use systems function are fundamental for development planning and for identifying priorities for more detailed research. Key elements are the actual and potential roles of multipurpose trees and shrubs, the problems experienced by land users, and the opportunities for solving these problems through agroforestry. Thus ICRAF's programme on agroforestry and land use systems is the basis for further agroforestry research.

In addition, there is a continuing need to gather and synthesize information about agroforestry systems in order to provide scientific continuity and to increase the efficiency of research efforts. The goal is to contribute to sustainable increases in the output of land-use systems through an understanding of how they operate and their potential for development through agroforestry.

The approach is multidisciplinary, covering both the biophysical and socio economic aspects of agroforestry. Specific objectives of the programme include:

- Identification of the most beneficial agroforestry systems for specific environmental and socio-economic conditions
- Biophysical and socio-economic evaluation of existing agroforestry systems
- Measurement of the long term sustainability of land-use systems
- Evaluation of multipurpose tree products and services, including their potential role in food production, family farm income and maintenance of soil fertility
- Study of the potential role of agroforestry in halting forest clearance in the humid zone and easing pressure on grazing lands in the semi-arid zone

Agroforestry Technologies

- Improved tree fallows
- Taungya afforestation
- Trees on cropland
- Plantation crop combinations
- Multistorey home gardens
- Hedgerow intercropping (alley cropping)
- Boundary planting
- Trees on contours for erosion control
- Windbreaks and shelterbelts
- Tree biomass transfer (mulching)
- Trees scattered on rangeland or pastures
- Tree plantations with pastures
- Living fences
- Fodder banks
- Woodlots with multipurpose management
- Reclamation forestry leading to multiple use
- Entomoforestry (e.g. silk, honey production)
- Aquaforestry (trees with fisheries)

Source: A. Young (1989). *Agroforestry for soil conservation.* Wallingford (UK): CAB International (CABI) and ICRAF, p. 12.

- Compilation and updating of agroforestry databases, including a technology register and a systems inventory
- Development of models to assist in the evaluation and application of experimental data
- Continuing review and improvements of methods for planning agroforestry research
- Assessment of the role of agroforestry in land-use planning and watershed management.

Agroforestry systems inventory

A global database of agroforestry systems was created as part of ICRAF's agroforestry systems inventory project, conducted over a five-year period between 1982 and 1987. The overall objective was to compile information on the extent of existing agroforestry practices and their role within land-use systems. By 1990, the database contained information on 130 indigenous agroforestry systems in Latin America, Africa and Asia.

ICRAF has entered a collaborative agreement with the School of Agricultural and Forest Sciences of the University of Wales at Bangor (UK) to develop, extend and maintain the agroforestry systems database. This will entail evaluating and verifying the existing data and designing a new database structure. The database will then be expanded to achieve a more systematic sample of agroforestry practices and to quantify their performance and extent. This will permit comparative analysis across ecological and socio-economic gradients.

Agroforestry and sustainability

A study was completed in 1990 on agroforestry, the environment and sustainability, focusing on the current state of knowledge and priority areas for future research. Sustainability is defined as production plus conservation, that is, continued production at or above present levels coupled with conservation of the natural resources on which this production depends. This work included an assessment of the potential of agroforestry for combining diversified production with conservation of soil, water, forest and pasture resources.

Soil changes under agroforestry

In 1990, ICRAF released Version 2 of *SCUAF: soil changes under agroforestry*, an interactive microcomputer model that estimates the effects on soils of specified agroforestry systems within given environments. The environmental conditions included in SCUAF are climate, soil in its initial state, and slope. The model estimates changes in the rate of erosion and carbon (representing soil organic matter) and nitrogen cycli..., together with the effects of changes in soil properties on plant growth and harvest.

An agroforestry system is entered as a sequence of periods, each with a stated proportion of trees and crops. An improved tree-fallow system, for example, might be input as three years with 100% crops followed by two years with 100% trees, while a hedgerow-intercropping system might be one period with 15% trees and 85% crops. 'Cutyears' are specified in which the trees are felled or coppiced, usually with additional harvest.

Other inputs are the initial rates of tree and crop growth; external inputs such as manure and fertilizer; harvest, stating which parts of the trees and crops (fruit, leafy matter, wood) are removed; soil processes; and soil-plant feedback factors. Where data are missing, they are supplied by environment-specific default values built into the model.

Apart from a record of the data, SCUAF provides eight outputs—one for the rate of erosion, two for soil carbon, three for the nitrogen cycle, and two for plant growth and harvest. Each output shows predicted changes over any chosen period, such as 20 years. Each is produced as a table that can be converted into a graph by an interface with Lotus 1-2-3.

SCUAF can be used to:

- Investigate whether a proposed agroforestry system is likely to be sustainable in terms of soil conservation
- Assist in designing agroforestry field experiments
- Indicate what measurements are needed in experiments to model soil changes
- Assess the likely effects on soils of treatments not included in a field trial
- Compare agroforestry with alternative non-agroforestry systems
- Support exploratory, conceptual studies, for example to predict the possible impact of agroforestry on the global carbon cycle
- Contribute to agroforestry education and training programmes.

The model runs on an IBM-compatible MS-DOS-based microcomputer. ICRAF is distributing copies of the computer program on diskette, with a handbook, to users around the world. Version 3 will be expanded to incorporate phosphorus cycling and improved graphic facilities.

A farmer in Kenya's South Nyanza District grazes his goats and cattle on the roadside. The boundaries of neighbouring fields are demarcated by Grevillea robusta *and crops are protected from the animals by an inert fence reinforced with* Parkinsonia aculeata.

Photo: A. Njenga

Agroforestry and animal husbandry

A review on agroforestry and animal husbandry, prepared in 1990, will be published in 1991, bringing together information from a wide range of sources on the current and potential role of agroforestry in animal-production systems. This study covers biophysical issues, such as the relationship between soils, trees and animals, as well as economic and policy considerations.

The review begins with descriptions of agroforestry technologies—such as improved fallows, windbreaks, trees in pastures and tree plantations—that may play a role in livestock-production systems. This is followed by a discussion of the multiple roles of trees and shrubs in providing fodder, shade, shelter from wind, and protection of grazing resources. Both wild and domestic animals are considered, defined broadly to include bees, silkworms and many other species.

Case studies are described from all over the world. In particular, the discussion concentrates on the Amazon, the humid zone of West Africa, and the arid and semi-arid zones bordering the Sahara, plus examples from Asia, Australia and Europe.

The role of browse is assessed, including productivity, palatability, feed value and descriptions of several valuable browse species. Finally, management issues are reviewed and recommendations are presented for improved propagation of useful species, identification of research priorities, and selection of appropriate economic and social policies.

Agroforestry and pastoralism

In 1990, ICRAF initiated a series of reviews on agroforestry in arid and semi-arid lands. This work focuses primarily on experience in the pastoral areas of Eastern Africa but considers issues of relevance to other pastoral land-use systems. Support is provided by the Norwegian Agency for International Development (NORAD). Specific topics include:

- Evaluation of the effectiveness of participatory extension and research in a pastoral system. This case study from Turkana, Kenya, describes how to monitor an extensive, participatory extension programme in order to learn from the problems and potentials of an existing natural-resource management system, leading to the identification of management and research priorities from within.
- Tenure rights to trees among the Turkana pastoralists. Tree tenure is an important issue in agroforestry that has received little attention in pastoral areas where trees are vital to the integrity of land-use systems. The Turkana system of usufruct rights to trees is described in order to draw out the relevant lessons for research and development.
- Agroforestry in the interface between pastoralism and agriculture. ICRAF is currently embarking on a collaborative research programme in the semi-arid lowlands of West Africa that may have important consequences for pastoralists and agriculturalists in the region. The current and potential role of agroforestry in regions shared by pastoralists and agriculturalists is being reviewed to identify important research and policy issues, and in particular to ensure that the introduction of agroforestry does not further marginalize pastoralists.
- Local knowledge, natural-resource management and participatory extension in pastoral areas. A review is being prepared for practitioners in the field, making use of case material to show how research, development and policy decisions can build on the existing knowledge base through the direct involvement of pastoralists living in arid lands.

Component Interactions in Agroforestry Systems

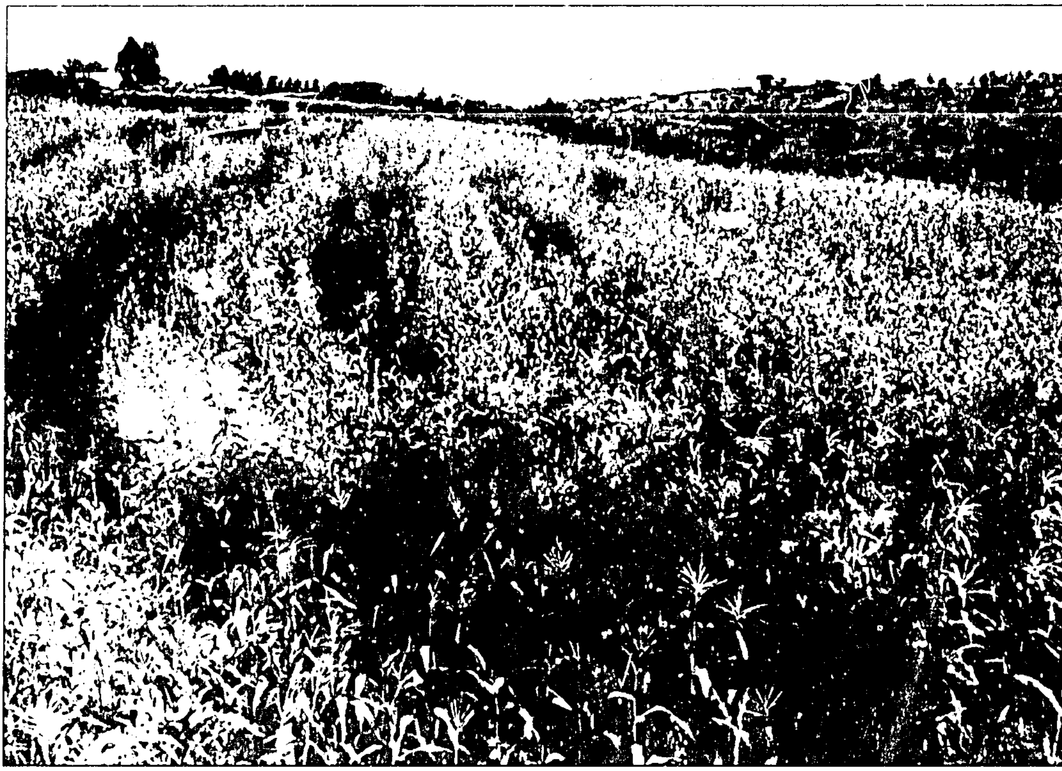


Photo A Njenga

Prototype trial with Leucaena leucocephala *planted in hedgerows along the contours at ICRAF's field station in Machakos, Kenya. The interplanted crop is maize.*

ICRAF's strategic research on component interactions in agroforestry systems focuses on the processes involved in agroforestry particularly on tree-crop interactions. Further objectives are to provide support and advice on efficient experimental designs, to develop and evaluate methodologies for agroforestry research, and to prepare tools for the analysis of data generated by agroforestry experiments.

On-station experimentation

In 1990, experimental work under this programme was based primarily at ICRAF's field station at Machakos, Kenya. The Kenya Government provided the 40-ha site in 1981, located 70 km southeast of Nairobi at an altitude of 1600 m. The climate is transitional between dry subhumid and semi-arid, with annual rainfall averaging 760 mm.

Most of the station consists of sloping land. Soils are predominantly haplic lixisols (Food and Agricultural Organization of the United Nations 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 observational studies. This demonstration function is still important: in 1990, the station received 1800 visitors.

In recent years, more formal, strategic research has also been initiated, aimed at developing a better understanding of component interactions in agroforestry. This understanding is an essential prerequisite for the correct interpretation of results from field trials, such as those in progress under the AFRENA pro-

Experiments	Demonstrations
• Evaluation of prototype hedgerow-intercropping systems • Comparison of hedgerow intercropping and green-leaf manuring • Tree/crop interface with *Grevillea robusta* and maize • Hedge-alley-hedge-alley (HAHA) experimental design • *Gliricidia sepium* provenance 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 • Soil-conservation studies	• Multipurpose tree and shrub collection (70 species) • Intercropping with multipurpose trees • Windbreak demonstration • Living fences • Soil-conservation practices with trees • Short- and long-term effects of trees • Y-shaped (120°) layout with *Cassia siamea* and *Ricinus communis* (living and inert fences) • Single-tree/environment interaction • Rotational hedgerow intercropping • Parallel-row systematic design with *Grevillea robusta* • Nelder fan systematic design • Systematic design for determining optimum alley width for hedgerow intercropping • Farm woodlots and fodder banks

Table 1. Experiments and demonstrations in progress in 1990 at ICRAF's Machakos field station.

grammes, and for the design of improved agroforestry technologies.

Strategic research is still at a preliminary stage, focusing primarily on studies of tree/crop interactions using simple measurements. Demonstrations and trials in progress at Machakos during 1990 are listed in Table 1. The most important of these will be discussed here and also in the section on multipurpose-tree improvement.

Rainfall in 1990—at 1031 mm—was 35% higher than the long-term average. Total rainfall included 620 mm during the first growing season, from March to May, and 306 mm during the second season, from October to December. Plants at the field station did not experience any drought stress during the first season, but some showed signs of nitrogen deficiency. This may have been due to nitrogen leaching from the soil during heavy rains. Irregular rainfall distribution during the second growing season resulted in some evidence of moisture stress towards the end of the year.

Assessment of interactions at the tree/crop interface

By definition, all agroforestry systems involve interactions between trees and crops or pasture plants. 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, conducted at the Machakos field station. Most experiments were completed in 1989, but a final trial, focusing on interactions between maize and *Grevillea robusta*, continued into 1991.

Early observations from various tree/crop interaction studies led to the identification of three crop zones in tree/crop-interface plots—the zone adjacent to the interface where crops are affected by the trees, the middle zone where crops are relatively free from outside effects, and the edge where crops are affected by the environment. This work suggested that after-

Photo: A. Njenga

Hedgerows of Leucaena leucocephala *and Napier grass (*Pennisetum purpureum*) interplanted with maize on a sloping field at the Agroforestry Research Centre in Maseno, western Kenya. The Centre is a collaborative project of the Kenya Forestry Research Institute (KEFRI), the Kenya Agricultural Research Institute (KARI) and ICRAF.*

noon shade could have a positive effect on crop growth during the hot, dry season, indicating the importance of the orientation of trees and crops.

Triple-row hedges of *Grevillea robusta* were established in 1986 on small plots (11.75 x 16.00 m), at four orientations. Maize is planted next to the hedges and in control plots every season. Some areas of hedgerow are left without adjacent crops to assess hedge growth in the absence of competition from crops. The hedges are pruned at the beginning of each cropping season.

Hedge measurements include height before the annual pruning, stem-collar diameter and the amount of biomass removed as prunings. Crop measurements include plant height and yields of stover, cobs and grain.

The experiment will be completed in 1991, but some early observations are of interest:

1. Maize yields from the middle of intercropped plots are similar to controls, suggesting that even in these small plots—only 11.75 m wide—the crop in the middle is influenced neither by tree/crop-interface nor by edge effects.
2. Depending on orientation, the crop on the sheltered side of a hedge has benefited in some, but not all, seasons.
3. Prunings from hedges under intercropping are about 20% lower than from hedges without adjacent crops.
4. For some purposes, it is useful to compare crop data from individual plants or rows, but aggregated data from the three zones—tree/crop interface, middle and edge—provide a general practical assessment of the effects of an agroforestry technology.

Resource-utilization study

The productivity of plants depends on their ability to use available growth resources—light, water and nutrients. To judge the potential productivity of an agroforestry system, it is useful to know the potential of the component species. An experiment was completed in 1990 at the Machakos field station to assess the potential productivity of three agroforestry species that were considered well adapted to the site: *Grevillea robusta*, a multipurpose tree; *Panicum maximum*, a fodder grass; and maize, the dominant agricultural crop in the area.

Pure stands of each species were established in October 1987, and plots were harvested at the end of each growing season, finishing in July 1990. At the end of 33 months, or six growing seasons, total above-ground biomass harvested was 45.07 t/ha for the trees, 63.96 t/ha for the grass, and 22.98 t/ha for the maize.

These values must be treated with some caution since they do not include the biomass of leaves and twigs shed naturally by the trees. In addition, probable differences in root biomass production are not included. Furthermore, the grass and maize were fertilized every season while the trees were only fertilized once, at the time of establishment. However, this assessment of total biomass production illustrates the advantages of trees and grasses that exploit growth resources over longer periods than annual crops. It also suggests the importance of incorporating perennial grasses into agroforestry systems where appropriate.

Soil-conservation aspects of agroforestry technologies

Agroforestry's most important service function is soil conservation, including both control of erosion and maintenance of fertility. The soil-conservation potential of agroforestry technologies has been demonstrated and tested at the Machakos field station since 1984. In 1990, eight interlinked trials and demonstrations were in progress on land sloping at 14%.

The trials focused on the direct use of trees in hedgerows to control runoff and erosion, while the demonstrations showed the supplementary use of trees as additions to conventional conservation structures. Trials and demonstrations in progress in 1990 included, among others:

- A prototype trial of contour-aligned hedgerow intercropping with single hedgerows of *Leucaena leucocephala* spaced 4 m apart. Treatments were: hedgerows with prunings removed; hedgerows with prunings retained as soil cover; and control with no hedgerows.
- A trial comparing barrier and cover effects of single, contour-aligned *Cassia siamea* hedgerows spaced 4 m apart. Treatments were: hedgerows with prunings removed; hedgerows with prunings retained as soil cover; no hedgerows but soil covered by

Soil-conservation Technology	Terrace Formation	Slope in 1983 (%)	Slope in 1989 (%)	Land Available for Crops (% area)
Fanya juu terraces	constructed	9.5	3.6	67
Bench terraces	constructed	10.6	5.5	78
Trees in grass strips	natural	13.8	6.8	81
Contour hedgerow intercropping	natural	14.6	6.7	84

Table 2. Terrace slopes and proportion of land available for crops with 4 soil-conservation technologies 6 years after establishment.

prunings from an external source; and control with no hedgerows or prunings.

- A trial comparing single and double hedgerows of *Cassia siamea* at different spacings. Treatments were: single hedgerows 4 m apart; single hedgerows 8 m apart; double hedgerows 8 m apart; control with no hedgerows; and trees spaced regularly throughout the plot without crops.
- A trial comparing the effects of single and multiple-row hedgerows on the movement of soil and water. Treatments were: *Cassia siamea* hedgerows composed of one, two, three or four lines of trees.
- A methods trial comparing the accuracy of erosion measurements from three plot sizes and two sizes of sediment-collection troughs.
- Demonstrations of the soil-conservation effects of trees on grass strips, trees on bench terraces and fruit trees with bank-over-ditch structures (called *fanya juu* in Kenya).

Most plots were cropped twice a year with cowpea and maize alternating. Observations included: biomass of hedgerow prunings, biomass and grain yields of crops, tree height, plant and soil cover, soil water, runoff, soil loss, nutrient loss, soil fertility and natural terrace formation. This work has led to the following useful observations:

1. When young trees are established on grass strips or banks, they must be protected from grass competition to ensure survival and early growth.
2. Fruit trees planted in the ditches of *fanya juu* structures included orange, grapefruit, guava, avocado, mango, banana, mulberry and papaya. All have performed well, making good use of the land taken up by the soil-conservation structures. Planting in ditches avoids competition from the grass on the banks and improves tree growth due to increased soil-water availability.
3. Contour hedgerows have led to the formation of micro-terraces, with risers stabilized by the hedgerow roots and stems.
4. After seven years, yields of two crops a year—lightly fertilized maize and unfertilized cowpea—have been maintained on agroforestry plots.
5. Contour hedgerow intercropping has created terraces as effectively as any of the other technologies tested and has taken up the smallest proportion of land (Table 2). Terrace formation using trees on grass strips appears to be as effective as the construction of bench terraces and takes up a similar proportion of land. *Fanya juu* structures have produced level terraces, but they take up the most land.

The major observation in 1990 resulted from a storm in April in which 50 mm of rain fell in one hour on soil that was already saturated. Erosion on the control plots was 34 t/ha or higher, while erosion on the agroforestry plots ranged from 0.2 to 5.0 t/ha. Following the storm, cowpea growth and grain yield were higher on agroforestry plots than on control plots.

In summary, all indications are that a well-managed system of contour-aligned hedgerows is as effective in controlling runoff and soil erosion as conventional approaches, at least under the climate, soil and slope conditions found at this site.

Comparison of annual and tree legumes for soil-fertility improvement

Farmers throughout the world traditionally grow annual leguminous crops, such as beans and cowpea, in rotation or under intercropping with cereals. These legumes produce edible grain and help improve soil fertility. Before introducing agroforestry into traditional systems, it is important to ask whether trees are more valuable for soil-fertility improvement on a long-term basis than the commonly grown annual legumes.

An experiment was established in 1989 at ICRAF's Machakos field station to compare the soil-fertility effects of a short-season legume (cowpea), a full-season legume (pigeonpea) and a leguminous tree (*Gliricidia sepium*). These are being grown in various arrangements, using maize as a test crop to detect improvements in soil fertility. The first results should be available in 1991.

Mulch, root and barrier effects of hedgerow intercropping

Hedgerow intercropping may contribute to crop production through above-ground biomass applied as mulch, through nitrogen fixation and other root activity, or through control of soil erosion by hedges acting as barriers. An experiment began in 1987 at the Machakos field station to measure the effects of mulch separately from the other effects of hedgerows.

Leucaena leucocephala and *Cassia siamea* were planted with maize in a hedgerow-intercropping arrangement, cut regularly, and all prunings returned to the interplanted maize crops. The two tree species were also planted separately in blocks and again cut regularly and all prunings applied to maize grown separately in pure stands. The proportion of land under trees and crops was the same under the hedgerow-intercropping and the block-planting systems.

The trees were first pruned in November 1988 and afterwards four times a year. Average biomass yields increased from 0.85 t/ha in 1988 to about 4 t/ha in 1990 (Table 3). The two species produced similar amounts of biomass in the first two years, but in 1990 the productivity of leucaena surpassed that of cassia by 48%. Trees under hedgerow intercropping generally produced more biomass than trees planted in blocks.

Maize yields were on average 20 to 38% higher under hedgerow intercropping than with mulch from trees planted separately (Table 4). Maize yields were similar in association with either leucaena or cassia. The higher maize yields under hedgerow intercropping could be due to higher biomass incorporated in the alleys or to positive tree/crop interface effects. However, maize yields under hedgerow intercropping were only as high as yields of maize planted over entire plots in pure stands, indicating that, at this stage of the study, the improved fertility in alleys was only enough to compensate for the area taken up by hedgerows.

Tree/crop competition for above- and below-ground resources

The design of agroforestry technologies requires quantified information on resource sharing and competition effects between trees and crops—information that is not yet widely available. An experiment was established at the Machakos field station in November 1989 to assess

Table 3. Annual production of leafy biomass (t/ha dry wt) from Leucaena leucocephala *and* Cassia siamea *under hedgerow intercropping with maize and planted in blocks at Machakos, Kenya.*

	Leafy Biomass Production (t/ha dry wt)					
	1988 (1 pruning)		1989 (4 prunings)		1990 (4 prunings)	
	Leucaena	*Cassia*	*Leucaena*	*Cassia*	*Leucaena*	*Cassia*
Hedgerow intercropping	1.04	1.16	3.78	3.37	5.31	3.78
Block planting	0.55	0.62	3.55	3.07	4.37	2.76
Average	0.80	0.89	3.67	3.22	4.84	3.27

	Maize Grain Yields (t/ha dry wt)					
	1989 (March-July)		1989/90 (Oct-Feb)		1990 (March-July)	
	Leucaena	*Cassia*	*Leucaena*	*Cassia*	*Leucaena*	*Cassia*
Hedgerow intercropping	2.47	2.80	3.08	3.72	2.46	2.60
Block planting	2.04	1.95	2.51	2.75	1.83	1.86
Average	2.26	2.38	2.80	3.24	2.15	2.23
Control	2.04		2.86		1.84	

Table 4. Maize grain yields (t/ha dry wt) under hedgerow intercropping with two tree species and in pure stands with mulch added from separate blocks at Machakos, Kenya.

above- and below-ground competition between rows of *Leucaena leucocephala* and adjacent maize crops. On some plots, the leucaena is managed as hedgerows by regular cutting, while on other plots the trees are allowed to grow to their full height.

Galvanized iron sheets were buried to a depth of 1 m between tree and crop rows on some plots to eliminate most below-ground competition. On others, the trees were planted in trenches 40 cm below the ground surface on the premise that this might also minimize root competition with crops. On some plots, trees and crops will receive measured quantities of water—based on potential evapotranspiration and water deficits—to eliminate competition for moisture.

The trees grew well in 1990 except in one sunken-planting plot where they suffered from temporary waterlogging. There was no evidence that the metal barriers affected tree growth. The first maize crops also grew well, and all indications are that this experiment will provide useful information in the coming seasons.

Open-pit sunken planting

Water stress during the dry season can cause high mortality rates and poor growth when young trees are planted out, adding to the expense, labour requirements and delay in establishing an agroforestry technology. Two experiments were conducted at the Machakos field station to compare standard planting techniques with sunken planting in open pits, 60 cm deep, leaving the seedling root collar about 45 cm below ground level. Results were compared in terms of tree survival, growth, the timing of flowering and fruiting, and biomass allocation within the plant. The hypothesis was that open pits, together with upslope mini-catchments, would act as water reservoirs, increasing water retention and decreasing evapotranspiration. A further hypothesis was that trees planted in sunken pits would develop roots in deeper soil strata, reducing competition with adjacent field crops.

Work began in 1984 with *Acacia mellifera*. Early results showed a positive effect for sunken planting in terms of height growth and dry-matter yield. In April 1987, the experiment was repeated on a larger scale with *Leucaena leucocephala*. Again results showed better growth and significantly higher survival rates with sunken planting. Twenty months after planting, 74% of the seedlings in pits had survived, compared with only 45% of those planted at ground level. The average height increase for seedlings in pits was 205.5 cm, compared with 137.4 cm for seedlings at ground level (Figure 1). The positive effects of sunken planting began to taper off about 16 months after establishment.

The leucaena seedlings in pits showed fewer indications of water stress during the dry season: only 25% showed signs of wilting or top die back, compared with 55% of seedlings planted at ground level. Possibly due to their better condition at the end of the dry season, the seedlings in pits responded immediately to small levels of precipitation at the beginning of the rains.

The seedlings in pits also started flowering and producing pods six to eight months earlier than those at ground level. Perhaps for this reason, differences in total biomass 20 months after planting were not significant. The average shoot/root ratio for the seedlings in pits was 0.96, compared with 0.63 for those planted at ground level.

The second hypothesis—that seedlings planted in sunken pits would develop roots in deeper soil strata—was not substantiated. Many roots arched back towards the upper soil layers, where they would potentially compete with roots of adjacent crops.

Natural repellants against browsing

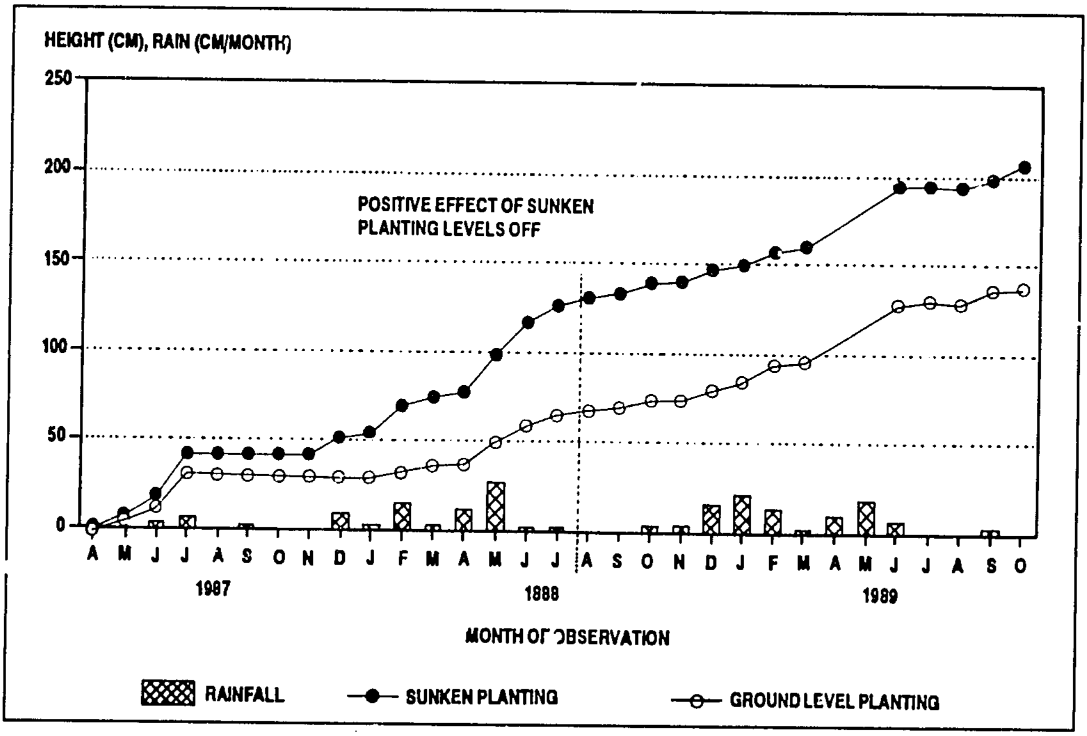
Two experiments conducted at the Machakos field station tested the effectiveness of natural repellents, widely available to farmers, in protecting *Leucaena leucocephala* seedlings from damage by browsing goats. The first experiment, completed in 1988, showed that terminal shoots protected with clipped sheep's wool or kapok (*Ceiba pentandra*) seed fibre suffered markedly less browsing damage than untreated shoots or shoots treated with other materials. In the second experiment, conducted in 1990, these two repellents were attached to terminal shoots and 10 days later the seedlings were exposed to browsing by five adult goats for a period of six days.

Again, the sheep's wool and kapok fibre reduced and delayed damage from browsing (Figure 2). Their declining effectiveness over the experimental period was largely due to strong winds that blew them off the seedlings. In this experiment, the repellents were attached to the seedlings using an inexpensive, commercially available glue; clearly, their effectiveness could be enhanced by using a better adhesive.

Hedgerow-intercropping prototype trial

The potential of hedgerow intercropping for sustained production has been demonstrated in the humid and sub-humid tropics, but its potential in the semi-arid tropics is not well established. In this environment, the tree component

Figure 1. Cumulative height increments of Leucaena leucocephala *seedlings planted at ground level and in sunken pits at Machakos, Kenya.*



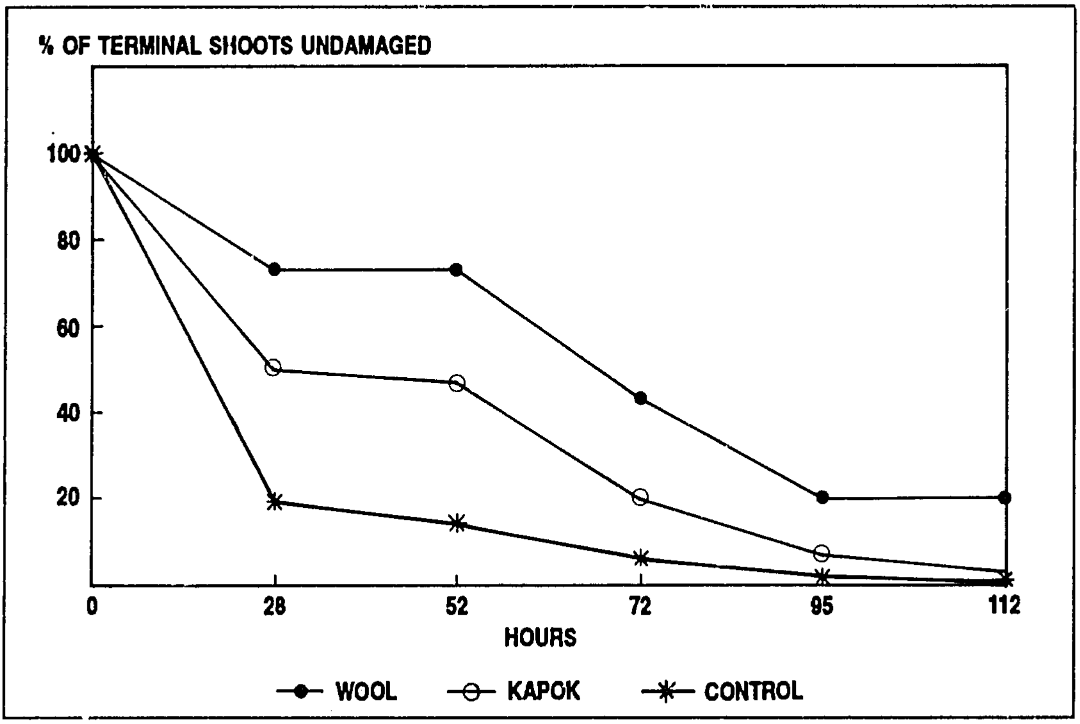


Figure 2. Damage to the terminal buds of Leucaena leucocephala *seedlings covered with sheep's wool or kapok seed fibre and exposed to intensive browsing by adult goats at Machakos, Kenya.*

may compete with annual crops for soil moisture, causing substantial reductions in crop yields. However, contour-aligned hedgerows on sloping land may reduce soil erosion and indirectly contribute to the improvement of soil fertility.

The establishment and maintenance of hedgerows is labour intensive and it is important to assess whether hedgerow intercropping is viable in economic terms. A system that produces hedgerow prunings for livestock fodder may be more attractive to farmers than a system in which prunings are returned to the soil.

Four systems are being tested at the Machakos field station on plots of 300 to 500 sq m—large enough to allow the evaluation of labour requirements and economic impact. Two are hedgerow-intercropping systems with *Leucaena leucocephala* and two are based on annual crops only, with and without moderate levels of fertilizer. 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 oxen and the manure is returned to the soil. This trial was initiated in November 1989. The first results will be available in 1991.

On-farm research

ICRAF's on-farm research programme is an essential component of the agroforestry technology development process. The objectives are:

- To study existing land-use problems and opportunities, use of multipurpose trees, and farmers' agroforestry systems in order to improve on-station and on-farm research planning and analysis
- To design and test agroforestry technologies that can be expected to contribute to the improved productivity and sustainability of farming systems

- To evaluate the acceptability and potential socio-economic impact of agroforestry technologies
- To develop on-farm research methods for wider use through ICRAF's collaborative programmes: these must be cost effective and scientifically rigorous and must ensure the active participation of farmers.

The programme emphasizes the interaction of scientists with farmers and extensionists, a focus on production systems, an interdisciplinary approach to research, collaboration with national and international research centres and development agencies, and complementarity with research on station.

In 1990, ICRAF conducted on-farm research in five small-farm areas of eastern and southern Africa—Kakuyuni and Maseno in Kenya, Lilongwe in Malawi, Kabale in Uganda, and Rwerere in Rwanda. In 1991, on-farm research will be extended to Embu in Kenya, Chipata in Zambia, and Gitega in Burundi. Work at Kakuyuni, initiated in 1985, is reported here, while on-farm research at other sites is reported under the respective AFRENA programmes.

Review of methods for on-farm research

A review of methods for on-farm research, undertaken in 1989, culminated in an international workshop on 'Methods for Participatory On-farm Agroforestry Research', held at ICRAF headquarters in February 1990. The objective was to review recent progress and to provide some preliminary guidelines for workers in the field. The 69 participants represented 28 agroforestry research and development projects in 16 countries, plus several international centres and three donor organizations—the Rockefeller Foundation, the Ford Foundation and the International Development Research Centre (IDRC) of Canada.

Thirty-four papers described newly developed research methods or on-farm research activities in specific agroforestry field projects. They raised several important issues.

ICRAF's collaborative research in western Kenya includes on-farm fodder-bank trials with Leucaena leucocephala *and Napier grass* (Pennisetum purpureum) *in a hedgerow-intercropping arrangement.*

Photo: A. Njenga

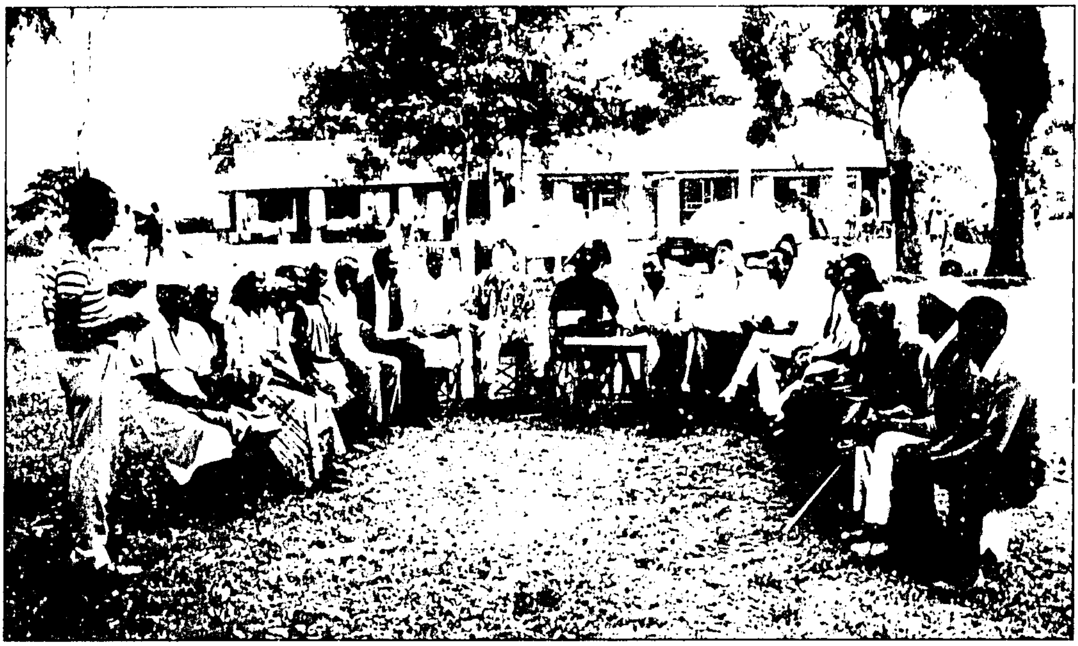


Photo: A. Njenga

Collaborative on-farm research team meets with a group of farmers in Kisumu District, western Kenya.

In the past, many on-farm agroforestry studies were descriptive, using rapid-appraisal methods to evaluate existing systems. Now there is a need for more rigorous quantitative description and for greater understanding of system functioning including socio-economic and biophysical interactions. More effective methods are also needed to involve farmers in setting research priorities and in developing and evaluating technologies.

Another important issue concerns determination of the proper role of on-farm research in relation to formal on-station experimentation. There is also the problem of interdisciplinarity: the 69 workshop participants represented no fewer than 17 different academic disciplines, each with its own approach and rules of evidence regarding how hypotheses are formulated and tested.

In addition, on-farm research needs to be organized to ensure effective participation and communication among researchers and extension workers. Finally, there is an urgent requirement for better statistical methods to deal with high on-farm variability and the evaluation of multiple outputs over long periods of time.

Twelve selected papers presented at this workshop, plus abstracts of the others, will be published in 1991 as a special issue of the international journal *Agroforestry Systems*. ICRAF will also publish an executive summary.

Selected problems identified at the workshop are being addressed by studies at ICRAF. One important area is the development of survey and monitoring techniques to investigate traditional agroforestry systems. Scientists working in the AFRENA programmes have conducted several surveys of existing systems, and methodologies are being refined based on this experience.

A second important area is to determine the proper role of on-farm experimentation in the process of technology development. In many situations, where the goal is to assess the potential acceptability of a technology, exploratory surveys combined with case studies are more appropriate than attempts to conduct statistically rigorous experiments. Case studies can be made more rigorous by making a few careful, but simple measurements on a large number of farms. These can be followed by formal surveys to define what proportion of farmers could potentially adopt a technology.

More formal experimentation may be appropriate in the latter stages of technology development to investigate factors influencing adoption. However in some cases, information on technology adoption and modification by farmers may be obtained more efficiently through cautious extension followed by careful monitoring. Experiments to investigate biophysical variables are often best conducted on stations and on 'satellite' research sites under the control of scientists.

In situations where biophysical variables need to be studied on farms, the wide variability in site, seasonal and management factors can pose serious problems. ICRAF initiated a study in 1990 to investigate the pattern, scale and seasonality of variability associated with different crop and tree components on small farms. The study focuses on 12 farms near Machakos, Kenya.

Yields from selected fields will be measured over six growing seasons using a grid of quadrants. The study will produce information on the relative magnitude and dynamics of variation within and between farms and between seasons, leading to guidelines for experimental design and analysis such as the optimum size and shape of experimental plots.

Another widespread problem relates to the collection and analysis of data on soils. ICRAF is compiling information on soil classification and soil analysis in Eastern and Southern Africa for use by agroforesters conducting on-farm research.

Socio-economic research

Enthusiasm about agroforestry as an approach to viable and sustainable land use must be accompanied by detailed analyses of the real benefits, costs and risks involved in the adoption of specific agroforestry technologies. As a first step, ICRAF has conducted three literature reviews on the economics of agroforestry. The most recent, conducted in 1990, will lead to the publication of an annotated bibliography on the economic analysis of agroforestry technologies.

The review covered 230 documents collected from institutions and individuals around the world (Table 5). About 80% of the studies reported were based at least partly on empirical data, for instance from farm surveys, case studies or research-plot measurements. The original documents covered in the bibliography are all available in the ICRAF library.

A special project on socio-economic research in agroforestry was initiated in 1990 with funding from IDRC. The specific objectives are:

- To conduct socio-economic research on the performance and adoption potential of agroforestry technologies for targeted land-use systems
- To train and support national scientists in planning and conducting socio-economic research within the AFRENA programmes
- To develop cost-effective methodologies for socio-economic research for wider use by national scientists.

Within the AFRENA programmes, the emphasis will be on short- and long-term cost-benefit assessment, household and community priority setting and decision making, and risk and uncertainty analysis as they affect the adoption and potential impact of specific agroforestry technologies. To share information and help coordinate socio-economic research and training activities in Eastern and Southern Africa, ICRAF contributed to an informal meeting of economists working with international centres in the region in June 1990.

Agroforestry extension methods and materials

Like agroforestry research, agroforestry extension is a new and rapidly expanding field with numerous, uncoordinated activities throughout the world. ICRAF has initiated a worldwide literature review on agroforestry extension, aimed at bringing together a complete collection of documents and publishing an annotated bibliography in 1992.

In addition to the literature review, this initiative includes field visits to agroforestry extension projects in Eastern and Central Africa. Work began in 1990 with visits to three projects in Kenya.

Preliminary observations suggest that opportunities exist for strengthening communication between researchers, extension workers and farmers. A common strategy is to experiment with agroforestry technologies on station and to demonstrate them to farmers at the same time, sometimes with incomplete information on their biophysical and economic performance. The risk of promoting untested technologies prematurely could be minimized by strengthening communication and collaborative links.

On-farm research project at Kakuyuni

In 1983, scientists from the Kenya Forestry Research Institute (KEFRI), the National Dryland Farming Systems Research Station, the Machakos Integrated Development Project (MIDP), and ICRAF conducted a diagnosis and design (D&D) survey in the area around Machakos, 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 funds provided by IDRC.

The goal is to develop improved land-management systems using agroforestry for mixed-farming areas in Kenya's semi-arid zone. The project has an on-station component near Machakos town that focuses on hedgerow intercropping and the effects of mulching on soil fertility and crop yields.

The on-farm component is based in the Kakuyuni catchment area, at an altitude of 1200 m. Annual rainfall averages 600 mm, divided roughly equally between two rainy seasons. Farm sizes vary from 3 to 17 ha, with a high proportion on sloping land. Farm boundaries were adjudicated in 1986 and are often demarcated by boundary plantings. The most common crops are maize, beans, pigeonpea and cowpea. Farmers use oxen for ploughing and also keep other cattle, goats, poultry and rabbits.

Most farms are divided into three sections: croplands, grazing lands and home compounds. Farmers address soil-fertility problems by rotating crops and applying manure; there is little evidence of fallowing and no use of chemical fertilizers.

The major problems reported during the D&D exercise were soil erosion, poor soil fertility and fodder shortages, especially at the end of the dry season. Major constraints to increased production were low and erratic rainfall and scarce farm labour.

The survey team identified several promising agroforestry technologies for the area. These included hedgerow intercropping, rehabilitation of grazing lands, fodder banks, living fences, trees in home compounds and fruit tree production.

Table 5. Distribution (%) by region, agroforestry technology and type of economic analysis of 230 documents covered in ICRAF's literature review on the economics of agroforestry.

Region	Percent of Total	Agroforestry Technology	Percent of Total	Type of Analysis	Percent of Total
Asia	31	Home gardens	4	Farm budgeting	20
Africa	27	Trees with annual crop	25	Cost-benefit analysis	54
Latin America	12	Trees with perennial crops	9	Optimization model	13
USA/Canada	5	Trees with pastures	19	Agroforestry sector analysis	18
Europe	1	Woodlots	23	Regression analysis	1
Australia/ New Zealand	8	Fodder banks	3	Economic concepts/ methodology	30
		Hedgerow intercropping	14		
Global	16	Trees on contours	4	Computer programs	4
		Boundary planting	5		
		Living fences	3		
		Windbreaks	6		
		Taungya afforestation	14		
		Improved fallow	5		
		Not specified'	20		

Note: Studies may cover more than one technology and type of analysis.

Hedgerow-intercropping trials were established on three local farms in 1985 and extended to six additional farms in 1988. The hedgerows are managed primarily by project staff, while the farmers manage the crops. It has been difficult to draw precise conclusions from these trials, due to variations in site conditions and in the farmers' management practices. However, by 1990, some observations were possible:

- 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* suffered high losses due to browsing.
- Choice of crops and decisions on crop management were left to the farmers. Although planting densities varied widely, crop densities under hedgerow intercropping, with hedges spaced at 4-m intervals, were not necessarily lower than in pure stands.
- Hedgerows were coppiced twice a year at the beginning of the two rainy seasons and were sometimes coppiced twice more during the growing seasons. Biomass production tended to be small, with wide variations.
- Some participating farmers expressed concern about the labour required to manage the system.

Given the low biomass yields from hedgerows, it is not yet certain whether hedgerow intercropping can contribute sufficiently to soil fertility in the semi-arid environment of Kakuyuni to justify land and labour costs. The farmers' assessment of hedgerow intercropping was not positive enough to stimulate wider adoption. One of the nine participating farmers has abandoned the trial, one has taken over management of the hedgerows, and one has decided to plant additional hedgerows independently. Only one non-participating farmer has adopted the technology.

During the D&D exercise, farmers expressed a strong interest in fodder improvement, particularly for their draught oxen. Experiments conducted in 1984 and 1985 focused on ways to increase fodder production through better management of indigenous trees. Useful species already growing on local farms included *Acacia tortilis*, *Balanites aegyptiaca* and *Commiphora africana*. Micro catchments were built around trees to improve water availability, young trees were protected against browsing animals, and trees were pruned to promote faster growth. Although results were encouraging, no farmers appear to have adopted these practices.

At the same time, the project team introduced a full rehabilitation package on severely eroded grazing land provided by two farmers. The main components included protection by fencing, ditch construction for erosion control, and introduction of fodder grasses and trees, including *Faidherbia albida*, *Prosopis juliflora* and *Leucaena leucocephala*. Although results were not monitored in quantitative terms, improvements are clearly visible and these plots serve as a demonstration to surrounding farmers.

In October 1988, leucaena fodder banks were established on four of the participating farms. Two of these are managed purely for fodder production, while the other two combine leucaena intercropped with maize and beans. Initially, poor tree survival and low productivity were related to poor-quality seedlings and poor planting techniques. As these problems were resolved, fodder production improved. By 1990, three of the participating farmers were managing their own fodder banks and two had extended the area devoted to tree fodder. Many farmers are interested in establishing fodder grasses and some are trying to establish fodder trees with support from the project. An important factor is the growing market for milk, with another project in the area focusing on small-scale milk production.

Boundary plantings are common in Kakuyuni, but most fences to control livestock are composed of dead thorny branches of *Balanites aegyptiaca* and various acacia species. The project team tested living fences on the grazing-land rehabilitation plots and at the central nursery using *Acacia mellifera*, *Parkinsonia aculeata*, *Commiphora africana*, *Caesalpinia spinosa* and *Ziziphus mauritiana*.

Problems for farmers wishing to introduce living fences included the labour required to establish, maintain and protect young trees and the long delay before living fences develop into an effective barrier. In 1990, two collaborating farmers planted living fences of *Aberia caffra*, *Acacia mellifera* and *Prosopis juliflora* around their home compounds on their own initiative.

During the D&D exercise, farmers expressed particular interest in fruit trees—including citrus, papaya, mango and guava—a reflection of good marketing potential in the area. Initially, project activities were limited to the provision of seedlings. A survey conducted in 1986 revealed poor survival rates, ranging from 7% for guava to 50% for rough lemon.

The most popular site for planting fruit species and other trees is the home compound. However, a survey conducted in 1989 indicated that tree survival rates were as low as 37% in home compounds and 30% in croplands.

In April 1989, the project team showed farmers a better way to plant trees. This involved pruning the roots of seedlings and the stems if necessary, digging larger planting holes (50 x 50 x 50 cm) to encourage rapid root development, and planting promptly at the beginning of the rainy season to take advantage of all available moisture. Researchers worked with 10 farmers who planted a total of 60 trees.

At the end of eight months, 90% of the seedlings had survived and growth rates had improved significantly. A much larger number of farmers adopted these practices in 1990, and they planted a wide range of species. Again survival rates were high, averaging more than 80%.

A survey in June 1990 of 15 farms—the 9 participating in the project plus a control group of 6—showed a total of 902 trees of 38 different species. More than 54% of trees growing in home compounds and more than 61% of those growing in croplands had been planted since November 1989.

The most popular species were *Cassia siamea, Grevillea robusta, Melia azedarach, Terminalia mantaly* and, among the fruits, rough lemon, papaya and banana.

Experience at Kakuyuni has shown that better tree-planting techniques can dramatically improve the cost/benefit ratio and risk factors that farmers consider when adopting an agroforestry technology. In particular, farmers must see economic benefits in addition to the long-term—and perhaps more intangible—benefit of improved sustainability.

Photo: A. Njenga

Better tree-planting techniques can improve the costs, benefits and risk of agroforestry. ICRAF staff worked with farmers in Kakuyuni, Kenya, to introduce new techniques that dramatically improved seedling survival rates.

Photo: A. Njenga

It is not unusual for a smallholding in Kenya's Embu District to include Leucaena leucocephala, Grevillea robusta *(lopped to provide fuelwood), banana, cassava and Napier grass* (Pennisetum purpureum)*—all densely interplanted.*

Multipurpose-tree Improvement for Agroforestry Systems

Photo: A. Njenga

Sesbania sesban *interplanted with maize on a farmer's field in western Kenya. This is one of six multipurpose-tree species selected for initial studies under ICRAF's breeding research programme.*

ICRAF's research programme on the improvement of multipurpose trees for agroforestry systems is designed as a decentralized collaborative activity within the framework of the Agroforestry Research Networks for Africa (AFRENAs). Much of this work is conducted at the Maseno Agroforestry Research Centre in western Kenya in collaboration with KEFRI and the Kenya Agricultural Research Institute (KARI). Work at Maseno in 1990 included species-preference surveys, selection and breeding research on five high-priority species, breeding biology and vegetative propagation studies, and research on tree root symbionts.

Research on multipurpose trees at the Machakos field station included trials of *Gliricidia sepium* provenances and *Cajanus cajan* progeny. A study was also completed in 1990 to help develop more precise methods for assessing tree phenology.

Programme activities in 1990 at ICRAF headquarters included the further development of a computerized inventorial database of multipurpose trees and shrubs and preparation of the second edition of a multipurpose tree and shrub seed directory. Programme staff also contributed to ICRAF's training activities.

Finally, a project was initiated in 1990 to evaluate tree species for the low-nutrient, acid soils of West Africa's humid lowlands. This work is based at the International Institute of Tropical Agriculture (IITA) in Nigeria.

Species selection and breeding research

Results from diagnosis and design (D&D) exercises, multipurpose-tree surveys, and species and provenance trials in Eastern and Central

Species	Number Mentioning	Percentage Mentioning
Markhamia lutea	69	78
Grevillea robusta	61	69
Sesbania sesban	41	47
Leucaena leucocephala	32	36
Cassia siamea	12	14
Calliandra calothyrsus	22	25
Albizia zygia	17	19
Melia azedarach	8	9
Terminalia brownii	3	3
Chlorophora excelsa	4	5
Maesopsis eminii	4	5
Casuarina cunninghamiana	4	5
Cassia spectabilis	2	2
Vernonia amygdalina	2	2

Table 6. Multipurpose-tree species mentioned by 88 farmers in 5 districts of western Kenya in response to the question: 'If you could plant only 5 tree species in your cropland, other than for fencing or for fruit, which would they be?'.

Africa led to the selection of six species for initial breeding research. These are *Sesbania sesban*, *Grevillea robusta*, *Calliandra calothyrsus*, *Markhamia lutea*, *Leucaena leucocephala* and *Leucaena diversifolia*.

Species-preference surveys conducted among farmers in western Kenya in 1989 and 1990 generally supported this selection. For example, Table 6 summarizes results from a multipurpose-tree species-preference survey carried out in March 1990 in South Nyanza, Siaya, Kakamega, Busia and Bungoma Districts.

The next step was to identify base breeding populations of each species. Variations in tree growth forms (ideotypes) and growth performance were recorded from field surveys, and an ideal ideotype ('plus tree') was identified for each of the six species, taking into account the requirements of agroforestry technologies, desirable tree products from different species, and compatibility with appropriate crops. Grading rules were developed for plus trees of each species based on minimum standards for specific traits.

In early 1990, programme staff carried out a comprehensive search for plus trees in Kenya, using different methods of selection depending on patterns of tree distribution in the field. Seed was collected from the following trees identified as superior phenotypes: 38 *Sesbania sesban*, 15 bushy and 4 tall types of *Calliandra calothyrsus*, 2 bushy and 10 tall types of *Leucaena leucocephala*, 6 tall types of *Leucaena diversifolia*, 57 *Grevillea robusta* from western Kenya, 93 *Grevillea robusta* from Meru and Embu Districts in eastern Kenya, and 48 *Markhamia lutea*.

The genetic traits of all these plus trees will be assessed by open-pollinated progeny trials in multiple locations. Results will provide a basis for selecting trees for advanced-generation breeding. Seed orchards and tree banks are also being established at different locations in Kenya.

Breeding biology and propagation studies

Programme staff are recording data on tree development sequences in order to construct flowering and fruiting calendars as guidelines for pollen and seed collection. This work has already led to interesting observations on pollination and fertilization mechanisms in *Grevillea robusta*.

Although this species is preponderantly self-pollinating, artificial cross-pollination was readily performed, which suggests that populations of *Grevillea robusta* may not be as inbred as was previously believed. Similar work is leading to the identification of improved pollen-handling and controlled-pollination techniques for two other species—*Calliandra calothyrsus* and *Sesbania sesban*.

Research also started at Maseno in late 1989 to develop vegetative propagation techniques using simple, low-cost equipment. A non-misting propagator system, designed by the Institute of Terrestrial Ecology (ITE), is being used in the following studies:

- Selection of appropriate rooting media for cuttings of different species

- Effects of scion size (number of nodes) on the success of cleft grafting
- Effects of ortet (parent tree) age and the location of scions within the tree canopy on the success of rooting and grafting.

Evaluation of *Gliricidia sepium* provenances

Gliricidia sepium is a leguminous tree distributed naturally in the Western Hemisphere—from Southern Mexico through Central America to northern South America. It is now also cultivated in East and Southern Africa, Southeast Asia and Australia.

This species is well adapted to a wide range of soil and climatic conditions. It is easy to propagate, coppices well, and produces abundant leafy biomass. All these advantages make *Gliricidia sepium* a potential alternative to *Leucaena leucocephala* in many agroforestry systems.

Fourteen provenances of this species are being tested at the Machakos field station. These were provided by the Oxford Forestry Institute (UK). They represent collections from extreme ecological conditions that might be promising for the drier areas of East Africa.

Seedlings were planted in April 1989 in pure stands to assess their suitability for woodlots. Measurements include height, number and diameter of branches, and stem diameter at 30 cm above ground. Leaf-retention, flowering and podding characteristics are recorded, as well as susceptibility to aphid attack. All trees will be cut back at the end of two years to assess coppicing ability.

Evaluation of pigeonpea genotypes for agroforestry

Pigeonpea (*Cajanus cajan*) is widely grown in semi-arid areas of India, East Africa and the Caribbean. This legume provides farmers with

A farmer on India's Deccan Plateau harvests pigeonpea branches for fuelwood and livestock fodder.

Photo: C.K. Ong

food, fuelwood, fodder and building material. Although intrinsically a perennial, it is often grown as an annual because of its susceptibility to pests and diseases.

A trial was initiated at the Machakos field station in November 1989 to evaluate 10 pigeonpea genotypes for biomass production, coppicing ability, grain yields, soil-fertility improvement and effects on adjacent crops. Germplasm was provided by the National Dryland Farming Research Centre (NDFRC) in Katumani, Kenya, and by the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) in Hyderabad, India.

Two planting arrangements were compared with control plots of maize planted in pure stands: intercropping, with one row of pigeonpea followed by two rows of maize, and strip cropping, with four rows of pigeonpea followed by eight rows of maize. Both agroforestry systems had one-third fewer maize plants than the plots with maize only. During the first year, two crops were produced from the maize-only plots and from the plots under strip cropping, but only one crop was produced under intercropping due to moisture competition from the pigeonpea. Even so, annual maize yields under intercropping with different pigeonpea genotypes ranged from 56 to 80% of the yields obtained from maize-only plots. Maize yields under strip cropping ranged from 85 to 100% of yields from maize in pure stands.

As expected, there appeared to be a trade-off between maize and pigeonpea production, with intercropping favourable to pigeonpea and strip cropping favourable to maize. Some of the pigeonpea genotypes that grew fastest were associated with the lowest maize yields.

The genotypes from Kenya were among the highest yielding pigeonpeas under both cropping systems. Four genotypes appeared particularly promising after the first year, but definitive recommendations will have to await results from a longer period.

Improved method for studying tree phenology

Seasonal patterns of growth and flowering ('phenology') vary widely among different multipurpose-tree species. These patterns respond to environmental conditions and management practices. To assess a tree's suitability for a particular site and agroforestry technology, it is essential to have information on growth patterns and responses to management.

Most studies on tree responses to seasonal changes and management practices are based on general observations of whole trees. In order to produce more precise information, ICRAF initiated a study in 1985 to count and measure important phenological events on individual branches of a few species, selected for their widely varying growth and flowering characteristics.

Phenological behaviour was recorded at the Machakos field station from August 1985 to June 1988 for *Faidherbia albida*, *Acacia stulmanii*, *Grevillea robusta*, *Leucaena leucocephala* (K8), *Psidium guajava* and *Parkinsonia aculeata*. Records were kept for three well-spaced trees of each species—these were all three years old at the beginning of the experiment. The data were subsequently analysed and results were published in 1990.

Eight primary branches were observed on each tree. Six times during the first year of the experiment, the terminal 10 cm of a different branch was removed. The remaining two branches were not disturbed. Scientists measured and recorded the growth of all these main branches, the development of any lateral branching, and flowering and fruiting.

As expected, the different species varied widely in the timing and overall rate of branch growth. *Faidherbia albida* grew slowly, with only two periods of active growth. *Parkinsonia aculeata* and *Psidium guajava* had several active growth periods. *Grevillea robusta* grew vigorously over extended periods, but not every season, with growth tending to follow heavy rain. *Leucaena leucocephala* showed brief, erratic periods of rapid growth, unrelated to climatic conditions.

Lateral branching was much greater in *Leucaena leucocephala*, *Parkinsonia aculeata* and *Psidium guajava* than in the other three species. An important characteristic of a good hedgerow-intercropping species, clearly exhibited by *Leucaena leucocephala*, is rapid and vigorous growth of lateral shoots in response to cutting.

Photo A N[illegible]

A branch of Psidium guajava *in flower. This fruit-tree species was included in ICRAF's research project to develop improved methods for studying tree phenology*

By contrast, cutting actually inhibited lateral branching in the other species. Responses to cutting at different times also varied widely among the different species.

More important than these specific findings, the methods developed for studying branch phenology provide a useful tool for agroforestry research and development. Information on growth patterns can be compared with local meteorological data to help predict which species will grow well at a particular site. Responses to cutting provide clues for identifying species suitable for a number of agroforestry technologies.

Research on root symbionts

For optimal growth and contribution to soil fertility, different tree species require the presence of specific bacterial and fungal root symbionts in the soil. Many of the bacterial symbionts that promote nitrogen fixation in leguminous plants belong to the *Rhizobium* genus. ICRAF's multipurpose-tree improvement programme is conducting research on root symbionts in collaboration with the Soil Science Department of the University of Nairobi. The objectives are:

- To characterize soil biological factors that constrain biological nitrogen fixation
- To identify the rhizobial strains most effective as symbionts with the leguminous trees emphasized in ICRAF's breeding programme
- To test the influence of soil acidity, aluminium toxicity, and levels of nitrogen, calcium and phosphorus on the performance of different rhizobial strains.

Samples were collected in 1990 from the nursery and field sites at the Maseno Centre and from a nearby swamp. Programme and university staff have carried out chemical analyses of soil samples, assessed mycorrhizal infections in root samples, and identified rhizobial strains from samples of root nodules.

Rhizobial strains were isolated from 137 samples of *Sesbania sesban* root nodules. Results showed that this species can be infected by both *Rhizobium* and *Bradyrhizobium* bacteria. Thirty isolates have been authenticated so far as pure cultures. Their effectiveness in inducing root nodulation will be tested, as well as their level of specificity across a range of the *Sesbania* provenances. In connection with this work, root samples of *Sesbania*, *Grevillea* and *Markhamia* spp. will be analysed for mycorrhizal characterization.

Chemical analysis of 79 soil samples from western Kenya revealed pH levels that ranged from 4.8 to 6.9 and organic carbon ranging from 0.6 to 3.2%. Both pH and organic carbon tended to be higher in the topsoil than in the subsoil. The fairly high pH values indicated that problems of aluminium toxicity, widespread elsewhere in the tropics, may not be important in these soils.

Multipurpose tree and shrub database

In 1983, ICRAF began compiling a global inventory of multipurpose trees and shrubs (MPTS). This work has resulted in the development of a computerized database with information on a variety of tropical and subtropical agroforestry species. Potential users include researchers, field staff, universities and organizations responsible for the implementation of agroforestry projects. The project has been financed by the Ministry of Economic Cooperation (BMZ) of the Federal Republic of Germany through the German Agency for Technical Cooperation (GTZ).

At the end of 1990, the database contained 2400 descriptions of 1093 species. About half of this information was obtained from questionnaires completed by researchers and workers in the field who have direct experience and access to local knowledge on different tree species. Other information has been gathered from the scientific literature.

The major components of the standardized descriptors used in the database are:

- Taxonomic nomenclature and geographic occurrence
- Biophysical characterization of the site in which the species was described, including climate and soil
- Phenology and morphology
- Applied reproduction and tree manipulation and management
- Tree cultivation problems and other environmental and tree characteristics
- Tree products and services.

The database can generate different types of print-outs. These include lists of species binomials; species profiles with summary information in a structured format; species summary sheets with profile information plus comments and links between tree descriptions and the sites where they were obtained; species data sheets that include the original sources of information; and reference lists.

One important use of this database is to help field workers choose species for agroforestry projects and experiments. Selection is based on computerized matching of the biophysical requirements and desired uses of multipurpose trees with site characteristics and project objectives. More than 540 requests for this type of information have already been answered.

The multipurpose tree and shrub database, including diskettes and user's manual, will be released for wider distribution in 1991. It can be operated on an IBM XT/AT or compatible computer with a hard disk, diskette drive, 640 kilobytes of random access memory, and a minimum of 10 megabytes of available disk space.

Multipurpose tree and shrub seed directory

One project in 1990 concentrated on compiling the second edition of ICRAF's multipurpose tree and shrub seed directory. The directory will include about 110 seed suppliers with seed reportedly available for nearly 900 species. In addition, 28 suppliers will be listed who offer microsymbionts, either in pure culture or in ready-to-apply inoculants. The directory will also include information on seed storage facilities and seed documentation and delivery procedures, plus species-specific data on number of seeds per kg, germination rates and recommended pretreatment methods. The directory will be published in 1991.

Multipurpose-tree improvement in West Africa

In October 1990, ICRAF, IITA and Oregon State University (USA) started a collaborative project on improvement of multipurpose trees for agroforestry development in the humid lowlands of West Africa. Work is based at IITA headquarters in Ibadan, Nigeria, but will also include evaluation trials at Onne in southern Nigeria, and in Cameroon. The project is supported by the United States Agency for International Development (USAID).

Work focuses on the evaluation of a broad range of indigenous and exotic tree species with a potential role in agroforestry systems. The project began with a review of the literature on food- and fruit-producing trees of Nigeria. This was followed by field visits to collect seed. By the end of 1990, seed had been obtained from about 40 species for evaluation at various sites. This project will place special emphasis on indigenous trees with the potential to produce fruit, food or fodder and on the adaptation of trees and shrubs to the acid soils of the region.

Workshop on *Grevillea robusta*

ICRAF's research programme on multipurpose-tree improvement included an international workshop, held in August 1990, in collaboration with the Australian Centre for International Agricultural Research (ACIAR) and CSIRO-Australia. The topic was 'The Use of *Grevillea robusta* in Agroforestry and Forestry Systems'.

This was the first international workshop devoted solely to this species. It brought together 30 specialists from eight countries to report on current progress in research, utilization and management. The participants discussed *Grevillea robusta*'s natural distribution and ecology; seed collection and storage; vegetative propagation; nursery practices; growth performance and utilization in different ecological zones; extension strategies; and the design of genetic improvement programmes. Working groups on seed management and nursery techniques, silviculture, and genetic improvement drew up lists of research priorities and identified issues that would benefit from efforts in extension and international collaboration.

ICRAF and CSIRO will publish the workshop proceedings in 1991. This will be a valuable companion to the annotated bibliography on *Grevillea robusta*, which was published in 1989.

Training and institution building

Individual training activities in 1990 included a field research project conducted by a Kenyan postgraduate student as part of a Ph.D. programme at the University of Edinburgh (UK). This work focused on a collection of 74 *Sesbania sesban* and 7 *Sesbania goetzii* provenances provided by the International Livestock Centre for Africa (ILCA)—genetic material that offers a unique opportunity to cross-breed tree provenances from widely diverse areas. In addition, a national scientist from Malawi and an M.Sc. student from Moi University (Kenya) carried out field work under the project.

Agroforestry Policy and Institutional Issues

Photo: A. Njenga

Field surveys show that most farmers are eager to increase production of fruit crops, such as banana, mango and papaya growing with leucaena and maize on this small plot in Kenya. Marketing infrastructure and pricing policies are important factors in the development of agroforestry technologies to generate cash incomes.

In many parts of the world today, the interaction between increasing population, pressure on land and degradation of natural resources is leading to a vicious circle of poverty for land users combined with an irreversible decline in the natural resource base. Agroforestry can potentially make several contributions towards the alleviation of these problems. These contributions include:

- Increased and more stable food production, resulting either directly from the introduction of trees (fodder, fruit) or indirectly through the contribution of trees to soil fertility and the sustainability of agriculture
- Higher incomes for small-scale farmers and other land users, resulting from the sale of tree products
- More products and services provided by small-scale farms, with associated benefits to rural and national economies
- Reduced dependence on external sources for key agricultural inputs (fertilizers) and subsistence products (fuelwood, building materials)
- Improved soil structure and fertility, with important effects on crop yields
- Improved microclimates through increased standing biomass, with benefits to crops, animals and people
- Reduced pressure on remaining forests due to expanded supplies of fuelwood and other products from non-forested areas
- Reduced soil erosion and siltation of waterways, achieved through the prevention of runoff on sloping land
- Reduced pressure on grazing lands through the intensification of fodder and animal production.

Agroforestry is still a new field. Considerable research and development work is needed to design technologies that are suitable for specific agro-ecological zones and to introduce these into farming and other land-use systems. However, the design and introduction of agroforestry technologies will depend as much on government policies as on research results. Crucial areas are the coordination of national agroforestry systems and the provision of adequate support for research and development activities.

Strengthening the institutional base

In many countries, there is no national institution with a mandate for agroforestry and few national scientists have training or experience in the interdisciplinary approach required for agroforestry research. Several national governments are now testing different models for organizing and managing agroforestry research. ICRAF will focus on analysing, synthesizing and sharing experience from different countries.

ICRAF is also helping to address these problems through inter-institutional coordination within and across countries, joining in the implementation of agroforestry research and providing scientific support to national institutions. In Africa, the AFRENA programme provides the framework for most of this collaborative activity. The goal is for each participating 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.

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 illustrate this:

1. All countries participating in the AFRENA programmes have established National Steering Committees for agroforestry. These meet regularly and are instrumental in establishing priorities and shaping national agroforestry strategies.
2. Agroforestry units or departments have been established by national governments in Malawi, Ghana, Niger, Senegal, Tanzania and Rwanda. In Cameroon, agroforestry has become a component of the farming systems research programme.
3. Agroforestry is increasingly included as a component of national development plans and science and technology policies, for

Ghana Expands Agroforestry Activity

ACCRA, GHANA—The Government of Ghana's commitment to agroforestry was reflected this year in the expansion of the institutional framework for increased agroforestry research, education and extension activities. This included:

- Creation of an Agroforestry Unit in the Ministry of Agriculture to implement a National Agroforestry Programme
- Establishment of a National Agroforestry Committee to advise on policy issues and to coordinate agroforestry activities of both government and non-governmental organizations
- Introduction of undergraduate and postgraduate agroforestry courses at the University of Science and Technology (UST) in Kumasi
- Implementation, with ICRAF, of the Ghana Agroforestry Systems Research and Education Project, aimed at extending agroforestry to small-scale farmers and strengthening agroforestry education and training.

...The first Ghana National Agroforestry Workshop ... took place in September, with more than 60 participants drawn from across the country. The workshop provided a forum for discussion among policy makers, planners, extension staff, researchers, educationists and staff of non-governmental organizations. Participants reviewed current activities and identified future directions and priorities for the coordinated implementation of agroforestry programmes in Ghana.

—*Agroforestry Today*
October–December 1990

Zimbabwe Takes a Place in the Southern Africa AFRENA

HARARE, ZIMBABWE—Following meetings in June this year, Zimbabwe has become a fully active participant in the Southern Africa programme of the Agroforestry Research Networks for Africa (AFRENA). Zimbabwe's participation in the network will include agroforestry research, training and education activities, coordinated through the Southern Africa Development Coordination Conference (SADCC) and ICRAF. Funding is provided by the Canadian International Development Agency (CIDA).

The Southern Africa AFRENA programme was initiated in 1986.... Participation in Zimbabwe was confined initially to training courses, workshops, and research planning and formulation. Following a macro D&D exercise in 1987, a team of Zimbabwean scientists and ICRAF staff joined in 1989 to survey ongoing agroforestry programmes in the country. This survey led to the design of an agroforestry research project for Zimbabwe, plus expansion of education and training activities.

Direction is provided by the Committee for Agroforestry, Soil and Water Conservation (CASAWAC), under the Zimbabwe Science Council, with representation from all relevant government departments. Field experiments will be established during the November/December planting season at two sites—the Makoholi Agricultural Research Station and the Domboshawa AGRITEX Demonstration Station....

CASAWAC is planning a national seminar on agroforestry for March 1991. This will provide a forum for reporting on research projects in Zimbabwe, both completed and in progress, and for clarifying future research directions and opportunities for cooperation.

—*Agroforestry Today*
July–September 1990

example in Tanzania, Kenya, Zambia, Rwanda and Ethiopia.

4. In 1990, national seminars for scientists and agroforestry practitioners were held in Malawi, Rwanda, Nigeria and Ghana.
5. AFRENA projects have featured in field days and national agricultural shows in several countries.
6. ICRAF increasingly receives requests from national governments for assistance in developing agroforestry plans and strategies and implementing agroforestry research programmes. For example, in 1990 the Government of Ethiopia asked ICRAF for assistance in developing a national agroforestry research strategy.

Studies on policy and institutional issues

In 1990, ICRAF formulated a joint research proposal with the International Service for National Agricultural Research (ISNAR). The objective is to review various strategies for institutionalizing national agroforestry research programmes including, among others, the AFRENA model.

ICRAF has also developed a collaborative research project with the Land Tenure Centre of the University of Wisconsin (USA). This project will undertake three case studies in Eastern and Southern Africa focusing on land and tree tenure issues as they relate to agroforestry. Another project currently in progress focuses on the use of different extension channels for promoting agroforestry development.

Other research topics will be addressed as needs and opportunities arise. These may include:

- Effect of the availability and price of mineral fertilizers and other inputs on the adoption of agroforestry and on its economic and environmental impact
- Role of credit in the adoption of agroforestry
- Effect of commodity prices on production from agroforestry systems
- Development of private- or public-sector services to control pests and diseases in agroforestry species.

Agroforestry Research Networks for Africa

Photo D G Peden

The multipurpose tree Maesopsis eminii *interplanted with maize at the AFRENA research site at Kabanyolo, Uganda.*

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 focus on the unimodal upland plateau of Southern Africa, the bimodal highlands of Eastern and Central Africa, the semi-arid lowlands of West Africa, and the humid lowlands of West Africa. Collaborative arrangements in each participating country are formalized through a Memorandum of Understanding between ICRAF and the national government. By the end of 1990, eight countries 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.

The AFRENA programmes in each country are led by 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.

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 begin with a macro D&D survey, 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.

The macro D&D 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 single land-use system within the target zone, called a micro D&D. This leads to the preliminary design of promising agroforestry technologies for the system and to the identification of research priorities. In 1990, scientists from ICRAF and from national programmes conducted micro D&Ds in Bangladesh, Burkina Faso, Ethiopia, Ghana, Kenya, Mali, Niger and Senegal.

Another objective of the D&D process is to identify which national institutions will contribute to the implementation of agroforestry research. These institutions plan collaborative experimental work according to the results of the micro D&D. 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. Based on these results, agroforestry technologies are designed and 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 among biological and social scientists, farmers, extensionists, development planners and policy makers. There is also a strong emphasis on communication and coordination among AFRENA research projects, particularly those in the same ecological zone. Activities are coordinated at the regional level through Regional Steering Committees.

The three Regional Steering Committees each met twice in 1990. Venues were in Malawi and Tanzania in Southern Africa, in Burundi and Kenya in Eastern and Central Africa, and in Niger and Senegal in the semi-arid lowlands of West Africa.

Through these mechanisms, opportunities for collaboration go beyond information sharing among national programmes. They involve 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.

In 1990, field experiments were in progress at 18 AFRENA sites in 8 African countries—Burundi, Cameroon, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia. In addition, experiments were starting up in Burkina Faso, Mali, Niger, Senegal, Zimbabwe and at a second site in Tanzania. This broad network of carefully coordinated experiments ensures that comparable data will be collected on agroforestry components and technologies over a wide range of altitudes, soils and climatic conditions.

On-station and on-farm experiments have been designed to test a number of different agroforestry technologies. In 1990, these included hedgerow intercropping, improved fallows, woodlots, fodderlots, trees with fodder grass on erosion-control structures, upperstorey trees on boundaries, trees in banana plots, trees planted in relay with food crops, living fences, and hedgerow intercropping with livestock. Table 7 lists the multipurpose-tree species being evaluated in the context of these technologies. General screening trials include a much larger number of species.

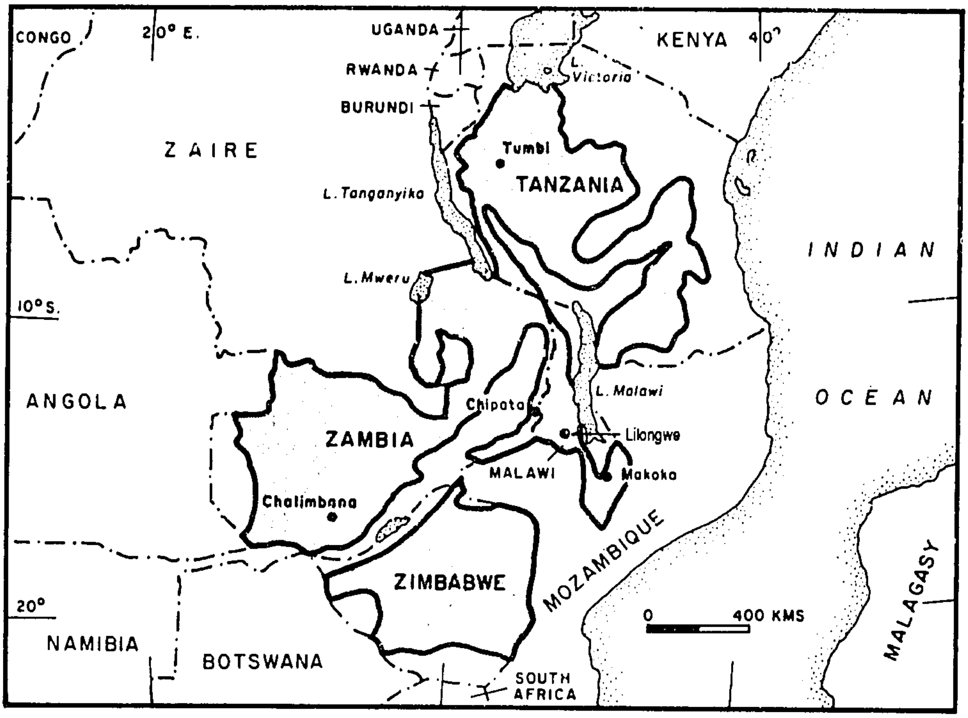
Photo: A. Njenga

Coffee and banana are major cash crops on the slopes of Mount Kilimanjaro in northern Tanzania. Both crops thrive under partial shade from pollarded Grevillea robusta *trees.*

Species (Family)	Southern Africa	Eastern and Central Africa	Humid Lowlands of West Africa
Acacia auriculiformis (Leguminosae)			Hedgerow intercropping
Alnus acuminata (Betulaceae)		Trees in upperstorey	
Cajanus cajan (Leguminosae)			Hedgerow intercropping Improved fallow
Calliandra calothyrsus (Leguminosae)	Hedgerow intercropping	Hedgerow intercropping Erosion-control structures	
Cassia siamea (Leguminosae)	Hedgerow intercropping	Trees in upperstorey	
Cassia spectabilis (Leguminosae)		Hedgerow intercropping	
Casuarina cunninghamiana (Casuarinaceae)		Trees in upperstorey	
Casuarina equisetifolia (Casuarinaceae)		Trees in upperstorey	
Cedrela odorata (Meliaceae)		Banana plots	
Cedrela serrata (Meliaceae)		Banana plots	
Cordia abyssinica (Boraginaceae)		Trees in upperstorey	
Crotalaria anagyroides (Leguminosae)			Improved fallow
Desmodium discolor (Leguminosae)			Improved fallow
Desmodium distortum (Leguminosae)			Improved fallow
Erythrina caffra (Leguminosae)		Hedgerow intercropping	
Faidherbia albida (Leguminosae)	Wood/fodder lots		
Flemingia congesta (Leguminosae)	Hedgerow intercropping		
Gliricidia sepium (Leguminosae)	Hedgerow intercropping	Hedgerow intercropping	Hedgerow intercropping
Grevillea robusta (Proteaceae)		Trees in upperstorey Banana plots	
Jacaranda mimosifolia (Bignoniaceae)		Trees in upperstorey	
Leucaena diversifolia (Leguminosae)		Hedgerow intercropping	
Leucaena leucocephala (Leguminosae)	Hedgerow intercropping	Hedgerow intercropping Erosion-control structures Banana plots	Hedgerow intercropping Wood/fodder lots
Maesopsis eminii (Rhamnaceae)		Trees in upperstorey	
Markhamia lutea (Bignoniaceae)		Trees in upperstorey	
Melia azedarach (Meliaceae)		Trees in upperstorey	
Paraserianthes falcataria (Leguminosae)			Hedgerow intercropping
Psidium guajava (Myrtaceae)	Mixed intercropping		
Sesbania sesban (Leguminosae)	Hedgerow intercropping	Hedgerow intercropping Mixed intercropping Improved fallow Erosion-control structures Wood/fodder lots	
Sesbania macrantha (Leguminosae)	Hedgerow intercropping		

Table 7. Multipurpose-tree species in agroforestry technology trials at 18 AFRENA sites in 1990.

Unimodal Upland Plateau of Southern Africa



Research Site	Associated National Research Institute	Altitude	Minimum/ Maximum Temperatures	Average Annual Rainfall	Soils
Zomba, Malawi	Makoka Agricultural Research Station	1000 m	15.0°/26.0°C	850 mm	luvisols
Lilongwe, Malawi	Chitedze Research Station	1180 m	13.0°/27.2°C	890 mm	luvisols
Tabora, Tanzania	Tumbi Research Institute	1200 m	16.3°/28.0°C	880 mm	ferric acrisols
Chalimbana, Zambia	Mount Makulu Research Station	1143 m	14.0°/28.0°C	800 mm	luvisols
Chipata, Zambia	Msekera Regional Research Station	1020 m	13.8°/32.5°C	1000 mm	ferric luvisols

The Southern Africa AFRENA programme was launched in 1986 with funding provided by IDRC and the Canadian International Development Agency (CIDA). The programme focuses on the upland plateau ecological zone of southern Africa, a region that covers approximately 1 million sq km at an altitude of 900 to 1500 m. In 1990, agroforestry research was in progress in Malawi, Tanzania and Zambia, and a programme was at the planning stage in Zimbabwe.

The main land-use system in this region is small-scale farming. Crop production relies on one growing season, from December to April, with a long dry season the rest of the year. D&D studies in the four countries revealed two major land-use problems that affect farmers across the region—declining soil fertility and dry-season shortages of livestock fodder. Research was designed to develop agroforestry interventions that address these problems in the zone as a

Malawi: Makoka and Lilongwe	Tanzania: Tumbi
• MPT screening: 37 species • MPT screening: 4 species • Sesbania cutting techniques • Sesbania relay planting • Indigenous fruit-tree seed germination • Effects of *Gmelina arborea* on crop seed germination • On-farm trials (Lilongwe)	• MPT screening: 11 species • Leucaena management • Pigeonpea management • Sesbania management • Susceptibility to nematodes • Rotational hedgerow intercropping • Hedgerow intercropping with livestock • Animal feeding: forage selection • Animal feeding: supplementation
Zambia: Chalimbana	**Zambia: Chipata**
• MPT screening: 16 species • MPT screening: 25 species • Hedgerow intercropping • Hedgerow intercropping with livestock • Hedgerow intercropping: pruning application • Improved fallow • Intercropping with guava	• MPT screening: 16 *Gliricidia sepium* provenances • Improved fallow with *Sesbania sesban* • Hedgerow intercropping: role of mulch • Wood- and fodderlots • On-farm trials

Table 8. Experiments in progress in Southern Africa during 1990.

whole. This work is now in progress at Makoka in Malawi, at Tumbi in Tanzania, and at Chalimbana in Zambia.

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).

A second national project was initiated in Malawi in 1990, emphasizing on-farm research, with funding provided by IDRC and the Rockefeller Foundation. A national project is also starting in Tanzania, based at Shinyanga, with support from the Norwegian Agency for International Development (NORAD).

ICRAF helps coordinate all these activities together with the Southern Africa Centre for Cooperation in Agricultural Research (SACCAR), which acts on behalf of the Southern Africa Development Coordination Conference (SADCC). Complementarity of research efforts is ensured primarily through regular zonal workshops and meetings of National Agroforestry Steering Committees.

Malawi

Collaborative research in Malawi began at the Makoka Agricultural Research Station near Zomba. Within the zonal programme, Makoka has the major responsibility for identifying, acquiring and evaluating multipurpose-tree germplasm. The objective is to select promising multipurpose trees for testing in relation to specific agroforestry technologies.

In addition, an on-farm research project was launched in 1990 in collaboration with the Ministry of Agriculture's Agroforestry Commodity Team, based at the Chitedze Research Station near Lilongwe.

Multipurpose-tree screening trials

The largest multipurpose-tree screening trial at Makoka covers 49 accessions of 37 species (Table 9). Since planting in December 1988, field staff have collected information every four months on survival, height, root-collar

Good Performance	Moderate Performance	Poor Performance
Acrocarpus fraxinifolius (2)	*Acacia aulacocarpa* (1)	*Acacia ampliceps* (1)
Calliandra calothyrsus (2)	*Acacia auriculiformis* (1)	*Acacia burrowii* (1)
Cassia siamea (3)	*Acacia cyanophylla* (1)	*Acacia eripoda* (1)
Cassia spectabilis (2)	*Acacia julifera* (1)	*Acacia difficilis* (1)
Flemingia congesta (1)	*Acacia melanoxylon* (1)	*Acacia murrayana* (1)
Gliricidia sepium (6)	*Albizia falcataria* (1)	*Acacia pachycarpa* (1)
Gmelina arborea (1)	*Albizia schimperiana* (1)	*Acacia salicina* (1)
	Faidherbia albida (3)	*Acacia shirleyi* (1)
	Maesopsis eminii (1)	*Acacia stenophyla* (1)
	Schizolobium excelsum (1)	*Acacia trachycarpa* (1)
	Vangueria infausta (1)	*Acacia tumida* (1)
		Acacia victoriae (1)
		Cassia brewsteri (1)
		Prosopis chilensis (1)
		Prosopis cineraria (1)
		Prosopis juliflora (1)
		Prosopis pallida (1)
		Prosopis tamarugo (1)
		Robinia pseudoacacia (1)

Table 9. Performance of 37 multipurpose-tree species 15 months after establishment at Makoka, Malawi. Assessment was based on survival, growth, biomass production and coppicing ability. Number of accessions in brackets.

diameter, branching pattern and crown spread. In February 1990—15 months after establishment—half the trees were harvested from each accession. Harvested material was assessed for biomass (dry wt) and nutrient content, and coppicing characteristics were evaluated from the stumps left after cutting.

Table 10. Average heights (m) and root-collar diameters (cm) of the best accessions of 7 multipurpose-tree species 15 months after establishment at Makoka, Malawi.

Species	Height (m)	Root-collar Diameter (cm)
Calliandra calothyrsus	4.2	6.4
Acrocarpus fraxinifolius	4.1	7.5
Gmelina arborea	3.3	9.6
Gliricidia sepium	3.1	5.7
Cassia spectabilis	3.1	4.8
Casssia siamea	2.5	5.6
Flemingia congesta	2.3	2.8

Seven species showed the best overall performance based on growth, biomass production and coppicing ability. These were *Calliandra calothyrsus*, *Gmelina arborea*, *Cassia siamea*, *Gliricidia sepium*, *Acrocarpus fraxinifolius*, *Cassia spectabilis* and *Flemingia congesta*. The fastest growing was *Calliandra calothyrsus* (ex Guatemala) (Table 10). Above-ground biomass from these species ranged from 3.5 to 12.1 t/ha (dry wt), with estimated mean annual increments ranging from 2.0 to 8.0 t/ha. *Gmelina arborea* and *Calliandra calothyrsus* showed the highest biomass production, exceeding 10 t/ha.

The Australian acacias generally grew slowly and coppiced poorly after cutting. The *Prosopis* species also performed poorly, while most of the other species tested showed slow to intermediate growth. The fruit tree *Vangueria infausta* flowered and produced fruits only 18 months after planting.

Four multipurpose-tree species were tested in a separate trial focusing on growth, coppicing ability, and quantity and quality of biomass production. Established in January 1989, this

Species and Provenance	Survival (%)	Mean Height (m)	Total Biomass (t /ha dry wt)	Mean % Foliage
S. sesban (ex Magoye, Zambia)	88	3.96	13.7	14
S. macrantha (ex Kasama, Zambia)	59	4.57	14.6	11
S. sesban (ex Kakamega, Kenya)	56	4.54	20.4	15
S. sesban (ex Jamhuri, Kenya)	49	4.19	29.4	17
S. bispinosa (ex Machakos, Kenya)	43	4.43	17.7	12

Table 11. Survival and growth of 5 sesbania provenances 1 year after cutting at Makoka, Malawi.

trial included 17 seed sources of *Leucaena leucocephala*, 4 provenances of *Sesbania sesban*, and 1 provenance each of *Sesbania macrantha*, *Sesbania bispinosa* and *Sesbania formosa*. Survival at three months after planting was better than 90% for all accessions except *Sesbania formosa* and one source of *Leucaena leucocephala* (ex Machakos, Kenya).

The other sesbanias grew extremely well during the first three months after establishment. At this point, they were cut at 30 cm above ground. They produced high biomass yields, but only one accession coppiced well after cutting—*Sesbania sesban* (ex Magoye, Zambia). Another provenance—ex Phalombe, Malawi—matured and died after five months.

In April 1990—15 months after establishment and 12 months after the first cutting—the remaining trees were assessed for height, root-collar diameter and crown characteristics and were then cut again and biomass partitioned and measured. The sesbanias that survived the first cutting produced multiple stems and heavy branching. This resulted in high above-ground biomass production from the second cutting (Table 11), with foliage constituting 11 to 17% of the total.

The leaves contained 3.1 to 3.6% nitrogen. Results indicated that one hectare of sesbanias could produce green manure containing at least 70 kg of nitrogen. However, this green manure would not supply enough phosphorus for maize production, suggesting that farmers would have to supplement green manure from sesbanias with phosphorus fertilizer.

The leucaenas generally grew well, although less quickly than the sesbanias, and production characteristics tended to be rather uniform. All grew back well after the first cutting. At the time of the second cutting, the best provenances were more than 3 m tall and had produced more than 5 t/ha (dry wt) of above-ground biomass, with proportions of foliage ranging from 14 to 26%. Selection of specific accessions will have to await an assessment of growth and coppicing ability over the next two years.

Management of sesbanias

Due to their rapid growth and spreading crowns, the sesbanias may not be suitable for intercropping unless they can be cut on a regular basis. Problems of crowding and competition could be particularly serious in the Shire highlands of Malawi where most landholdings are only 0.2 to 0.5 ha.

At the same time, the capacity to regrow after cutting appears to vary widely among different sesbania species and provenances. Thus, an experiment was conducted to assess the response of three sesbania species to different cutting techniques plus the effects of sesbania mulch on interplanted maize. *Sesbania sesban*, *Sesbania bispinosa* and *Sesbania macrantha* seedlings were planted in February 1989, and cutting began in January 1990. The three cutting techniques tested were:

- Coppicing: cutting all stems at 30 cm
- Hedge formation: cutting all branches at 1 m
- Pruning: removing branches to leave only 25% of the crown.

Coppicing generally produced the most biomass and pruning the least. However, none of the species grew back well after coppicing. Pruning turned out to be difficult because many of the one-year-old trees were already more than 4 m tall. When cut at 1 m, *Sesbania sesban* formed good hedges, which were harvested three times during the 1990 growing season.

The other species did not form hedges well because they did not produce branches below a stem height of 2 m.

Interplanted maize grew well with sesbania mulch on plots where the sesbanias were coppiced or cut to form hedges, but not on plots where the trees were only pruned. All the sesbanias produced a good supply of fuelwood, small poles and stakes, particularly *Sesbania sesban*.

A second experiment began in December 1989 to test a relay-planting arrangement designed to maintain the recommended population of maize plants on cropland while utilizing the soil-improving capability of the sesbanias. Maize was planted at the standard spacing and sesbania seedlings were interplanted at four stages of maize growth—at sowing, at the time of rapid stem elongation, at tasselling, and at maturity. Three levels of fertilization were also incorporated in the trial: the full recommended amount for Malawi (18 kg N/ha and 20 kg P/ha plus 42 kg N/ha applied as top dressing), 50% of this amount, and none.

After harvesting the maize, the sesbanias were allowed to grow until the end of the dry season. Then they were harvested and the leaves, flowers, pods, twigs and small branches were incorporated into the soil. Maize was replanted in December 1990.

Both tree growth and crop yield were poor due to below-average rainfall in early 1990. Maize yields were only slightly reduced on plots where maize and sesbania were planted at the same time, but sesbania growth was poor on plots where the trees were planted late in the growing season. It is too early to draw conclusions, but it may be possible, at a minimum, to produce fuelwood and green manure from sesbanias under this arrangement without reducing maize yields.

Germination of indigenous fruit trees

A multipurpose-tree survey conducted in 1989 indicated that farmers in Malawi's upland plateau region value several indigenous fruit trees as a family food supplement and, in some cases, a source of cash income. Many of these fruit trees are found only in natural stands and are thus declining as more land is brought under cultivation.

Farmers expressed an interest in planting indigenous fruit trees on boundaries or around

Photo: H. Prins

Farmers in Malawi have to travel long distances to find fuelwood. The malformed tree in the background shows the results of indiscriminate cutting, which could be alleviated by the expansion of agroforestry.

their homes, but they lacked information on how to propagate them. Thus, project staff conducted studies to identify simple and effective germination techniques for 18 species. The simplest methods were removal of fruit pulp or soaking in cold water for 24 hours or both.

Using these methods, the following species showed 80% or higher germination rates: *Bridelia cathartica, Bridelia micrantha, Diospyros usambariensis, Parkia filicoidea, Piliostigma thonningii, Strychnos spinosa, Syzygium cordatum, Tamarindus indica, Terminalia catappa, Uapaca kirkiana, Ziziphus abyssinica* and *Ziziphus mauritiana*.

For good germination, *Azanza garckeana* required more complicated techniques, such as scarification by nicking or complete removal of the seed-coat, whereas *Flacourtia indica* and *Parinari curatellifolia* germinated poorly regardless of the treatment.

Effects of *Gmelina arborea* leachates on crop-seed germination

Gmelina arborea was identified as a potentially useful multipurpose tree in early screening trials. This species is widely grown in Malawi to produce fuelwood for domestic use and for curing tobacco.

However, a number of farmers interviewed in the 1989 multipurpose-tree survey observed that gmelina may have an inhibiting effect on the germination of food crops. Thus, laboratory and nursery trials were conducted in 1990 to test the effects of gmelina leachates on the germination of maize, rice, sorghum, finger millet and pearl millet.

Root and litter leachates tended to slow down germination, while leachates from bark, green leaves and green fruit had some inhibiting effect. Leachates from ripe fruit depressed seed germination dramatically.

In Malawi, the gmelina fruits ripen and fall in large numbers in November and December, just when farmers are sowing maize and other cereal crops. Raking away the fruit or pruning the trees to limit flowering could improve conditions for crop production. However, gmelina roots and litter also tend to slow down seed germination for cereal crops and this could have a serious impact in areas with a short growing season.

On-farm research

A national on-farm research project began in the Lilongwe area in 1990, with collaboration from ICRAF. Based at the Chitedze Research Station, the project builds on the research programme of the Ministry of Agriculture's Agroforestry Commodity Team.

Maize and other agricultural crops predominate on the plains around Lilongwe and livestock play an important, but secondary, role. The average farm size is only 2 ha and cultivation is intensive. Major problems are declining soil fertility, lack of fodder and fuelwood, and poor control of livestock in areas of permanent cultivation.

Earlier research indicated that hedgerow intercropping with *Leucaena leucocephala* could increase maize yields, particularly when complemented by the application of inorganic fertilizer at half the recommended rate. It is possible to establish hedgerows by direct seeding, with minimum labour requirements and establishment rates as high as 75% on level ground with good soils. On-farm studies have also shown that the traditional system of mixed intercropping with *Faidherbia albida* can result in substantial increases in crop yields.

Ten farmers have been selected within the Lilongwe West Rural Development Programme to participate in hedgerow-intercropping trials. Five are also testing living fences for livestock control. In the Lilongwe East Rural Development Programme, six farmers are participating in a hedgerow-intercropping trial and five are testing fodder banks. Some fodder banks are composed of *Leucaena leucocephala* in pure stands and some are leucaena mixed with napier grass (*Pennisetum purpureum*) in a hedgerow-intercropping arrangement.

A total of 13 farmers from the two areas are participating in a mixed-intercropping trial with fruit trees and 11 are testing an improved system for mixed intercropping with *Faidherbia albida*. In addition, field surveys have been initiated to evaluate traditional agroforestry systems.

Training and institution building

Three B.Sc. students conducted agroforestry studies within the Malawi AFRENA programme in 1990 as part of their final-year degree requirements from the the University of

Malawi's Chancellor College. In addition, 15 students from Mulunguzi Secondary School at Zomba completed agroforestry research projects with assistance from ICRAF staff. One Malawian member of a national working group on indigenous fruit trees has received a one-year ICRAF Visiting Fellowship to work under the project in 1991, with funding provided by GTZ.

ICRAF helped organize the first Malawi National Agroforestry Symposium, which took place in November 1990. Project staff participated in a seminar to discuss the introduction of agroforestry into the curricula of southern African forestry colleges, took part in a national working group on indigenous fruit trees, and gave advice on the design of agroforestry demonstrations to the Agricultural Development Division and the Forestry Research Institute. The project also provided multipurpose-tree seedlings to farmers and research and development institutions in Malawi.

The on-farm research programme based at Lilongwe conducted a training course for collaborating extension staff. About 30 extensionists participated.

Tanzania

Collaborative research in Tanzania is based in Tabora in the western part of the country at the Ministry of Agriculture and Livestock Development's Tumbi Research Institute. Maize and tobacco are the main crops in the area and livestock production is also important. Major problems include low soil fertility, shortages of fuelwood for tobacco curing and household use, and inadequate grazing during the long dry season. The zonal mandate for agroforestry research at Tumbi focuses primarily on fast-growing multipurpose trees for fodder production.

Multipurpose-tree screening trials

A screening trial was established at Tabora in the 1987/88 cropping season to investigate the growth, coppicing ability, biomass production and palatability of seven Australian acacias plus *Faidherbia albida*, *Leucaena leucocephala* and *Sesbania sesban*. Two of the Australian species, *Acacia cincinnata* and *Acacia platycarpa*, failed to establish and were eliminated from the trial.

Height, root-collar diameter and biomass yields were recorded in 1990, two years after establishment (Table 12). The *Sesbania sesban* had died by this time, while the *Faidherbia albida* was the least productive of the remaining species. Among the Australian acacias, *Acacia julifera*, *Acacia auriculiformis*, *Acacia leptocarpa* and *Acacia tortuosa* performed well.

Trees randomly selected from each species were then cut back, either at 50 cm or at ground level. *Acacia julifera* died after cutting at either height. *Acacia leptocarpa* and *Acacia tortuosa* survived after cutting at 50 cm, but not after cutting at ground level. *Acacia auriculiformis*, *Faidherbia albida* and *Leucaena leucocephala*

Table 12. Average height and biomass production of 8 multipurpose-tree species at first coppicing, 24 months after establishment at Tabora, Tanzania.

Species	Height (m)	Dry Matter Yield (t /ha) Wood	Dry Matter Yield (t /ha) Leaves and Twigs
Acacia julifera	5.9	44.5	13.5
Acacia auriculiformis	5.9	39.0	4.3
Acacia leptocarpa	5.7	49.3	20.0
Leucaena leucocephala	5.5	49.3	7.3
Acacia platycarpa	4.9	20.8	—*
Acacia tortuosa	4.6	27.8	17.3
Sesbania sesban	3.7	14.3	—*
Faidherbia albida	0.6	8.3	0.8

*Trees had died and shed leaves at time of coppicing.

survived and grew back after cutting at either height. Material from all the species tested was palatable to goats.

Management trials

Management trials in progress in 1990 focused primarily on leucaena, sesbania and pigeonpea. One experiment was initiated in the 1988/89 cropping season to assess optimal cutting heights for eight *Leucaena leucocephala* provenances plus one provenance each of *Leucaena esculenta* and *Leucaena diversifolia*. Trees were cut at 25, 50 or 100 cm above ground every three months during the growing season and every six months during the dry season.

Yields from the *Leucaena leucocephala* provenances were generally higher than from the other two species. Different provenances yielded best when cut at different heights. General recommendations on optimum cutting heights will have to await the accumulation of data over a longer period.

Pigeonpea (*Cajanus cajan*) is a fast-growing legume that can provide farmers with food grain, fuelwood and livestock fodder. An experiment in 1990 assessed biomass production and management strategies for 22 provenances of pigeonpea, including 11 biennial fodder types and 11 perennial tree types. Half the plants were cut in November 1989—at 60 cm above ground for the fodder types and 75 cm for the tree types—and half were allowed to grow undisturbed. Beginning in March 1990, all were sampled on a monthly basis to estimate fodder and wood yields.

For all provenances, as expected, the proportion of wood increased in relation to fodder as the plants matured. The tree types were generally more productive than the fodder types. Plants that had been cut the previous year yielded a higher proportion of fodder, while those that had not been cut yielded more wood. Detailed recommendations on provenances and cutting regimes must await an assessment of grain production at the end of at least two growing seasons.

Another experiment in 1990 assessed the effects of different cutting regimes on survival and biomass production of nine provenances of *Sesbania sesban* and six provenances of *Sesbania macrantha*. Seedlings were planted in March and samples from each provenance were cut in June at a height of 75 cm above ground. Additional samples were cut at the same height each month thereafter.

The *Sesbania sesban* provenances showed higher ratios of fodder to wood than the *Sesbania macrantha* provenances, but, in absolute terms, the *Sesbania macrantha* produced both more wood and more fodder. Fodder and wood production were generally higher for trees cut in June than for those cut in August, probably due to leaf shed at maturity and damage from insect pests.

Finally, a nursery study conducted during the 1989/90 growing season assessed the susceptibility of *Sesbania sesban*, *Sesbania macrantha* and *Acacia auriculiformis* to root damage from the nematodes *Meloidogyne javanica* and *Meloidogyne incognita*. Sesbania and tobacco are both susceptible to root damage by nematodes, and infestation can become a serious problem if sesbanias are planted on land where tobacco has grown.

In this experiment, both sesbania species showed root damage, although the *Sesbania macrantha* showed more resistance than the *Sesbania sesban*. The *Acacia auriculiformis* was not affected.

Hedgerow-intercropping trials

An experiment was established during the 1987/88 cropping season to evaluate a rotational hedgerow-intercropping system with *Leucaena leucocephala*. Leucaena seedlings were planted in double hedgerows 75 cm apart with 4-m alleys.

The following year, the hedgerows were cut at 50 cm above ground and the cuttings were chopped and incorporated into the alleys at rates of 0, 50 and 100% of total biomass harvested from each plot. Maize was then planted in the alleys without fertilizer.

Biomass yields from the hedgerows varied widely during the 1989/90 cropping season. Both maize stover weights and grain yields were highest when all the mulch was incorporated in the alleys, but they were still below normal yield figures with standard fertilizer application.


Photo J A Maghembe

At 18 months of age. Acrocarpus fraxinifolius *trees at the Makoka Agricultural Research Station in Malawi tower over ICRAF's research associate.*

A second experiment is in progress to evaluate hedgerow intercropping systems with a livestock component. Hedgerows of *Leucaena leucocephala* and *Sesbania sesban* were established in the 1988/89 cropping season. They were cut the following year at 75 cm above ground and maize was planted in the alleys. Three treatments were compared:

- All prunings removed
- All prunings removed and fed to goats and all manure returned to the soil
- All prunings returned to the soil as mulch.

No significant differences were detected in terms of maize stover or grain yields. This may be due to a dry period in the middle of the 1989/90 growing season that seriously affected the maize crop.

Feeding trials

Two animal feeding trials began in the dry season of 1990. The objective is to assess supplementary feed requirements for livestock maintained in this area on natural pasture.

One study monitors the forage selected by cattle, sheep and goats grazing freely on an unimproved pasture. The second assesses the feed intake and growth rate of kids supplemented with leucaena, sesbania or pigeonpea fodder. The first results will be available in 1991.

Training and institution building

In 1990, one Tanzanian M.Sc. student carried out a research assignment in association with the project. In addition, one collaborating national scientist from Tanzania completed a three-week fellowship at ICRAF headquarters in Kenya.

Zambia: Chalimbana

A zonal agroforestry research project was established in 1987 at Chalimbana Agricultural Research Station in Zambia, concentrating on the contribution of agroforestry to soil fertility. Experiments in progress include multipurpose-tree screening trials and agroforestry technology trials focusing on hedgerow intercropping and improved fallows. All results for the 1989/90 growing season were affected by low and erratic rainfall.

Multipurpose-tree screening trials

The first screening trial at Chalimbana, established in December 1987, included 6 exotic and 10 local species. All were successfully established except *Sesbania grandiflora* and *Sesbania macrantha*. In April 1990—28 months after planting—average heights for the other 14 species ranged from more than 6 m for *Sesbania sesban* and *Eucalyptus camaldulensis* to less than 1.0 m for *Afzelia quanzensis* and *Ventilago viminalis* (Table 13).

There was also wide variation in biomass yields, with *Sesbania sesban* giving the highest wood yields and *Eucalyptus camaldulensis* yielding the largest amount of leafy biomass. Total leafy biomass was higher than indicated for all species because the amounts measured did not include litterfall during the growing period.

A second screening trial began in January 1989 with 25 species, including several Australian acacias. Five species did not establish successfully—*Acacia stenophylla*, *Acacia ampliceps*, *Acacia murrayana*, *Acacia cyanophylla*, *Robinia pseudoacacia* and *Sesbania formosa*.

Among the others, height and root-collar diameter 16 months after establishment were greatest for *Sesbania sesban* and *Sesbania macrantha*. For *Acacia stenophylla*, *Calliandra calothyrsus* and *Acacia murrayana*, heights varied among individual trees by as much as 50%.

Hedgerow intercropping

A trial was established in December 1987 to assess the effects on maize of hedgerow intercropping with *Leucaena leucocephala*, *Flemingia congesta* and *Sesbania sesban* with and without inorganic fertilizer. The hedgerows were pruned twice during the 1989/90 growing season at heights of 50 or 100 cm and prunings were applied to the maize rows.

In the first year of the trial, the sesbania showed the best height growth, biomass production and wood yield. However, this species suffered from termite attack in the second year and as a result total biomass production in 1990 was higher for leucaena and flemingia. Leucaena also provided the best ground cover, which resulted in better suppression of weed growth. Maize yields were low for all treatments due to

Table 13. Average height and biomass production of 14 multipurpose-tree species 28 months after establishment at Chalimbana, Zambia.

Species	Height (m)	Dry Matter Yield (t/ha dry wt) Wood	Leaves and Twigs
Sesbania sesban	6.3	55.5	2.2
Eucalyptus camaldulensis	6.3	45.9	11.3
Eucalyptus grandis	5.6	16.0	3.0
Cassia siamea	4.5	32.9	5.9
Leucaena leucocephala	3.9	23.1	3.7
Acacia polyacantha	3.8	24.0	1.8
Flemingia congesta	3.6	21.5	1.3
Albizia adianthiflora	3.0	4.5	0.8
Casuarina cunninghamiana	2.5	1.7	0.5
Faidherbia albida	1.6	1.2	0.1
Acacia ataxacantha	1.5	4.7	0.2
Sterculia africanum	1.0	0.8	0.5
Afzelia quanzensis	0.6	0.1	0.1
Ventilago viminalis	0.4	0.0	0.1

Species	Fertilizer Application (kg N/ha)	Maize Grain Yield (t/ha dry wt) At 50 cm Cutting Height	At 100 cm Cutting Height
Leucaena leucocephala	0	0.5	0.4
	68	2.0	1.2
Flemingia congesta	0	1.2	0.7
	68	1.8	1.7
Sesbania sesban	0	1.5	1.3
	68	1.8	2.3
Control (maize only)	0	0.4	
	68	1.1	

Table 14. Maize grain yields under hedgerow intercropping with leucaena, flemingia or sesbania, cut at 50 or 100 cm, with or without inorganic fertilizer, 1989/90 cropping season, Chalimbana, Zambia.

low and erratic rainfall during the growing season (Table 14). The experiment will continue in 1991.

In January 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 management regimes:

- All prunings removed
- All prunings removed and fed to goats and all manure returned to the soil
- All prunings returned to the soil as mulch.

After one year's growth the hedgerows were pruned at a height of 100 cm. The two sesbania species produced much more biomass than the leucaena. The animal component will be introduced in the 1990/91 growing season.

A third hedgerow-intercropping experiment is in progress to compare the effects of different amounts of *Leucaena leucocephala* prunings on maize plus the effects of different application methods on yields and soil properties. Hedgerows established during the 1989/90 growing season will be pruned in 1990/91. Four levels of prunings will be applied to interplanted maize using four methods of application.

Improved fallows

An improved-fallow trial is in progress comparing *Sesbania sesban* planted with maize in one-, two- or three-year rotations and maize planted continuously without fallows, both with and without fertilizer at the standard recommended rate. The sesbania was planted in January 1989 and cut at ground level in December. Leaves and twigs were separated from wood and incorporated into the soil.

Wood yields from one year's growth averaged 21 t/ha (dry wt). The yield of leaves and twigs averaged 11 t/ha plus litterfall, which was not measured.

Maize grain yields after a one-year sesbania fallow without fertilizer were double the yields from control plots with no fallow and no fertilizer and about 60% higher than yields from plots with fertilizer alone (Table 15). These early results suggest that improved fallows with *Sesbania sesban* could have considerable potential for improving maize production in Southern Africa.

Intercropping with guava

D&D surveys have indicated that farmers in the region would like to raise fruit trees, both to provide a cash income and to enhance family nutrition. Guava (*Psidium guajava*) is a popular species that grows quickly but may be affected by declining soil fertility. Thus, an experiment was established to test the effects of *Sesbania sesban* prunings on the growth of three types of guava.

Guava and sesbania seedlings were interplanted in early 1989. In 1990, two years after establishment, the height of guava trees interplanted with sesbania was slightly less than the height of guava grown in pure stands. The ses-

Multipurpose-tree screening trials at Yaoundé, Cameroon, include studies of root distribution and analyses of soil changes under different tree species.

bania will be cut and prunings applied during the 1990/91 growing season.

Training and institution building

One M.Sc. student from Malawi completed his thesis research at Chalimbana in 1990, and one Zambian M.Sc. student will conduct research with the project in 1991. Plans are also under consideration for undergraduate students from the University of Zambia to conduct B.Sc. research with the project. One member of the project staff and one staff member from the University of Zambia participated in ICRAF's Technician Training Course in 1990.

Project staff contributed to the University's M.Sc. programme in crop science and supplied sesbania fodder for experiments conducted by the University's Animal Science Department. The project also participated in the Zambia National Agricultural and Commercial Show.

Zambia: Chipata

A national agroforestry research project was established in 1987 at Msekera Regional Research Station at Chipata in Zambia's Eastern Province. 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 trees capable of improving soil fertility and providing supplementary dry-season fodder and fuelwood and to design and test agroforestry technologies, such as hedgerow intercropping and improved fallows, that are suitable for local land-use systems. As at Chalimbana, all results from the 1989/90 growing season were affected by low and erratic rainfall.

Multipurpose-tree screening trial

A screening trial began in 1988 to test 15 provenances of *Gliricidia sepium* for survival, growth and biomass production for green manure and dry-season livestock fodder. There was considerable variability both between and within provenances. Two years after establishment, average heights ranged from 2.8 to 4.6 m and total biomass ranged from 13.0 to 32.1 t/ha (dry wt).

Treatment	Grain Yield (t/ha dry wt)	Stover Yield (t/ha dry wt)
Fallow only	3.2	5.4
Fertilizer only (recommended rate)	2.0	4.9
No fallow/no fertilizer	1.4	3.7

Table 15. Maize grain and stover yields after a 1-year Sesbania sesban *fallow compared with non-fallowed plots with and without inorganic fertilizer, 1989/90 cropping season, Chalimbana, Zambia.*

Two particularly promising provenances were selected for further testing in hedgerow-intercropping systems—one from Colombia and one from Guatemala. In an associated feeding trial, 90% of fresh *Gliricidia sepium* foliage was rejected by goats, indicating the need for further palatability tests.

Improved fallows

An improved-fallow trial, launched in December 1987, involved growing *Sesbania sesban* for one, two or three years, felling the trees, and planting maize with or without inorganic fertilizer. All biomass from the trees was incorporated into the soil except the stems, which farmers would normally use as fuelwood. Early results indicated that a sesbania fallow could increase maize grain yields from the crop immediately following the fallow and even from the second crop planted a year later (Table 16).

A two-year fallow increased subsequent maize yields more than a one-year fallow. For one-year fallows, the beneficial effect appeared to increase when trees were densely planted—at a spacing of 50 x 50 cm. Results from plots under three-year fallows will be available in 1991.

Hedgerow intercropping

Results are now available from two years of hedgerow intercropping with *Flemingia congesta*, *Cassia siamea* and *Leucaena leucocephala*, with and without fertilizer. The hedgerows were pruned twice a year, at the

Fallow and Cropping Cycle	Fertilizer (kg N/ha)	Maize Grain Yield (t/ha dry wt) Trees Spaced At 50 cm	Trees Spaced At 100 cm
Two years sesbania:	0	5.0	5.1
First year maize	37	6.3	5.6
(1989/90)	74	6.7	6.6
	112	7.1	7.2
One year sesbania:	0	2.3	1.6
First year maize	37	3.9	3.3
(1988/89)	74	6.0	4.3
	112	7.3	5.9
One year sesbania:	0	3.0	3.1
Second year maize	37	5.2	4.2
(1989/90)	74	5.6	4.4
	112	6.2	5.9
Control:	0	1.2	
Maize only	37	3.2	
(1989/90)	74	4.2	
	112	4.9	

Table 16. Maize grain yields after sesbania fallows, with and without inorganic fertilizer, during the 1988/89 and the 1989/90 cropping seasons at Chipata, Zambia.

beginning and the end of the growing season, and all prunings were applied to maize grown in the alleys.

Total production of leafy biomass in the second year was generally highest for cassia. Leucaena and cassia hedgerows cut at 100 cm produced more leafy biomass than hedgerows cut at 50 cm, whereas cutting height had no effect on biomass production from flemingia. Fertilizer application to the crop generally lowered leafy biomass production from the hedgerows.

Maize grain yields in the second year were highest, at 6.3 t/ha (dry wt), with cassia cut at 100 cm plus fertilizer, and lowest, at 1.5 t/ha, with leucaena cut at 100 cm without fertilizer. In general, yields were highest with cassia, followed by flemingia and leucaena. Maize grain yields were considerably higher with fertilizer, but the effects of hedgerow cutting heights were inconsistent.

In the first year, none of the hedgerow treatments yielded as well as comparable controls—maize grown in pure stands with and without fertilizer. In the second year, 3 out of 12 hedgerow treatments performed better than controls. The real value of this technology can only be assessed over a longer period.

A second trial was started in 1989 to assess the effects on maize yields of *Leucaena leucocephala* and *Gliricidia sepium* mulch with and without nitrogen fertilizer. Mulch from separate plots was applied at levels ranging from 0 to 20 t/ha (fresh wt) and maize was planted three weeks later. Fertilizer was applied at rates ranging from 0 to 120 kg N/ha.

Maize grain yields averaged 1.4 t/ha (dry wt) on the gliricidia plots and 1.7 t/ha (dry wt) on the leucaena plots without mulch or fertilizer and increased as mulch and fertilizer levels increased (Table 17). The combination of 10 t/ha (fresh wt) of gliricidia or leucaena mulch with nitrogen fertilizer at half the recommended rate (60 kg N/ha) produced yields comparable with levels achieved using the full recommended rate

(120 kg N/ha) of fertilizer without mulch. The trial will be repeated on the same plots in 1991.

Wood and fodder lots

In addition to their potential to increase soil fertility and thus enhance crop production, fast-growing multipurpose trees could play an important role in supplying farm wood and fodder requirements. Three lots of *Leucaena leucocephala* seedlings were established in December 1988, planted in pure stands at three spacings: 2 x 2, 1 x 1, and 0.5 x 0.5 m. They were harvested in January 1990 by cutting at heights of 50 or 100 cm above ground.

Establishment rates were good. At the time of cutting, average heights ranged from 3.5 to 4.6 m. Individual trees grew best at the widest spacing, as expected, but both woody and leafy biomass per unit of land were greatest for trees planted at the closest spacing. Cutting height did not have a consistent effect on the amount of leafy biomass harvested, but may affect subsequent yields from coppice regrowth. Cutting at 50 cm resulted in slightly higher wood yields.

On average, the total above-ground biomass of these 14-month-old leucaenas comprised 23% leaves, 14% branches and 63% stem. With stem and branches accounting for 77% of total biomass, *Leucaena leucocephala* could be a useful species for fuelwood production in this region.

Faidherbia albida seedlings were planted at the same time at spacings ranging from 2 x 2 to 5 x 5 m. Average heights at 14 months ranged from 2.5 to 2.7 m for different cutting heights, but there was considerable variability among individual trees.

Seedlings of *Sesbania sesban* were planted in January 1989 at a spacing of 1 x 1 m, and the trees were cut back to 30 or 60 cm above ground after three, four, five or six months of growth. They were then cut repeatedly on a monthly basis during the latter part of the dry season, beginning in August when fodder requirements are greatest on local farms. The production of leafy biomass varied widely between treatments and between individual trees.

Trees grew up to a height of 2.8 m in six months, making harvesting difficult if left this late. On average, total above-ground biomass at the time of first cutting comprised 17% leaves, 11% unpalatable flowers and pods, and 72% stem and branches. Trees cut at 30 cm tended to produce more leafy biomass, while trees cut at 60 cm produced more wood.

However, regrowth of leafy biomass was poor after the first cutting and generally declined further after each cutting during the dry

Table 17. Maize grain yields (t/ha dry wt) with Gliricidia sepium *and* Leucaena leucocephala *leaf mulch and nitrogen fertilizer in 1990 at Chipata, Zambia.*

Mulch Species and Application Rate (t/ha fresh wt)	— Fertilizer Application (kg N/ha) —				
	0	30	60	90	120
Gliricidia sepium					
0	1.4	2.0	2.6	2.8	3.2
5	2.4	2.8	3.2	3.6	3.8
10	2.9	3.3	3.5	3.6	4.0
15	3.2	3.9	3.8	4.5	4.6
20	3.8	4.3	4.4	4.8	5.1
Leucaena leucocephala					
0	1.7	2.3	3.0	3.2	3.6
5	2.2	2.8	3.3	3.4	3.9
10	2.6	3.1	3.6	3.7	4.3
15	2.8	3.2	3.8	4.0	4.6
20	3.1	3.5	4.4	4.5	5.0

season. This suggests that *Sesbania sesban* may not be an appropriate species in this region for agroforestry systems that require substantial leaf production, either for fodder or for mulch and green manure.

On-farm research

Experiments were initiated in 1990 on five farms in Chipata South and Katete Districts. The objective is to test hedgerow-intercropping and improved-fallow technologies across a variety of sites. In connection with this work, two farmers have successfully established nurseries to produce multipurpose-tree seedlings.

Training and institution building

The Southern Africa AFRENA programme has sponsored two Zambian students for M.Sc. studies in North America. One completed a study in 1990 on *Leucaena leucocephala* and *Calliandra calothyrsus* as supplementary feed for goats. The second student will conduct research in 1991 on the decomposition rates of mulch from multipurpose trees.

The project continues to work closely with the Research Branch of the Ministry of Agriculture, the University of Zambia's School of Agricultural Sciences, and the Zambian Forestry Department.

Zimbabwe

Zimbabwe's participation in the Southern Africa AFRENA programme was confined initially to training courses, workshops, and research planning and formulation. Following a macro D&D study in 1987, a team of Zimbabwean scientists and ICRAF staff joined in 1989 to survey ongoing agroforestry programmes. These are conducted by the Forestry Commission, the University of Zimbabwe, the Agricultural Technical and Extension Services (AGRITEX) and the Department of Research and Specialist Services.

This survey led to the design of an agroforestry research project for Zimbabwe, as well as expansion of agroforestry education and training activities. Project planning was completed in 1990 and the Zimbabwe Government assigned two national scientists to work with the project. An ICRAF scientist will join them in 1991, to be based in the Department of Research and Specialist Services in Harare.

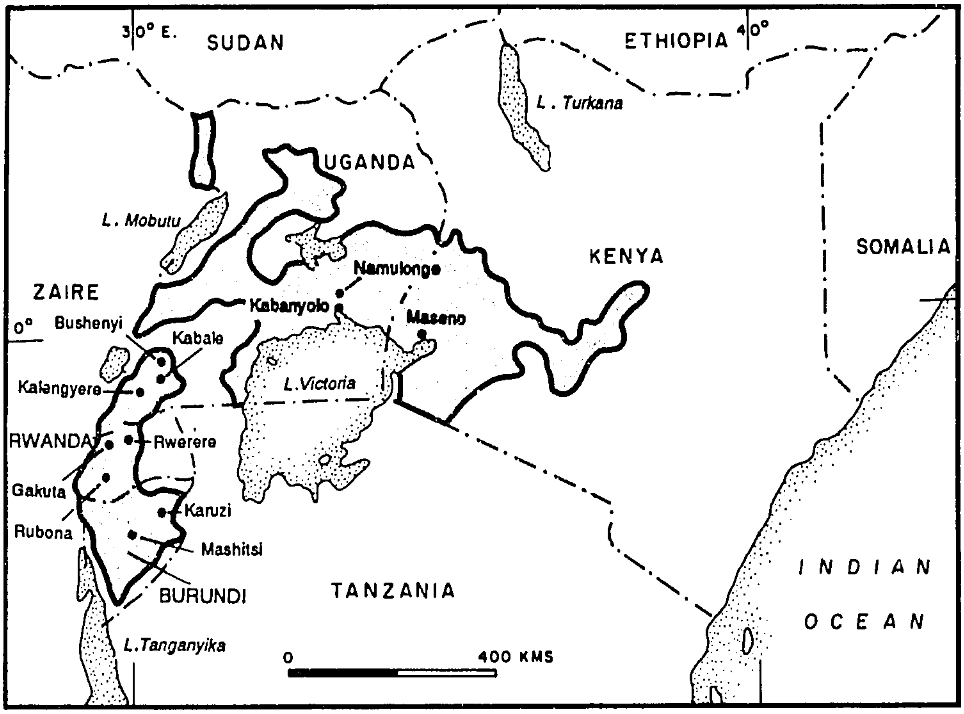
The project also includes two M.Sc. fellows who will undertake university course work in agroforestry followed by thesis research at the AFRENA sites.

Direction is provided by the Committee for Agroforestry, Soil and Water Conservation (CASAWAC), under the Zimbabwe Science Council, with representation from all relevant government departments. Zimbabwe's participation in the AFRENA programme is coordinated through SADCC and ICRAF, with funding provided by CIDA.

In November and December 1990, the first trials were established at two sites—the Makoholi Agricultural Research Station and the Domboshawa AGRITEX Demonstration Station. Domboshawa is located near Harare in the highland area best suited for intensive crop and livestock production, with annual rainfall ranging from 750 to 1000 mm. Makoholi is located to the southwest, in a region with annual rainfall averaging only 450 to 650 mm and farming systems based primarily on livestock plus limited drought-resistant crops.

At both sites, experimentation will begin with multipurpose-tree screening trials. The goal is to identify promising species for soil improvement and provision of fodder in the dry season. Selection of trees for agroforestry in Zimbabwe must take into account frost tolerance, in addition to the criteria of fast growth, high yield and quality of biomass.

Bimodal Highlands of Eastern and Central Africa



Research Site	Associated National or Regional Research Institute	Altitude	Minimum/ Maximum Temperatures	Average Annual Rainfall	Soils
Karuzi, Burundi	ISABU	1600 m	13.3°/25.7°C	1140 mm	ferralsol
Mashitsi, Burundi	ISABU, IRAZ	1620 m	13.2°/25.6°C	1210 mm	ferralsol
Maseno, Kenya	KEFRI, KARI	1500 m	15.0°/31.0°C	1740 mm	lixisol
Gakuta, Rwanda	ISAR	2350 m	8.8°/21.5°C	1500 mm	cambisol
Rwerere, Rwanda	ISAR	2300 m	10.9°/20.7°C	1160 mm	ferralsol
Rubona, Rwanda	ISAR	1650 m	13.0°/25.[illegible]°C	1170 mm	acrisol
Bushenyi, Uganda	Bushenyi District Farm Institute	1610 m	13.3°/25.6°C	1200 mm	ferralsol
Kabale, Uganda	Kachwekano District Farm Institute	2000 m	10.9°/23.5°C	1040 mm	ferralsol
Kabanyolo, Uganda	Makerere University Farm	1205 m	15.7°/27.9°C	1440 mm	ferralsol
Kalengyere, Uganda	Highland Agricultural Research Station	2470 m	8.1°/20.9°C	1800 mm	andosol
Namulonge, Uganda	Namulonge Agricultural Research Station	1250 m	10.2°/29.5°C	1100 mm	ferralsol

Background

The AFRENA programme for the bimodal highlands of Eastern and Central Africa was launched in late 1986 with support from USAID. Research focuses on the sub-humid to humid highland areas, at altitudes between 1000 and 2500 m, in Kenya, Rwanda, Burundi and Uganda. In 1989, Ethiopia joined the network under separate funding.

As a result of favourable climates, population density in the region 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 D&D 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.

In the design of the research programme, a key consideration has been complementarity among activities in each country. Different agroforestry technologies are being tested in different countries, or, in some cases, the same technology is tested at different sites under different environmental conditions. Research in Kenya, Rwanda and Burundi has also included screening trials of multipurpose-tree species and provenances of potential value in the region. Table 18 gives an overview of work in progress in 1990.

On-farm surveys and trials were initiated in 1990, focusing on the land-use systems surrounding the research sites. The objective is to evaluate the problems of local land users and to assess the potential of some of the species and technologies under study on station.

Multipurpose-tree screening trials

General screening trials include multipurpose trees already found in the highlands of Eastern and Central Africa plus promising species and provenances that are new to the region. Screening trials cover only the first two to three years after establishment.

Measurements of survival, height, root-collar diameter and biomass production are taken at regular intervals, and pest and disease incidence is recorded. Additional trees, planted separately, are coppiced and their responses observed. Multipurpose trees are ranked according to these measurements, and promising species and provenances are examined in more detail in

Table 18. Research in progress in the Eastern and Central Africa AFRENA programme in 1990.

Research	— Altitude Range — 1000–1500 m	1500–2000 m	2000—2500 m
• Initial species screening, management, establishment	Maseno, Kenya	Mashitsi, Burundi Karuzi, Burundi	Rwerere, Rwanda Gakuta, Rwanda
• Hedges in cropland (soil conservation, green manure, fodder)	Maseno, Kenya	Mashitsi, Burundi	Rwerere, Rwanda
• Grass and shrubs on bunds (soil conservation, fodder)	Maseno, Kenya	Mashitsi, Burundi Karuzi, Burundi	Rwerere, Rwanda
• Upper/multistorey boundary plantings (timber, poles, fuelwood, fodder)	Kabanyolo, Uganda Namulonge, Uganda	Bushenyi, Uganda	Kachwekano, Uganda Kalengyere, Uganda
• Trees mixed in banana plots (timber, poles, fuelwood, fruit)	Kabanyolo, Uganda	Mashitsi, Burundi	
• Trees mixed in coffee plots (mulch)		Rubona, Rwanda	
• Fodderlots		Mashitsi, Burundi	

the context of specific agroforestry technologies at different sites.

Kenya: Maseno

At the Maseno Agroforestry Research Centre in western Kenya, ICRAF is conducting research in collaboration with KEFRI and KARI. General multipurpose-tree screening trials, initiated at Maseno in 1988, include 58 accessions of 28 species. A new trial began in 1990 to test five leucaena hybrids obtained from the Nitrogen Fixing Tree Association (NFTA).

Among those species evaluated for 21 months or longer, *Acrocarpus fraxinifolius*, *Casuarina junghuhniana*, *Grevillea robusta*, *Markhamia lutea* and *Tipuana tipu* showed excellent growth (Table 19), while *Erythrina abyssinica*, *Croton* spp and *Cordia abyssinica* were attacked by pests and performed poorly.

In a separate trial, average heights of five provenances of *Leucaena leucocephala* 26 months after establishment ranged from 5.05 to 5.88 m. Root-collar diameters ranged from 9.5 to 14.4 cm, and fresh harvested biomass ranged from 20.1 to 61.2 kg per tree. A provenance from Hawaii (USA) showed the best performance.

The performance of three provenances of *Calliandra calothyrsus* 26 months after establishment was rather uniform, and generally better than that of the leucaenas. The best performance was recorded for an accession from Guatemala, averaging 6.0 m in height, 18.9 cm in root-collar diameter and 68.2 kg of fresh biomass per tree.

The height and root-collar diameter of six *Gliricidia sepium* provenances obtained from the Oxford Forestry Institute (UK) were fairly uniform, but biomass production varied widely—from 7.5 to 57.5 kg fresh wt per tree. The best provenance was from Playa de Samala, Guyatenaga, Guatemala, with an average height 26 months after establishment of 4.93 m, an average root-collar diameter of 16.8 cm, and average biomass production of 57.5 kg fresh wt per tree.

Another interesting result was the substantial difference between *Cassia spectabilis* and *Cassia siamea*. At 26 months after establishment, *Cassia spectabilis* produced twice as much biomass as *Cassia siamea*—52.9 kg compared to 25.0 kg fresh wt per tree. Of the multipurpose trees planted more recently, *Albizia falcataria*, *Acacia auriculiformis*, *Grevillea robusta*, *Alnus acuminata*, *Jacaranda mimosifolia*, *Leucaena leucocephala* (ILCA 14198), *Leucaena diversifolia* (K156), *Leucaena paniculata* (ILCA 14203) and *Calliandra calothyrsus* (Patullil) showed excellent growth.

Species	Height (m)	Root-collar Diameter (cm)
Acrocarpus fraxinifolius	5.3	11.2
Casuarina junghuhniana	4.8	7.6
Tipuana tipu	4.3	5.9
Grevillea robusta	4.2	9.9
Markhamia lutea	3.4	6.5

Table 19. Height and root-collar diameter of 6 promising multipurpose-tree species 21 months after establishment, Maseno, Kenya.

Rwanda: Rwerere and Gakuta

ICRAF is conducting research at Rwerere Research Station in northern Rwanda in collaboration with the Institut des sciences agronomiques du Rwanda (ISAR). In 1990, experiments were also initiated at Gakuta Research Station in the Crête-Zaïre-Nil region.

Species screening trials were established at Rwerere in 1989 and 1990. Altogether, 30 accessions of 24 species are being tested. Table 20 gives the average heights and root-collar diameters of 13 promising species 14 months after establishment.

Based on these criteria, *Sesbania sesban* performed extremely well at this altitude. Several pole, timber and fuelwood species that are new to the area also gave good results, including *Alnus nepalensis*, *Casuarina* spp, *Croton* spp, *Grevillea robusta* and *Cupressus lusitanica*. They all grew considerably faster than *Markhamia lutea*, a traditional species in the area that only attained an average height of 61 cm in 14 months. Two valuable fodder trees from Nepal, *Schima wallichii* and *Saurauia napaulensis*, also appear to be well adapted to this high-altitude environment.

Species	Height (m)	Root-Collar Diameter (cm)
Sesbania sesban	5.3	5.6
Grevillea robusta	2.4	3.9
Alnus nepalensis	2.3	2.8
Casuarina equisetifolia	2.2	3.1
Casuarina cunninghamiana	2.2	3.0
Leucaena diversifolia	1.9	2.6
Cupressus lusitanica	1.9	2.9
Croton macrostachys	1.8	2.3
Acrocarpus fraxinifolius	1.7	3.2
Calliandra calothyrsus	1.5	1.9
Schima wallichii	1.4	3.0
Croton megalocarpus	1.2	2.6
Saurauia napaulensis	0.8	2.5

Note: These data were obtained from different trials that started at different times. Comparisons between species are not entirely valid.

Table 20. Height and root-collar diameter of 13 promising multipurpose-tree species 14 months after establishment at Rwerere, Rwanda.

With acid soils and an altitude of 2450 m, environmental conditions at Gakuta are harsh and few multipurpose-tree species are available locally. For this reason, the research project puts considerable emphasis on general species screening.

A total of 69 accessions of 47 species were planted in 1990. Six months after establishment, the best accessions in terms of height growth were *Mimosa scabrella* (Brazil), *Chamaecytisus proliferus*, *Sesbania sesban* (Kakamega), *Tephrosia vogelii* (Arboretum), *Sesbania sesban* (Nyabisindu), *Acacia melanoxylon*, *Acacia koa* (Hawaii), *Acacia koa* (Umikoa Hawaii), *Sesbania sesban* (Kitale), *Alnus acuminata* (Congelin Townsite) and *Grevillea robusta* (Mwea).

Burundi: Mashitsi and Karuzi

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

One new screening trial was established at Mashitsi in 1990, focusing primarily on multipurpose trees provided by NFTA. Altogether, screening trials at Mashitsi included 21 accessions of 15 species, while trials at Karuzi included 30 accessions of 24 species. Table 21 shows height and root-collar diameter of eight promising species 15 to 16 months after establishment.

Tree establishment methods

Trees used in general screening trials are all established from seedlings raised in nurseries. However, this approach may not always be feasible for farmers in the region because nursery-grown seedlings are expensive, difficult to transport and often simply not available.

For this reason, scientists are looking at other ways to establish trees and also at ways to reduce the cost of transporting seedlings. This work is being conducted at Maseno by ICRAF's multipurpose-tree improvement programme and at Rwerere.

Studies at Rwerere focus on direct seeding of hedges and on methods to reduce transport costs by using bare-rooted seedlings. Establishment trials using bare-rooted seedlings of *Sesbania sesban* have given good results.

Fodder production

Fodder shortages in the dry season are a common problem throughout the zone. Farmers in some areas have introduced zero-grazing systems for dairy cows based on grasses, in particular napier grass (*Pennisetum purpureum*), planted on field bunds, along boundaries or in blocks. While this has alleviated some animal-nutrition problems, it has also become obvious that protein requirements for dairy production are difficult to meet if only grass is available. Thus, the AFRENA programme has initiated several experiments to examine the use of trees in combinations with grass for high-protein fodder production.

Kenya

Two fodder-production trials have been in progress at Maseno since 1988. The first was designed to evaluate the effect of different cutting heights on biomass production from *Leucaena leucocephala* hedges in cropland. As in 1989, results in 1990 showed an increase in harvested leafy biomass (fresh wt) with an increase in cutting height (see Figure 3). It was not possible to assess the effects of hedges cut at different heights on adjacent crops.

In the second trial, initiated in 1988, rows of *Leucaena leucocephala*, *Sesbania sesban* and *Calliandra calothyrsus* were planted in pure stand or combined with *Pennisetum purpureum*. The sesbania died early in 1990 after six cuttings.

As in 1989, both the grass and the other two tree species were more productive when planted together than separately. In 1990, the calliandra produced 27% more leafy biomass per m of hedge when planted in single rows with one row of pennisetum than when planted in double rows of trees alone (Table 22). The leucaena produced 18% more biomass when mixed with pennisetum. The grass was 25% more productive when mixed with leucaena and 5% more productive when mixed with calliandra.

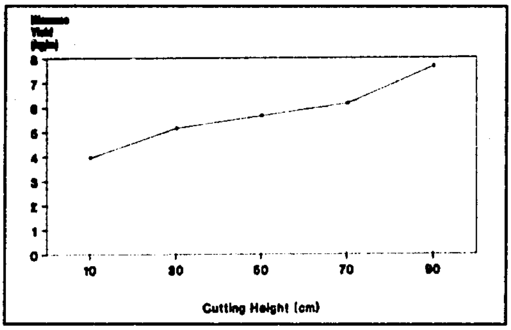


Figure 3. Annual leafy biomass production (kg/m fresh wt) from 2-year-old hedges of Leucaena leucocephala *at Maseno, Kenya, cut 4 times a year.*

Rwanda

A parallel trial was established in 1988 at Rwerere, combining calliandra on contour bunds with pennisetum and with another fodder grass, *Setaria splendida* (Table 23). Biomass production from the calliandra was about 20% of the level recorded at Maseno, while production from pennisetum was similar at the two sites.

The results of combining trees and grasses were similar to those at Maseno. Production of calliandra and of the two grasses was higher when planted in combination than in pure stands. As at Maseno, the *Sesbania sesban* originally included in the trial died in 1990.

Table 21. Height and root-collar diameter of 13 promising multipurpose-tree species 15 to 16 months after establishment at Mashitsi and Karuzi, Burundi.

Species	— Mashitsi —		— Karuzi —	
	Height (m)	Root-collar Diameter (cm)	Height (m)	Root-collar Diameter (cm)
Casuarina cunninghamiana	3.2	3.8	2.9	3.1
Grevillea robusta	2.9	5.3	2.2	4.1
Cupressus lusitanica	2.6	4.3	2.4	4.1
Acrocarpus fraxinifolius	2.5	3.9	—	—
Maesopsis eminii	1.8	4.2	1.3	3.3
Alnus acuminata	1.8	4.4	—	—
Alnus nepalensis	1.6	3.3	1.6	3.4
Casuarina equisetifolia	1.5	2.5	3.0	3.5

Note: These data were obtained from different trials that started at different times. Comparisons between species are not entirely valid.

Species	Biomass Production (kg/m fresh wt) From Trees	From Grass	Total
Leucaena (2 rows)	8.5	—	8.5
Calliandra (2 rows)	12.6	—	12.6
Pennisetum (2 rows)	—	44.0	44.0
Leucaena + pennisetum (1 row each)	5.8	33.1	38.9
Calliandra + pennisetum (1 row each)	9.7	24.2	33.9

Table 22. Annual leafy biomass production (fresh wt) from different grass and shrub combinations grown on field bunds at Maseno, Kenya.

The different combinations of calliandra and grass had significantly different effects on adjacent wheat and bean crops. Pennisetum, which had the highest fodder yields, had a much more depressing effect on crop yields than setaria or calliandra, either in combination or in pure stands. Thus, with trees and grasses planted on contour bunds, there appears to be a trade-off between maximum fodder production, obtained by using pennisetum, and maximum production of adjacent crops.

Burundi

Another parallel trial was established at Mashitsi in 1989, combining calliandra and leucaena on contour bunds with pennisetum and another fodder grass, *Tripsacum laxum*. Table 24 gives 1990 biomass production from the different combinations.

The tripsacum appeared to benefit from interplanting with both tree species, while the pennisetum generally performed poorly. Apart from leucaena with pennisetum, the trees did not appear to benefit from interplanting with grasses at this site. There were no significant differences in the effects of different combinations on a bean crop planted next to the bunds.

These figures cannot be compared with those from Maseno and Rwerere (Tables 22 and 23) because production at Mashitsi was measured in dry wt and because one grass harvest at Mashitsi was not included due to damage by livestock.

Uganda

Collaborative research is in progress at five sites in Uganda. Experiments started in 1988 at the Kabanyolo University Farm near Kampala and in 1989 at the Kachwekano District Farm Institute in Kabale District. In 1990, this work extended to Namulonge near Kabanyolo, Kalengyere near Kachwekano, and Bushenyi in western Uganda.

An experiment on steeply sloping land at Kachwekano was designed to investigate the potential for establishing rows of calliandra and pennisetum on the upper and lower sides of

Table 23. Annual leafy biomass production (fresh wt) from different grass and shrub combinations grown on field bunds at Rwerere, Rwanda.

Species	Biomass Production (kg/m fresh wt) From Trees	From Grass	Total
Calliandra (2 rows)	2.6	—	2.6
Setaria (2 rows)	—	13.4	13.4
Pennisetum (2 rows)	—	46.0	46.0
Calliandra + setaria (1 row each)	2.1	7.5	9.6
Calliandra + pennisetum (1 row each)	1.7	25.0	26.7

Species	Biomass Production (kg/m dry wt) From Trees	From Grass	Total
Calliandra (2 rows)	1.9	—	1.9
Leucaena (2 rows)	1.2	—	1.2
Pennisetum (2 rows)	—	1.1	1.1
Tripsacum (2 rows)	—	1.0	1.0
Calliandra + pennisetum (1 row each)	0.8	0.4	1.2
Calliandra + tripsacum (1 row each)	0.8	1.1	1.9
Leucaena + pennisetum (1 row each)	0.6	0.4	1.0
Leucaena + tripsacum (1 row each)	0.4	1.0	1.4

Table 24. Annual leafy biomass production (dry wt) from different grass and shrub combinations grown on field bunds at Mashitsi, Burundi.

terrace risers. Biomass production was assessed for the first time in September 1990. Yields of trees and grass were greater on the upper sides of the terraces. As at other sites, pennisetum appeared to have a stronger negative effect on adjacent crops than did calliandra.

Hedgerow intercropping

Research on hedgerow intercropping is designed to address problems of declining soil fertility and soil erosion. Experiments include screening of potential hedgerow species, assessment of hedgerow and crop arrangements and management techniques, and evaluation of crop production using green manure from hedgerows plus fertilizer.

Kenya

In a hedgerow-species screening trial established in 1988, *Calliandra calothyrsus* consistently showed the highest production of leafy biomass. Total fresh leafy biomass from four cuttings in 1990 was 37.5 t/ha.

Two provenances of *Leucaena leucocephala* each yielded about 20 t/ha, *Erythrina caffra* yielded 14.9 t/ha, *Gliricidia sepium* yielded 11.4 t/ha, and *Cassia siamea* yielded 7.5 t/ha. Maize yields from the alleys between hedgerows compared very favourably with yields from the control plot even though the plots with hedgerows had a 25% lower maize population (Table 25).

A parallel trial on more fertile soil included fertilizer applied at different rates. Here, the role of hedgerows was less consistent. With fertilizer, the effect of green manure application was not enough to compensate for the 20% lower population of maize plants on hedgerow plots. However, on plots without fertilizer, the positive effect of green manure was significant.

The problem of reduced space available for crops under hedgerow intercropping was addressed in another experiment, comparing yields from maize at the standard spacing of 75 cm from a *Leucaena leucocephala* hedgerow to yields from maize only 37.5 cm from the hedgerow. Maize dry-grain yields from two growing seasons in 1990 were only slightly less from rows at the reduced spacing, suggesting that hedgerows might be interplanted with maize without decreasing the overall maize population.

The same experiment included a comparison of tree biomass production under different hedgerow arrangements. A double hedgerow at a spacing of 50 cm between rows produced only 50% more biomass than a single hedgerow, while a triple hedgerow produced only 80% more biomass than a single one. Similarly, doubling the number of trees in a hedgerow by reducing the space between trees from 50 to 25 cm resulted in increased biomass production of only 15 to 27%.

A hedgerow-intercropping trial initiated in 1990 on 22 farms around Maseno is discussed under on-farm research.

Hedgerow Species	Maize Grain Yields (t/ha dry wt) First Season	Second Season	Total 1990
Calliandra calothyrsus	3.0	3.0	6.0
Gliricidia sepium	3.3	2.6	5.9
Erythrina caffra	3.4	2.1	5.5
Leucaena leucocephala (Hengchun)	3.2	2.2	5.4
Leucaena leucocephala (Melinda)	2.7	2.0	4.7
Cassia siamea	1.9	1.7	3.6
Control: no hedge	2.0	1.5	3.5

Table 25. Maize grain yields under hedgerow intercropping at Maseno, Kenya.

Rwanda

Two hedgerow-intercropping trials began at Rwerere in 1988, designed to test this technology in the high-altitude zone. The first trial focuses on the identification of suitable hedgerow species. Fresh biomass production in 1990 was highest from hedgerows of *Calliandra calothyrsus*, followed by *Leucaena diversifolia* (ex Ruhande). Two *Leucaena leucocephala* accessions and one leucaena hybrid appeared poorly adapted to this environment, and the *Sesbania sesban* died during the year.

Wheat and bean yields were highest with *Leucaena leucocephala* (K8), one of the hedgerow types with the lowest biomass production. Otherwise, crop yields were generally higher with the higher-yielding hedgerow species.

The second trial included fertilizer application at different rates. Here, there was no measurable response to the various treatments, probably due to site heterogeneity.

Burundi

At Mashitsi, two screening trials for hedgerow intercropping include provenances of *Leucaena leucocephala*, *Leucaena diversifolia*, *Calliandra calothyrsus*, *Cassia spectabilis* and *Sesbania sesban*. Hedgerows were cut three times in 1990. The three provenances of *Calliandra calothyrsus* and the two local provenances of *Leucaena diversifolia* produced the most leafy biomass (Table 26).

The second trial, established in 1988, focuses on the effect of hedgerow prunings on crop yield, both alone and in combination with four levels of nitrogen fertilizer. Fertilizer treatment had no effect on hedgerow growth. Data on crop growth will be available in 1991.

Upperstorey trees on field bunds and boundaries

Research has been initiated at five sites in Uganda to increase the production of timber, building poles and fuelwood from trees planted on field bunds and boundaries. Initial work concentrates on selecting appropriate species. Altogether, 35 accessions of 21 species are being tested at Kabanyolo, Kachwekano, Namulonge, Bushenyi and Kalengyere.

Initial growth performance has been assessed from the first three of these trials. At Kabanyolo near Kampala, *Melia azedarach* reached 7.9 m in height in 26 months, with a root-collar diameter of 19.8 cm, producing a sizeable pole. Although ranking second in height, at 5.3 m, *Casuarina equisetifolia* had a low estimated stem volume, with a root-collar diameter of only 6.9 cm. *Alnus acuminata* and *Cupressus lusitanica* grew least well at this site, with *Cordia abyssinica*, *Maesopsis eminii* and *Markhamia lutea* in an intermediate position.

In a second trial at Kabanyolo, *Cassia siamea* was 5.2 m tall after 19 months. *Jacaranda mimosifolia* was 4.8 m, one accession of *Grevillea robusta* was 4.0 m, and *Casuarina equisetifolia* was 3.8 m. *Cupressus sempervirens* did not grow well, while *Erythrina abyssinica* suffered from insect damage.

ICRAF research associate checks tree-mulch decomposition experiment at Maseno in western Kenya.

Species	Leafy Biomass Harvested from Hedgerows (kg/m dry wt) February	October	December	Total
Calliandra calothyrsus (Guatemala)	1.4	1.5	0.9	3.8
Leucaena diversifolia (Ruhande)	1.3	0.9	1.0	3.2
Calliandra calothyrsus (Ruhande)	1.1	1.3	0.7	3.1
Leucaena diversifolia (Murongwe)	1.2	0.9	0.9	3.0
Calliandra calothyrsus (Kibuye)	1.1	1.3	0.6	3.0
Cassia spectabilis (Kibuye)	0.5	0.9	0.7	2.1
Leucaena diversifolia (Colombia)	0.7	0.7	0.6	2.0
Cassia spectabilis (Bugarama)	0.5	0.7	0.6	1.8
Cassia spectabilis (Machakos)	0.4	0.6	0.8	1.8
Leucaena leucocephala (Siaya)	0.4	0.3	0.3	1.0
Cassia spectabilis (Embu)	0.3	0.6	0.7	1.6
Leucaena leucocephala (Kimberly)	0.2	0.2	0.4	0.8
Leucaena leucocephala (Murongwe)	—	—	0.1	0.1

Table 26. Leafy biomass production of selected hedgerow species at Mashitsi, Burundi.

In the more temperate climate at Kachwekano, *Alnus acuminata*, *Casuarina cunninghamiana* and *Grevillea robusta* reached heights of about 4 m after 21 months of growth. Like the *Casuarina equisetifolia* at Kabanyolo, *Casuarina cunninghamiana* had thin stems, resulting in a lower stem volume than that of the other two fast-growing species.

Another series of trials was established to investigate the spacing of upperstorey trees interplanted with *Calliandra calothyrsus* or *Pennisetum purpureum* adjacent to a maize crop. Results in 1990 indicated that the understorey species influenced the growth of the upperstorey trees and adjacent crop, at least during the early years of establishment, while the spacing of the upperstorey trees had no effect. In all cases, pennisetum and calliandra appeared to suppress tree growth—more in terms of stem and crown diameter than height. Both understorey species also suppressed growth of the adjacent crop, particularly the pennisetum.

Multipurpose trees mixed in banana plots

The introduction of multipurpose trees into banana plots is designed to augment the farmers' supply of wood products and fruit. Two species-screening trials are in progress at Kabanyolo, Uganda, and at Mashitsi, Burundi, covering a total of 11 species. After 12 months at Mashitsi, *Grevillea robusta* reached an average height of 2.1 m and *Leucaena leucocephala* reached 1.9 m with no negative effects on the height and stem diameter of the interplanted banana. *Calliandra calothyrsus* also grew vigorously, but growth of associated banana was significantly reduced. At Kabanyolo, several species have grown well, in particular *Cedrela odorata* and *Cedrela serrata*. A third trial has been established at Mashitsi to compare the effects of *Grevillea robusta* planted in banana plots at different densities.

On-farm research

Kenya

ICRAF and collaborating national scientists conducted a micro D&D survey in 1990 in the area around the Maseno Agroforestry Research Centre. Population density is high in the region, averaging more than 1000 people per sq km in some areas. Farms are small, often with less than 1 ha under crops, providing little opportunity for fallowing.

Farmers try to maintain soil fertility by manuring, but the quantities of manure available are inadequate to sustain yields. The major problems reported in a series of meetings with

Photo D G P

An upperstorey of Grevillea robusta *interplanted with* Calliandra calothyrsus *on steeply sloping land at Kabanyolo, Uganda.*

groups of farmers were declining soil fertility, shortages of fuelwood and dry season fodder, and limited opportunities to earn cash.

The survey included a review of existing information on land resources, land use and relevant research and extension in the area. The results showed that inherent soil fertility varies widely, with important implications for agroforestry potential and input requirements. Low nutrient reserves, phosphorus fixation, soil acidity and limited rooting depth are important constraints. Although slopes are generally less than 8%, soil erosion is a serious risk because of the intensity of land use. These problems are common to large areas of the Eastern Africa highlands.

On station trials at Maseno are confirming the biological potential of hedgerow intercropping for improving soil fertility in the area. However, labour constraints are critical. To elucidate labour requirements and opportunity costs, researchers are monitoring the activities of seven farmers who manage hedgerow-intercropping systems established through a CARE programme several years ago.

A review of existing agroforestry practices suggested several opportunities for improvement. To complement existing projects and build on previous experience, the AFRENA programme established a hedgerow-intercropping trial in August 1990 on 22 farms supplied with good-quality seedlings and technical advice. The major objective was to identify key biophysical and socio-economic factors that influence technology adoption.

Each farmer planted an average of 550 *Leucaena leucocephala* seedlings in hedgerows over an average total area of 900 sq m. Hedgerow intercropping and other farm activities will be monitored intensively to permit an assessment of the technology within the context of the whole farm system.

Participating farmers were selected from high-rainfall areas with contrasting levels of soil fertility. They saw examples of hedgerow intercropping and other agroforestry technologies at the Maseno Agroforestry Research Station and contributed to the detailed design of the technology through discussions in a series of meetings. For instance, the farmers specified that space be left at the end of hedgerows for turning oxen during ploughing. They were not overly worried about the labour required for hedgerow planting, but they expressed concern about competition between trees and crops and the effects of dry periods.

Most of the participating farmers planted hedgerows at a rate of 10 to 20 seedlings per person-hour. On average, 11% of the original seedlings died and had to be replaced in the first three months, with mortality rates ranging from less than 1 to 32% on individual farms. Termite attack and poor planting techniques were the main causes of seedling mortality.

Growth rates varied widely between farms due to browsing by antelopes, differences in soil type and local variation in rainfall. Average heights at three months after planting ranged from 21 to 86 cm. Additional species will be included in 1991 for a comparison of resistance to browsing and termite damage. Also, the trial will be extended to another area with higher land-use intensity.

Uganda

On-farm research started in 1990, focusing on farms near Kachwekano. Initial work was designed to assess the level of interest in agroforestry among local farmers, to identify any major constraints that would affect future acceptance of agroforestry technologies, and to develop methodologies for detailed on-farm studies. Trees were distributed to about 200 farmers. These are being managed in different ways by farmers and researchers.

Initial observations indicate that most farmers are keen to plant trees. Constraints to agroforestry adoption include poor access to planting material, damage to seedlings by grazing livestock, and loss of seedlings due to theft or vandalism. These findings underline the importance of providing effective protection for young trees.

Rwanda

In 1990, AFRENA scientists conducted a survey on the potential role of woody stakes for climbing beans in collaboration with a Farming-Systems Research Project based at Rwerere. Out of 135 farmers interviewed, 59% mentioned the lack of stakes as a problem restricting the production of climbing beans. Farmers frequently stake their beans on pennisetum stems harvested from contour bunds, but they reported that the grass stems are not very durable.

Also in 1990, AFRENA scientists began distributing seedlings of upperstorey-tree species to farmers, working through local development projects.

Special project on agroforestry in Kenya

In Kenya, a large number of ministerial departments, donor agencies and non-governmental organizations are involved in agroforestry research and development, all with strong support from the Kenya Government. 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 these numerous agroforestry research and development activities.

This project was conducted in close collaboration with other ministries and departments of the Kenya Government and with several non-governmental organizations. The Swedish International Development Authority (SIDA) provided financial support.

The information collected through this project will be published in several formats for a broad audience. Specific publications will include a field guide to trees and shrubs suitable for agroforestry development in Kenya, an annotated bibliography covering published and unpublished literature on Kenyan agroforestry, brochures on multipurpose-tree species of importance in specific regions of the country, and other training material for agroforestry extension.

In addition to collecting and disseminating useful information, the project made it possible for ICRAF to extend technical services and support to departments and research institutions of the Kenya Government and to non-governmental organizations working in agroforestry research, training and extension. Assistance was provided through participation in 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.

Training and institution building

In 1990, IDRC provided funding for five M.Sc. fellowships awarded to collaborating scientists within the Eastern and Central Africa AFRENA. IDRC also supported the participation of project staff in ICRAF's three-week field technicians' training course.

In Burundi, project scientists visited national agroforestry projects and conducted a training course for teachers at an agricultural college. In Rwanda, project staff visited agroforestry projects, organized a national agroforestry meeting in collaboration with ISAR, and helped with a training course conducted by CARE. In Uganda, project staff participated in a number of national and district-level workshops and provided thousands of multipurpose-tree seedlings to the district administration at Kabale.

Staff members from several projects in the region visited agroforestry field sites in western Kenya, with support from the Rockefeller Foundation. AFRENA scientists in Kenya also gave lectures on agroforestry at provincial meetings of Ministry of Agriculture staff.

In February, the zonal planning and evaluation workshop took place in Bujumbura, Burundi, accompanied by a meeting of the Regional Steering Committee. The workshop emphasized the development of on-farm research and included a one-day study tour to various agroforestry projects. The Regional Steering Committee resolved that Ethiopia and Zaire should join the network, subject to the provision of additional funding.

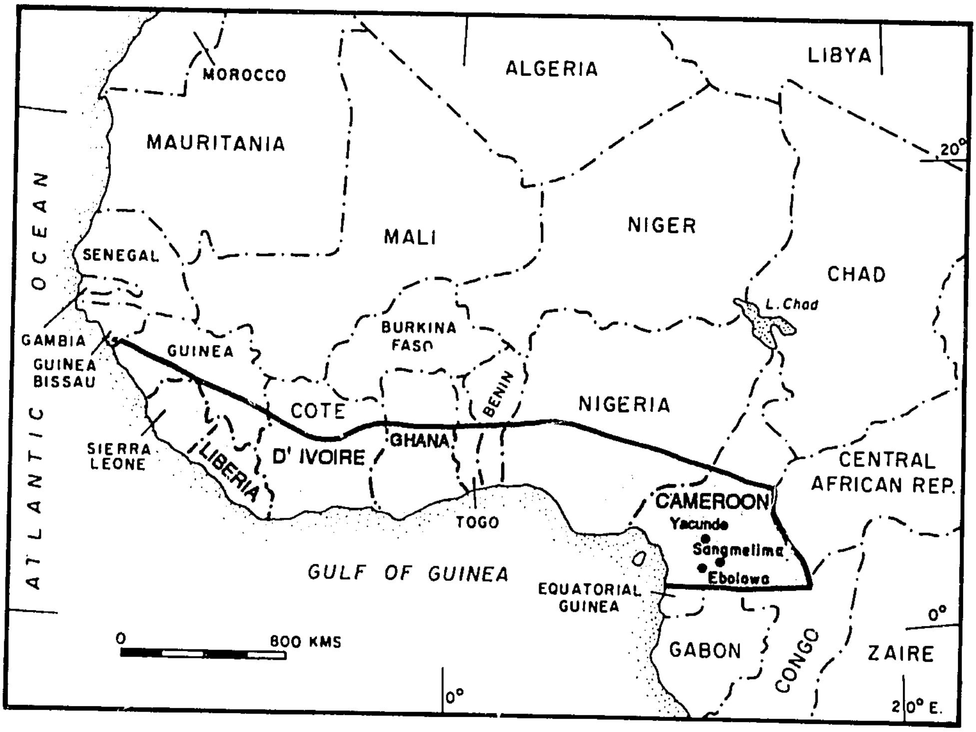
A proposal has been formulated for a five-year national agroforestry research project in the Ethiopian highlands. Field visits and meetings with national institutions in Ethiopia were supported by SIDA.

ICRAF staff also helped KEFRI and KARI prepare a proposal for an agroforestry research project focusing on the coffee-based land-use system in Embu District, Kenya. The proposal has been approved for funding by SIDA.

Banana interplanted with beans at Mashitsi, Burundi. Early results indicate that upperstorey trees can be added to such systems with no negative effects on the banana.

Photo: E. Akyeampong

Humid Lowlands of West Africa



Research Site	Associated National Research Institute	Altitude	Minimum/ Maximum Temperatures	Average Annual Rainfall	Soils
Yaoundé, Cameroon	IRA	700 m	19.2°/28.6°C	1600 mm	ferric acrisols
Ebolowa, Cameroon	IRA	710 m	19.2°/28.6°C	1650 mm	ferric acrisols
Sangmelima, Cameroon	IRA	720 m	19.0°/28.5°C	1680 mm	ferric acrisols

Background

The humid lowlands of West Africa, at an altitude of less than 1000 m, start in the west in Guinea Bissau, include parts of Guinea, Sierra Leone, Liberia, Côte d'Ivoire, Ghana, Togo, Benin and Nigeria, and extend in the east to Cameroon. Annual rainfall averages more than 1500 mm, with two rainy seasons and a total growing period of 270 to 365 days a year. The vegetation is tropical rain forest.

Within the region, ICRAF has been engaged in a Collaborative Agroforestry Project in Cameroon since 1986. Funding in 1990 was provided by IDRC. A second collaborative project started in Ghana in 1989, also with IDRC funding.

A third project was initiated in Nigeria in 1990, based at IITA. This activity is discussed in the section on ICRAF's research programme for multipurpose-tree improvement.

ICRAF also participates with IITA and ILCA in the Alley Farming Network for Tropical Africa (AFNETA), with a coordinating unit at IITA in Nigeria. This collaborative work is described in a separate section of this report.

Cameroon

ICRAF started an agroforestry research project in 1986 in collaboration with the Government of Cameroon's Institut de la recherche agronomique (IRA). The focus is on the cocoa/food

Yaoundé	Ebolowa	Sangemelima
• MPT screening: 10 species • Hedgerow intercropping: 7 species • Hedgerow intercropping: 4 species with and without fertilizer • Hedgerow intercropping: on farm • Hedgerow intercroppirng: alternative arrangements • Hedgerow intercropping: biomass assessment • Improved fallows: different fallow periods • Improved fallows: on farm • Improved fallows: time of planting on farm • Improved fallows: time of planting on station • Improved fallows: residue management • Rotational hedgerow intercropping with livestock	• Hedgerow intercropping: biomass assessment • Hedgerow intercropping: time of initial cutting • Short improved fallows	• MPT screening: 10 species

Table 27. Experiments in progress in 1990 at three sites in Cameroon.

crop production system in the southern plateau region of the country. The first phase of the project concentrates on the food-crop component. The second phase, beginning in 1991, will include research on the role of agroforestry in cocoa production.

In these humid lowlands, small-scale farmers generally grow food separately from cocoa according to a complex system of shifting cultivation. They begin the crop-production cycle by clearing small plots from natural forest or fallow land. The cleared vegetation is usually burnt. Then as many as seven or more different food crops are planted. These include short-term crops such as maize, groundnut and yam and longer-duration crops such as plantain, cassava and sugarcane.

Short-term crops are harvested at the end of one season, while other crops are left in the fields for one, two or even three years. During this period, farmers return to their plots to harvest, but do not practise any other form of management. By the time the last crops are removed, the plots have been completely overtaken by weeds and invading species, particularly *Eupatorium odoratum* and napier grass (*Pennisetum purpureum*). They remain under this natural fallow until the next cropping cycle begins.

As in many other farming regions of the tropics, there is increasing pressure on land with an accompanying reduction in the fallow period. Specific problems include: fragile and infertile soils; high labour requirements for land clearing, land preparation and weeding; crop destruction by free-ranging livestock; and limited resources to purchase chemical fertilizers or other inputs.

ICRAF is working on three agroforestry technologies that could potentially help solve these problems. These are hedgerow intercropping, improved fallows and rotational hedgerow intercropping with livestock. They were identified as promising approaches for farming systems in the region during the initial D&D exercise and subsequent surveys.

Collaborative on-station and on-farm research is conducted primarily at Yaoundé in Central Province. Limited work is also in progress at Sangmelima, and a new station was opened in 1990 at Ebolowa, both in South Province. Sixteen experiments were in progress in 1990, as shown in Table 27.

Multipurpose-tree screening trials

Experimental work began with two multipurpose-tree screening trials, starting in Yaoundé in 1987 and in Sangmelima in 1988. The goal was to identify which trees were well adapted to local conditions and suitable for priority agroforestry technologies.

The trial at Yaoundé included 10 promising exotic species, planted both in pure stands and intercropped with maize. Three years after establishment, *Paraserianthes falcataria* consistently showed the best growth in terms of height and stem diameter (Table 28). *Cassia siamea, Calliandra calothyrsus, Leucaena leucocephala, Gliricidia sepium* and *Acacia auriculiformis* also performed well.

Acacia mangium and *Cassia javanica* performed poorly and *Sesbania formosa* and *Sesbania grandiflora* died after the first cutting, one year after establishment. Intercropping with maize suppressed the growth of all species, particularly during the early establishment period.

Soil samples were taken under the most promising species from three levels: 0–5, 5–15 and 15–30 cm. Although results were preliminary, there appeared to be a trend towards soil improvement under multipurpose trees. Topsoil under calliandra had the highest levels of organic matter, organic carbon, total nitrogen, available phosphorus, calcium, magnesium and potassium, followed by soils under paraserianthes, cassia and gliricidia.

The performance of tree species at Sangmelima was somewhat different (Table 29). Ten species were planted in pure stands and intercropped with groundnut. Intercropping with the legume did not have any significant effect on the performance of the trees. Two years after establishment, *Acacia mangium* showed the best growth, followed by *Calliandra calothyrsus, Acacia auriculiformis* and *Paraserianthes falcataria*. Three local trees were included--*Duboscia macrocarpa, Dialium guinense* and *Chlorophora excelsa*—but all performed poorly relative to the exotic species. As expected, the worst performance was from *Chlorophora excelsa*, which is a slow-growing species.

Hedgerow intercropping

Six hedgerow-intercropping experiments were in progress in 1990. The oldest was an on-station experiment, established at Yaoundé in 1987 to compare the effects of mulch from seven multipurpose-tree species on interplanted maize crops.

Trees were planted by direct seeding and, beginning in 1988, different levels of fertilizer were applied. Results at the end of 1989 showed no significant differences in maize yields attributable to tree species or to the amount of mulch applied. This was mainly due to poor tree establishment and low biomass yields, too small to have a measurable effect. The trial was left to fallow in 1990 and will be resumed in 1991.

The second hedgerow-intercropping experiment, initiated in 1988 at Yaoundé, examined the effects on crop production of mulch from

Table 28. Average height and stem diameter at 50 cm above ground of 8 multipurpose trees established in pure stands and intercropped with maize, 3 years after planting at Yaoundé, Cameroon.

Species	Plant Height (m) With Maize	Plant Height (m) Without Maize	Plant Height (m) Average	Stem Diameter (cm) With Maize	Stem Diameter (cm) Without Maize	Stem Diameter (cm) Average
Paraserianthes falcataria	8.1	10.7	9.4	8.2	12.5	10.4
Cassia siamea	6.1	7.9	7.0	7.4	9.9	7.3
Leucaena leucocephala	5.5	7.4	6.4	5.1	6.9	6.0
Calliandra calothyrsus	5.9	6.6	6.3	4.5	6.3	5.4
Gliricidia sepium	5.3	5.6	5.4	3.9	4.8	5.4
Acacia auriculiformis	5.1	5.6	5.4	5.6	6.2	6.1
Cassia javanica	4.7	5.8	5.2	4.7	6.5	5.5
Acacia mangium	4.4	5.3	4.9	4.8	6.2	5.5

four multipurpose trees combined with different levels of fertilizer. *Leucaena leucocephala*, *Gliricidia sepium*, *Calliandra calothyrsus* and *Acacia auriculiformis* were all established from seedlings and NPK 20:10:10 was applied at rates of 0, 30 or 60 kg/ha. The trees were cut four times a year, at the beginning and end of each cropping season, and maize and groundnut were interplanted during the first cropping season of 1990.

Hedgerow establishment was good for all species. Two years after planting, total harvested leafy biomass yields were 3.39 t/ha (dry wt) for leucaena, 3.17 t/ha (dry wt) for calliandra, and 2.65 t/ha (dry wt) for gliricidia. This does not include leaf and litter fall, which can be considerable. The acacia could not withstand cutting at the beginning of the dry season and many trees died, but this species might be useful under a less frequent cutting regime.

The application of fertilizer alone at a rate of 30 kg/ha increased maize grain yields by 36% compared with the no-mulch/no-fertilizer treatment (Table 30). Fertilizer application at 60 kg/ha increased yields by 57%. The application of mulch alone increased yields by 86% for calliandra and acacia, 57% for leucaena and 36% for gliricidia. Maize grain yields with both mulch and fertilizer were 30 to 60% higher than yields with fertilizer alone.

By contrast, groundnut yields were highest with no hedgerows and no mulch. Competition from hedgerows severely inhibited groundnut growth, and mulch application was difficult as the low, spreading plants completely covered the ground. These results cast doubts on the potential of hedgerow intercropping to enhance groundnut production in the region.

A third hedgerow-intercropping trial was initiated in 1988 on six farms near Yaoundé. The objective was to assess the fertilizer requirements of improved maize under hedgerow intercropping. Maize was interplanted with three hedgerow species, *Leucaena leucocephala*, *Gliricidia sepium* and *Cajanus cajan* (pigeonpea), with the addition of NPK 20:10:10 at rates of 0, 30 or 60 kg/ha.

So far, results have been inconsistent, probably due to variations in management factors such as the timing of weeding, cutting and

Species	Plant Height (m)	Stem Diameter (cm)
Acacia mangium	5.7	5.8
Calliandra calothyrsus	5.1	4.0
Acacia auriculiformis	4.9	4.9
Paraserianthes falcataria	4.8	4.9
Cassia siamea	3.9	4.7
Leucaena leucocephala	2.8	2.2
Duboscia macrocarpa	2.3	4.1
Gliricidia sepium	1.7	2.5
Dialum guinense	1.0	2.1

Table 29. Average height and stem diameter at 50 cm above ground of 9 multipurpose trees, 18 months after planting at Sangmelima, Cameroon.

mulch application. However, the application of mulch and fertilizer together did improve crop yields. Four new farmers joined the project in 1990, and some of the participants, observing improvements in their experimental plots, asked for additional pigeonpea seed to plant hedgerows elsewhere on their farms.

Three other hedgerow-intercropping experiments have been established, but are too new to yield results. One trial, initiated at Yaoundé in 1989, compares the efficiency of the standard hedgerow-intercropping arrangement (4-m alleys between single rows of trees) with alternative arrangements based on grouping the hedges together in blocks.

The second newly established study, in progress at Ebolowa and Yaoundé, aims to develop constant formulae for estimating tree biomass. Current methods of biomass assessment, involving manual separation of the various plant components and direct weighing, are extremely tedious and expensive. The objective of this work is to derive estimates of above-ground biomass from simple measurements of stem diameter and number of branches.

Species Providing Mulch	Fertilizer Application (kg N/ha) 0	30	60	Average
Calliandra calothyrsus	2.6	3.1	3.2	3.0
Acacia auriculiformis	2.6	2.8	3.0	2.8
Leucaena leucocephala	2.2	2.5	2.7	2.5
Gliricidia sepium	1.9	2.9	3.1	2.6
Control (no trees)	1.4	1.9	2.2	1.9
Average	2.6	2.6	2.9	—

Table 30. Maize grain yields (t/ha dry wt) from a hedgerow-intercropping experiment with and without fertilizer, 2 years after establishment at Yaoundé, Cameroon.

Experience suggests that hedgerows given adequate time to establish before cutting produce larger biomass in the long term than hedgerows cut one or two seasons after establishment. Thus, a trial was established at Ebolowa in 1990 to identify the best time for initial cutting of *Calliandra calothyrsus*, *Gliricidia sepium*, *Leucaena leucocephala* and *Paraserianthes falcataria*.

Improved fallows

A simple improved-fallow experiment was established in 1989 at Yaoundé, aimed at evaluating the effects of one-year, two-year and three-year fallows on crop yields and soil properties. Five multipurpose shrubs are being tested—*Cajanus cajan*, *Desmodium distortum*, *Desmodium discolor*, *Crotalaria anagyroides* and *Pueraria phaseoloides*—plus various combinations.

After one year, leafy biomass yields were small for all species. Desmodium produced the largest above-ground biomass, followed by crotalaria, pigeonpea and natural fallow. Improvements in maize yields after one-year's fallow ranged from 15 to 100%, with the best yields from plots that had been under crotalaria (Table 31). Interestingly, although this species did not produce the greatest biomass, it did produce the largest and most numerous nitrogen-fixing root nodules. Groundnut yields also appeared to benefit from one years' improved fallow. This crop gave the highest yields following a fallow of pigeonpea.

A parallel experiment was set up at the same time on farmers' fields. *Cajanus cajan*, *Crotalaria anagyroides* and *Desmodium distortum* were planted as one-year fallows in 1989, and maize and groundnut were planted as test crops in 1990. Yields were higher after improved fallows than after natural fallow, but there were no significant differences associated with particular fallow species.

An on-station experiment started in 1990 at Ebolowa to evaluate the effects on crop yields and soil properties of short improved fallows under intensive cropping regimes. One- and two-season fallows will be followed by one, two or three seasons of crops. Fallow species will be *Cajanus cajan* and *Desmodium distortum*, plus two local leguminous plants, *Mimosa* sp. and *Mucuna* sp.

Three experiments at Yaoundé focused on different aspects of managing improved fallows within the traditional farming system. An on-farm trial was conducted in 1990 to determine whether multipurpose trees could be established from seed immediately after the maize and groundnut harvest, when cassava plants were about 1 m high. The seed germinated well, but seedlings were shaded out by the cassava and by *Eupatorium* weed.

This result underlined the urgency of identifying an effective establishment method for improved fallows. Thus, a second experiment was initiated on station to test the establishment of pigeonpea at different points in the cropping cycle. The objective is to identify the best possible planting time to ensure establishment, minimize labour requirements and obtain good yields from subsequent crops.

Another on-station experiment concentrates on identifying the best method of managing fallow residues. Three techniques are compared: burning, incorporating fallow material in the soil (green manuring), and mulching.

Rotational hedgerow intercropping with livestock

An experiment started up in Yaoundé in 1988 to assess a rotational hedgerow-intercropping system with a livestock component. This work involves the Cameroon Government's Institut de recherches zootechniques (IRZ). ICRAF signed a memorandum of agreement with this additional research partner in 1990.

The experiment tests the effects of *Leucaena leucocephala* and *Gliricidia sepium* intercropped with maize or groundnut for two years and left as fallow for two years. During the fallow period, sheep are allowed to browse the hedgerows and their manure is returned to the plot. Early results from the intercropping phase confirmed the results of other hedgerow-intercropping experiments: leucaena produced a larger biomass than gliricidia; maize yields were better under intercropping than in pure stands, but did not differ significantly with different hedgerow species; groundnut yields were better in pure stands. Sheep were introduced on the fallow plots in June 1990.

Training and institution building

One major objective of ICRAF's collaborative project in Cameroon is to improve the institutional basis for agroforestry research through training courses and workshops, training programmes for young researchers, and close collaboration with national scientists. In 1990, three final-year undergraduates from the University Centre of Dschang, one Ph.D. student from the University of Yaoundé, and one Cameroonian undergraduate from the University of Moncton in Canada conducted research under the project.

Fallow Species	Maize Grain Yield (t DM/ha)	Groundnut Grain Yield (kg DM/ha)
Crotalaria anagyroides	2.6	721
Desmodium discolor	2.2	864
Pueraria phaseoloides	1.9	588
Desmodium distortum	1.8	730
Cajanus cajan	1.5	972
Natural fallow	1.3	566

Table 31. Maize and groundnut grain yields after a one-year fallow at Yaoundé, Cameroon.

The project also sponsored one M.Sc. student at the University of Ibadan in Nigeria. Five national scientists were assigned to the project, including two who had carried out agroforestry research earlier as students from the University Centre of Dschang.

In August, the project coordinated a series of agroforestry research planning meetings. These involved national institutions and programmes responsible for research on soils, livestock, forestry, fruit crops and cocoa.

Finally, ICRAF's new research activities at Ebolowa will be featured in the Cameroon Government's National Agropastoral Show. This event was originally planned for the end of 1990, but it is now scheduled to take place in 1991.

Ghana

In 1989, ICRAF initiated a collaborative agroforestry research and training project with the Institute of Renewable Natural Resources (IRNR) of the University of Science and Technology in Kumasi, Ghana. Other participants in the project are the Ministry of Agriculture, the Council of Scientific and Industrial Research, the Forest Products Research Institute, and other departments of the University of Science and Technology. Funding is provided by IDRC.

The project began with a macro D&D survey to assess agroforestry needs and potentials in the humid zone of southern Ghana. This region accounts for 40% of the total area of the country and 50% of the population. It has a low-lying, gently undulating topography and annual rainfall averaging 1000 mm or more. Vegetation consists of thick rain forest, 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 rain forest, cocoa and coffee in the semi-deciduous rain forest, and oil palm 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 socio-economic problems including labour bottlenecks and poor access to markets. Crop yields are reported to be declining, largely due to a reduction in the fallow period.

Research planning

The survey team identified six land-use systems in the zone and proposed appropriate agroforestry interventions for each. A micro D&D study was initiated in 1990, focusing on the two most important land-use systems. In both, farmers raise oil palm, cocoa and food crops, but in one they emphasize oil palm and in the other the emphasis is on cocoa.

Analysis of these systems includes the three major crop-production activities plus homegardens and livestock components. The goal is to assess the potential contribution of agroforestry and to formulate a research programme to design and test agroforestry technologies for introduction to farmers. The D&D exercise will be completed in early 1991.

Training and institution building

In September 1990, ICRAF helped organize a two-week training course for 15 Ghanaian researchers and educators. Sessions covered agroforestry concepts and technologies, the D&D methodology, on-station and on-farm research methods, evaluation techniques, and management of hedgerow-intercropping systems. In addition, the course included a two-day field exercise.

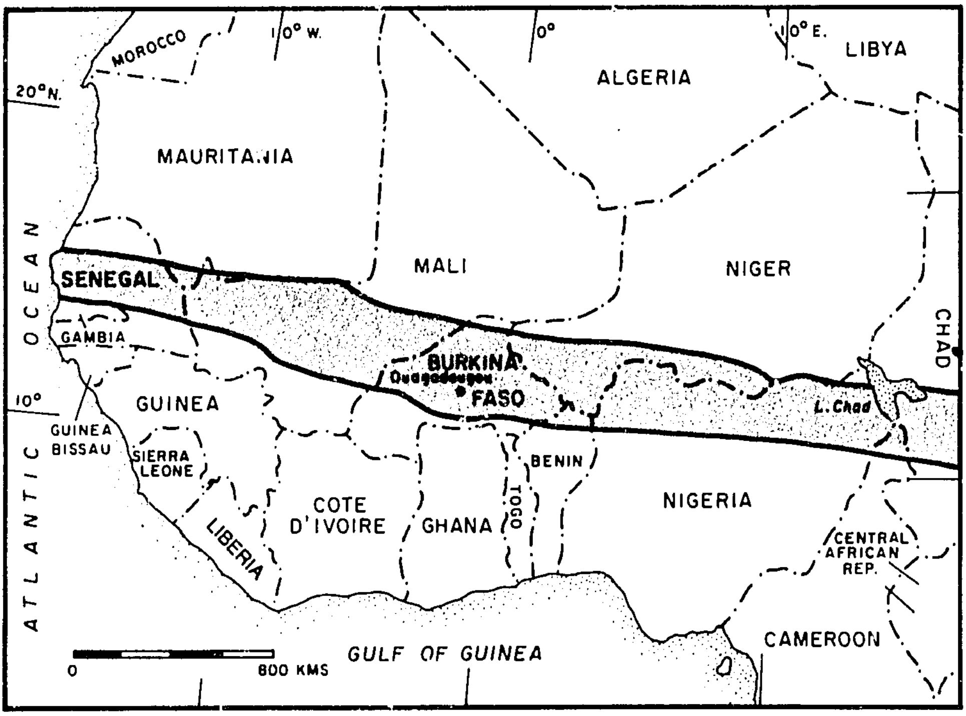
ICRAF staff have contributed to the development of the postgraduate diploma course in agroforestry offered by the University of Science and Technology. This support has included advice on updating the course curriculum, provision of resource materials, and training for six faculty members at ICRAF headquarters. ICRAF is now helping with the design of an M.Sc. programme in agroforestry, which will be introduced by the University in the 1990/91 academic year.

The first Ghana National Agroforestry Workshop, held in September, brought together more than 60 participants from across the country. The workshop provided a forum for discussion among policy makers, planners, extension staff, researchers, educationists and staff of non-governmental organizations. The participants reviewed current activities and identified future priorities for agroforestry programmes in Ghana.

The Government of Ghana's commitment to agroforestry is reflected in the expansion of the institutional framework for agroforestry research, education and extension activities. In 1990, this included:

- Creation of an Agroforestry Unit in the Ministry of Agriculture to implement a National Agroforestry Programme
- Establishment of a National Agroforestry Committee to advise on policy issues and to coordinate agroforestry activities of both government and non-governmental organizations
- Introduction of undergraduate and postgraduate agroforestry courses at the University of Science and Technology in Kumasi
- Implementation, with ICRAF, of the Ghana Agroforestry Systems Research and Education Project, aimed at extending agroforestry to farmers and strengthening agroforestry education and training.

Semi-arid Lowlands of West Africa



The AFRENA programme in the Semi-arid Lowlands of West Africa (SALWA) was launched in January 1989 with the establishment of National Steering Committees and task forces in the four participating countries—Burkina Faso, Mali, Niger and Senegal. In addition to national ministries and research institutes, regional and international organizations participating in the programme include the Institut du Sahel, the Consultative Advisory Committee on Semi-arid Food Grain Research and Development of the Organization of African Unity (OAU/SAFGRAD), ICRISAT's Sahelian Centre and ICRAF.

A Regional Steering Committee was established in December 1989, comprising the chairpersons of the four National Steering Committees plus representatives of the participating international and regional organizations. The Regional Steering Committee met twice in 1990, in Niamey, Niger, and in Dakar, Senegal.

A Regional Coordinator was appointed during the year, based in Burkina Faso. Funding for the SALWA programme is provided by the International Fund for Agricultural Development (IFAD) and CIDA.

Activities in 1990 focused on developing agroforestry research programmes for one priority land-use system in each of the four participating countries. These are:

- Burkina Faso: Agrosilvopastoral system of the northern sudanian zone
- Mali: 'Parkland' system of croplands with scattered trees
- Niger: Niger River valley system
- Senegal: groundnut basin system.

Rainfed agriculture with mixed cropping is the dominant land-use pattern in all four of these systems. Millet and sorghum are the staple food crops, and livestock production also plays an important role. In addition, farmers in Niger grow rice under irrigation near the Niger River.

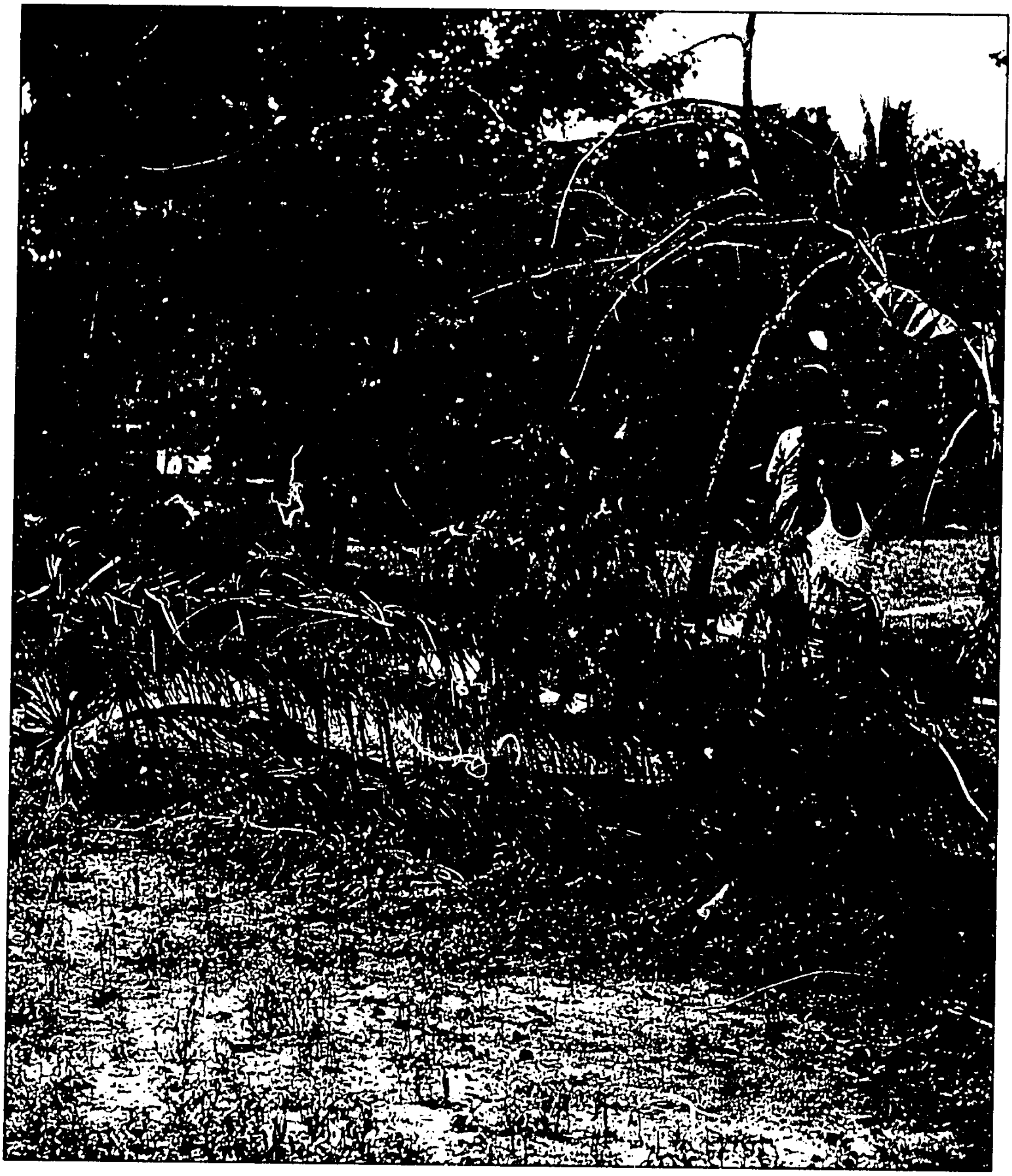


Photo: E. Torquebiau

In the traditional home gardens of Bangladesh, cultivation is intense but the variety of plants and trees growing together sustains the fertility of the soil. ICRAF is involved in a collaborative project in Bangladesh that includes information and documentation, research planning, and training components.

Work in 1990 began with a two-week training course at ICRAF headquarters to familiarize members of the national task forces with the micro D&D methodology developed at ICRAF. Participants discussed how to conduct diagnostic surveys and develop appropriate agroforestry research programmes for the selected land-use systems.

They went back to conduct field surveys in February and March. These involved interviews with individual farmers and groups of farmers on issues related to crop and animal production plus tree use and management. Farmers were also asked to comment on potential agroforestry technologies proposed for their areas.

In May, coordinators of the national tasks forces came to ICRAF headquarters to complete the analysis of their survey data and to prepare agroforestry research programmes, including descriptions of the priority land-use systems, identification of problems and constraints, recommendations for appropriate agroforestry technologies, and agenda for research.

The D&D studies led to the identification of several problems experienced by farmers in the region. The most serious were shortages of fuelwood and dry-season fodder, soil erosion caused by wind and water, poor soil fertility, and damage to crops by free-ranging livestock.

Agroforestry technologies were listed that could help address these problems. These included windbreaks, trees on erosion-control structures, trees on field and farm boundaries, hedgerow intercropping, trees in croplands and rangelands, and fodder banks.

The Institut national de recherches agronomiques du Niger (INRAN) joined ICRAF in June to sponsor a research planning workshop in Niamey. The objectives were:

- To present and discuss the results of the micro D&D exercises and proposed agroforestry research programmes
- To identify priority activities for the rest of 1990 and for 1991
- To identify sites for nurseries and field experiments, as well as site-characterization requirements
- To share information on seed sources.

Hon. Souna Adamou, Niger's Minister for Agriculture and Livestock, opened the workshop. The participation of several cabinet ministers and ambassadors was evidence of a high level of commitment to agroforestry as an approach for sustainable development.

Later in the year, scientists from ICRAF worked with colleagues in each of the national task forces to produce a draft programme of work and research protocols. These were presented in December at a regional meeting in Dakar, Senegal, organized jointly by ICRAF and the Institut sénégalais de recherches agricoles (ISRA). One outcome of this meeting was the development of a programme of work for the four participating countries in the area of information and documentation.

The Dakar meeting included intensive discussions on the proposed experimental protocols, which led to agreement on the following trials, to be initiated in 1991:

- In Burkina Faso, mixed intercropping with trees for soil-fertility improvement and increased crop production; screening and management trials for living fences that also help control soil erosion
- In Mali, management of *Gliricidia sepium*, *Leucaena leucocephala*, *Pterocarpus erinaceus* and *Pterocarpus lucens* for intensive fodder production; management of *Acacia* species for living fences; species screening for use as mulch; studies of the 'parkland' system
- In Niger, impact of tree and herbaceous species combined with erosion-control structures on crop yields and conservation of dune soils; screening of tree species for windbreaks in irrigation schemes; management of *Prosopis juliflora* living fences
- In Senegal, establishment of living fences of single or multiple species; establishment of windbreaks of single or multiple species and their impact on soil characteristics and crop yields; species screening for hedgerow intercropping; study of the physical environment and tree survey in the Keur Magueye area.

ICRAF and ICRISAT also signed an agreement in 1990 to begin a special research project in the SALWA region, aimed at improving selected multipurpose trees. An ICRAF scientist will conduct this work based at ICRISAT's Sahelian Centre in Niger.

Alley Farming Network for Tropical Africa

Photo: A. Njenga

AFNETA is coordinating alley-farming (hedgerow-intercropping) experiments in 20 African countries. This experiment is testing Lecuaena leucocephala *with cowpea.*

AFNETA the Alley Farming Network for Tropical Africa came into full operation in February 1989 with the establishment of a Co-ordination Unit in Ibadan, Nigeria, at IITA headquarters. The network is sponsored by IITA, ILCA and ICRAF.

AFNETA's overall objectives are to promote research on alley farming (or 'hedgerow intercropping') by national institutions in tropical Africa, to develop and test alley-farming systems across diverse environments, and to encourage cooperation in alley-farming research within and between countries. Funding is provided by IFAD, CIDA and IDRC.

Collaborative research activities

In 1990, ICRAF helped review proposals for alley-farming research projects submitted by national institutions. These were revised and approved for funding. Trials have been initiated in the humid, subhumid, semi-arid and highlands zones of 20 countries—Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ethiopia, Ghana, Guinea, Kenya, Liberia, Malawi, Mali, Nigeria, Rwanda, Senegal, Sierra Leone, Tanzania, Togo, Uganda, Zaire and Zambia.

Experiments in these countries are grouped in four broad areas:

- Multipurpose-tree screening
- Alley-farming management
- Livestock integration in alley farming
- On-farm research and socio-economic assessment.

Multipurpose-tree screening trials are in progress at 28 sites, covering more than 40 species. Management trials have been established at 32 sites, investigating factors such as spacing, pruning frequency, contribution of hedgerow prunings to soil fertility, fertilizer use and integration of fallows. Trials focusing specifically on livestock are in progress at six sites, and livestock are also included in a number of management trials. On-farm research has been initiated at 18 sites. As the network matures, the proportion of on-farm trials involving farmer participation is expected to increase.

The AFNETA coordinators are encouraging national research institutes to plan, implement and evaluate their activities in close collaboration with each other. An important aspect of this approach has been the preparation of standard research guidelines so that results from different sites can be compared and applied to a wider area.

Minimum standards have been set for the characterization of each research site—including information on climate, vegetation, soils and cropping systems. Standardized research designs, data-collection procedures and statistical analysis techniques have also been introduced. Finally, the coordinators have identified regional sources of multipurpose-tree germplasm and centres that can provide soil and plant analysis and other scientific services.

Training and institutional building

If research is to be of a high standard and results comparable across sites, then training and communications have an important role within the network. The Coordination Unit publishes a network newsletter, *AFNETAN*, and has prepared a number of technical documents to provide information to collaborating institutions.

In March 1990, AFNETA sponsored a three-week 'train the trainers' course for scientists, extensionists and training specialists working in national agricultural research systems. The course is described in the Training and Education section of this report.

Inaugural meeting of the Alley Farming Network for Tropical Africa (AFNETA), held at IITA headquarters in Ibadan, Nigeria, in August 1989.

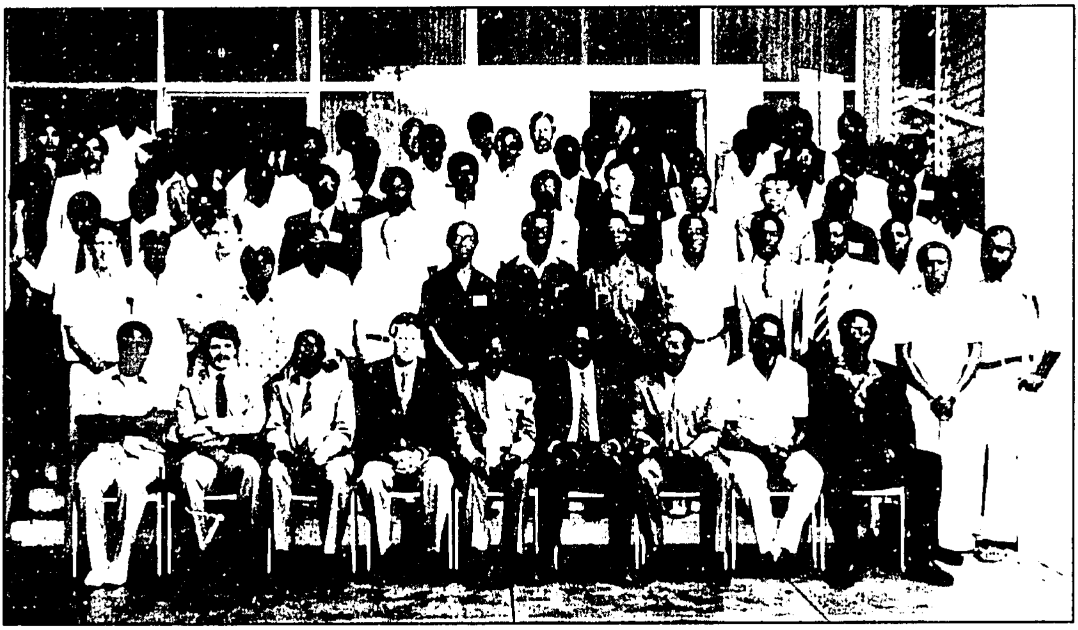


Photo: IITA

South Asia

Photo: E. Torquebiau

When ICRAF and Bangladeshi scientists conducted a micro D&D study at Mouchak, farmers in the area showed the team several agroforestry technologies already in use, including boundary plantings of Leucaena leucocephala.

Bangladesh

ICRAF launched a collaborative project in Bangladesh in 1989 with the Bangladesh Agricultural Research Council (BARC) and the National Agroforestry Working Group. The project has three components: research planning, training, and information and documentation. Funding is provided by the Ford Foundation.

Research planning

Collaboration in research planning relates primarily to micro D&D studies that provide information for setting future research and development priorities. In March 1990, 2 ICRAF staff members joined a multidisciplinary team of 11 national scientists to conduct a micro D&D in Mouchak, Kaliakair, in Dhaka Division.

The study area is a mosaic of irrigated rice fields and patches of higher ground. Some of the higher ground is occupied by long-standing settled farmers, while the rest, owned by the Forest Department, was formerly covered with *Shorea robusta*. The trees have nearly all been cut illegally, and landless families have started building small houses on the bare ground and planting some trees and food crops.

The Forest Department has accepted this encroachment, but wants the farmers to plant trees for timber and pole production along with their crops. The benefits would be shared between the farmers and the department. The department has established a tree nursery and wants the farmers to begin planting trees right away, so the D&D exercise had to be geared towards generating development and extension recommendations, rather than just plans for research.

Individual and group interviews with landless farmers led to the identification of food and cash as primary concerns, followed by shelter, fuel, savings and investment opportunities, and fodder for livestock. The team also learned that the settled farmers have already developed home gardens, boundary plantings, and production of shade-tolerant crops under trees—agroforestry systems that could be introduced to the recent settlers.

After discussion, the team proposed six agroforestry technologies to help meet the needs of the landless families: multi-species, multistrata home gardens; rows of trees in cropland for pole and food production; hedgerow intercropping for fodder and food production; woodlots; boundary planting with fruit trees; and mulberry trees for silk production. These technologies were discussed with the farmers and then the economic aspects were assessed in more detail. Two of the team members from Bangladesh came to ICRAF headquarters for further consultations, followed by preparation of a project document.

Because of the Forest Department's schedule, at least some agroforestry interventions will be introduced to farmers right away. These will possibly require readjustment later on, depending on results from on-station and on-farm research. A second micro D&D will be conducted in 1991 in the Barind Tract area.

Training

ICRAF helped conduct a three-week training course at the headquarters of the Bangladesh Agricultural Research Institute (BARI) in Joydebpur, Gazipur, for 31 participants. This activity is described in the Training and Education section of this report.

In addition, three Bangladeshi scientists participated in the 1990 course on agroforestry research for development at ICRAF headquarters in Nairobi. One additional scientist will come to ICRAF for the same course in 1991, bringing the total number of Bangladeshi scientists trained in ICRAF's D&D methodology to 42. This is the largest number for any single country.

Information and documentation

In 1990, a documentalist from BARC's Agricultural Information Centre came to ICRAF for training. On her return, she produced the first annotated bibliography on agroforestry in Bangladesh, which will be widely distributed.

India

India has one of the oldest national agroforestry research programmes in the world and was the first country to create a national institute for agroforestry, the National Research Centre for Agroforestry at Jhansi in Uttar Pradesh. The national agroforestry research network includes more than 31 institutions, headed by the All-India Coordinated Research Project on Agroforestry of the Indian Council of Agricultural Research (ICAR).

ICRAF staff members have participated in several D&D studies in India. The most recent, in 1990, was a micro D&D focusing on the land-use systems around Jhansi. ICRAF has also provided training and information to a wide range of research and education institutions in India and will continue to promote collaboration and to provide scientific support, especially through the National Research Centre for Agroforestry.

In January 1990, ICRAF took part in the Fourth All-India Biennial Workshop on Agroforestry, organized by ICAR and Gujarat Agricultural University at Navsari. The major sessions included:

1. Review of research progress, including D&D studies, the collection and evaluation of multipurpose-tree germplasm and agroforestry management trials, in five agroecological zones.
2. Discussion of several high-priority topics, such as the strengths and weaknesses of agroforestry research coordination, the role of economic evaluation in the research process, types of experiments, and intercropping systems involving trees with root crops.
3. Consideration of the current objectives of the All-India Coordinated Research Project in Agroforestry and recommendations for future activities.

ICRAF provides regular support to several national institutions in India, primarily in the form of publications and assistance with documentation. To build up India's capacity to store and disseminate information on agroforestry, ICRAF has provided a computer, printer and appropriate software to the national centre at Jhansi.

Training and Education

Participants in ICRAF's introductory course on agroforestry research for development discuss the posters they have prepared on agroforestry activities in their home countries.

Because agroforestry is a new science, there are few trained agroforesters or specialists in other fields with a sound knowledge of agroforestry principles and practices. This lack of trained personnel has been a major constraint on agroforestry programmes at the national level. For this reason, ICRAF places a special emphasis on agroforestry training and education, with all activities conducted in close cooperation with national programmes and with ICRAF's own research work.

To ensure better coordination of a wide range of training activities in Africa, ICRAF organized a workshop in 1990, together with IITA and the West African Rice Development Association (WARDA), to discuss each centre's current activities and future plans. The workshop, held in November at ICRAF headquarters, brought together training specialists from 10 international agricultural research organizations working in Africa.

One 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 in agroforestry to researchers and development specialists from all over the world.

Table 32 shows ICRAF's major training and education activities in 1990. Group training included both general and specialized courses, workshops and field trips. At the individual level, ICRAF offered fellowships to graduate students and internships to support student participation in the research programme. Education activities focused on the development of agroforestry curricula at the diploma, certificate and postgraduate levels.

Activity and Programme	Main Topic	Venue and Duration	Participants
Training courses			
Global	Agroforestry research for development	Kenya—3 weeks	40
AFRENA programmes	Experimental methods and data collection	Kenya—4 weeks	12
AFNETA programmes	'Train the trainers'	Nigeria—2 weeks	20
AFRENA/SALWA	D&D	Kenya—2 weeks	22
AFRENA/Ghana	D&D	Ghana—2 weeks	25
Workshops			
Southern Africa	Research planning	Malawi—10 days	20
SALWA	Research planning	Niger—4 days	46
SALWA	Experimental design	Senegal—6 days	35
Eastern and Central Africa	Experimental design	Burundi—5 days	30
Agroforestry education	Curriculum development	Kenya—4 days	13
Agroforestry education	Curriculum development	Ghana—4 days	12
Agroforestry education	Curriculum development	Kenya—10 days	31
Internships			
Southern Africa	Tree/crop interface	ICRAF/Machakos—3 months	1
Southern Africa	Germplasm evaluation	ICRAF/Maseno—3 months	1
Humid West Africa	B.Sc. field work	Cameroon—3 months	4
Bangladesh	Documentation	ICRAF/HQ—2 weeks	1
Kenya/CARE	Documentation	ICRAF/HQ—2 weeks	1
Fellowships			
Southern Africa	M.Sc. course work	Canada—2.5 years	1
Southern Africa	M.Sc. course work	USA—2.5 years	5
Humid West Africa	M.Sc. course work	Nigeria—2 years	1
Humid West Africa	Ph.D. research	Cameroon—3 years	1
Study tours and special programmes			
Southern Africa	Study tour	Malawi—2 days	20
Southern Africa	Study tour	Kenya—8 days	7
Southern Africa	Study tour	Kenya—6 days	8
Ghana	Study tour	Kenya—1 day	10
Thailand	Study tour	Kenya—1 day	5
CATIE	Scientific visit	ICRAF/HQ—1 month	1
Sokoine University	Scientific visit	ICRAF/HQ—2 months	1
University of Idaho	Scientific visit	ICRAF/HQ—2 weeks	1
Moi University	Scientific visit	ICRAF/HQ—1 month	1

Table 32. ICRAF training and education activities in 1990.

Training within the AFRENAs: a logical progression

In collaboration with the AFRENA programmes, ICRAF's training activities begin with courses 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, the AFRENA programme for the semi-arid lowlands of West Africa—including Burkina Faso, Mali, Niger and Senegal—offered a two-week training course on the methodology for micro D&D studies in January and February 1990 at ICRAF headquarters. Participants went home to conduct micro D&D exercises and came back together in June, in Niamey, Niger, for a regional planning workshop to discuss their results and to propose agroforestry research programmes for the four participating countries. In December, they met again in Dakar, Senegal, for a training workshop on experimental design.

In Southern Africa, training activities in 1990 included a course on research planning in Malawi for scientists collaborating in the AFRENA programme, followed by a two-day field trip. ICRAF also sponsored two internships for collaborating scientists to work in Kenya for three months. One came from Zambia to concentrate on tree/crop-interface studies at the Machakos field station, and the other came from Malawi to work on multipurpose-tree germplasm evaluation at the Maseno Agroforestry Research Centre.

In addition, ICRAF is sponsoring six graduate students from the region for M.Sc. course work in North America followed by field research at the AFRENA sites. Two of these students are from Malawi, two from Tanzania and two from Zambia.

In September 1990, the AFRENA programme for the Humid Lowlands of West Africa offered a two-week training course for national collaborating institutions in Ghana. The course was planned and implemented jointly by the University of Science and Technology in Kumasi, Ghana, AFNETA and ICRAF. The programme exposed participants to agroforestry concepts and approaches, with particular emphasis on the D&D methodology and on alley farming (hedgerow intercropping).

Training within AFNETA: 'train the trainers'

In March 1990, ILCA, IITA and ICRAF conducted a three-week 'train the trainers' course for scientists, extensionists and training specialists working in national agricultural research systems. The objectives were to prepare participants in AFNETA projects to plan and conduct basic and applied research in alley farming and to show them how to train other scientists and technicians in the concepts and methodologies of alley-farming research.

The course, conducted in English and French, was held at IITA headquarters in Ibadan, Nigeria. The 20 participants represented national institutions in Benin, Ghana, Kenya, Nigeria and Zaire. Three ICRAF staff members helped with the planning and instruction. The course covered the following topics:

- Methods for screening and selecting multipurpose trees
- Interaction of trees and crops in alley-farming systems
- Soil management for sustainable agriculture
- Integration of livestock into alley-farming systems
- Socio-economic and cultural factors in alley-farming research
- On-farm research methods
- Experimental design and statistical methods in alley-farming research
- Research planning
- Training methods and communication techniques useful for alley-farming research
- Planning, organizing and conducting regional and in-country training in alley-farming research.

Course participants went on to conduct their own regional training courses in collaboration with AFNETA. Regional courses took place later in the year in Ghana, Benin and Kenya, plus a national course in Nigeria. A regional course was scheduled to take place in Zaire in early 1991.

Agroforestry research for development

ICRAF's main training activity for a global audience is a three-week introductory course on agroforestry research for development, conducted every year since 1983. This course is intended for researchers, planners, policy-makers and extension workers from developing countries. The goal is to provide the technical background information necessary to plan and implement sound agroforestry research. Since 1987, financial support has been provided by the programme for Direct Support to Training Institutes in Developing Countries (DSO) of the Government of The Netherlands.

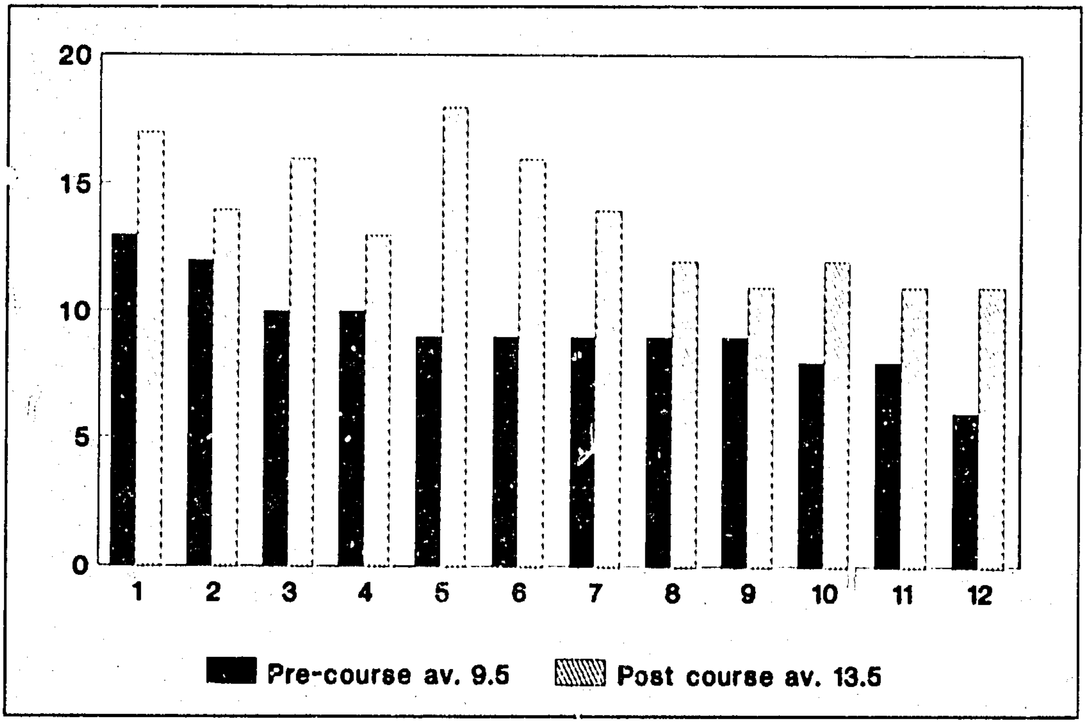
In May 1990, 40 participants attended this introductory course from 26 developing countries in Africa, Latin America, and South and Southeast Asia. They were selected from 332 applicants, a sign of the course's increasing popularity. Special emphasis was placed on ensuring the participation of women, resulting in 13 female participants. Instruction was organized in four modules:

- Introduction to agroforestry—the conceptual and technical background
- The D&D methodology
- Experimental design
- Evaluation methods for agroforestry.

The course consisted of lectures, poster presentations by participants, group sessions and discussions, meetings with ICRAF staff, and work in the ICRAF library. In addition, a two-day field exercise allowed participants to conduct a D&D survey in Kenya's Embu District with assistance from the District Agricultural Office and KARI.

In 1990, ICRAF's annual introductory course on agroforestry research for development was conducted in English. In 1991, the course will be conducted in French. Because of the large number of applicants, this course will be offered a second time in 1991, on a bilingual basis, specifically for participants with outside sponsorship.

Figure 4. Participants' scores on knowledge tests given at the beginning and end of ICRAF's 1990 training course on field experimental methods and data collection in agroforestry research.



Field experimental methods and data collection

Most field technicians involved in agroforestry research projects have been trained in one of the traditional disciplines, but many do not have a strong background in the management of complex land-use systems or in the collection, handling and storage of data on all the factors crucial to agroforestry experimentation. Thus, in 1989, ICRAF started a new course for field technicians working in agroforestry.

In 1990, the second course on field experimental methods and data collection in agroforestry research was held at the Machakos field station. The course took place over four weeks in November and December. Participants were field technicians working in the AFRENA programmes in Cameroon, Kenya, Malawi, Tanzania, Uganda and Zambia, plus four nominated by IDRC. IDRC provided financial support.

With only 12 participants, the approach was informal, emphasizing practical, hands-on sessions in the field. Instruction was organized in three modules. The first covered the preparation of agroforestry field experiments, including experimental design and field layout, use of contour lines, soil sampling, and methods of tree propagation. The second module covered the implementation and maintenance of agroforestry field experiments, including calculations of plant density, spacing, use of fertilizer and other chemicals, planting techniques, and tree management. The third module covered observations, measurements and data collection in agroforestry experiments, including weather, microclimate, soil, trees, crops, animals, pests and diseases.

There were also practical sessions on the use of computers and the maintenance of experimental records. In addition, one day was devoted to instruction and demonstrations on mycorrhizae organized in collaboration with ITE at the National Museums of Kenya.

The instructors distributed lecture notes and other written material on all the topics covered in the course. This material, originally developed from the field technicians' course in 1989, will provide a sound basis for the production of a training package for agroforestry field technicians.

Quizzes at the beginning and the end of the course indicated that participants improved their knowledge by about 50% during the four-week period (Figure 4). This, combined with their positive comments, suggested that the course was useful, and there are plans to repeat it on an annual basis.

Introduction to agroforestry in Bangladesh

Within the framework of the collaborative research programme in Bangladesh, ICRAF joined BARI and BARC to hold a three-week training course in October at BARI headquarters in Joydebpur, Gazipur. Participants were 31 research scientists from national institutions and non-governmental organizations. Funding was provided by the Ford Foundation.

Three ICRAF staff members conducted sessions on some of the subjects, while others were covered by national scientists, most of whom had attended earlier training courses at ICRAF. The course followed the general structure of ICRAF's training course on agroforestry research for development, but the emphasis was on topics and examples from the field of particular relevance to Bangladesh.

Introductory sessions covered basic concepts of agroforestry, classification of agroforestry technologies, the functions of multipurpose trees, and an overview of agroforestry in Bangladesh. Participants also made poster presentations on agroforestry case studies from different parts of the country.

The course went on to introduce ICRAF's D&D methodology, procedures for on-station and on-farm research, and methods for technology evaluation. The participants also visited agroforestry field sites and conducted a D&D exercise with farmers at Rangpur in northern Bangladesh.

After analysis and presentation of the D&D results, the course covered several topics of particular interest. These included gender and land-tenure issues, community forestry, agroforestry and rural agri-business, data analysis, entomology, the agroforestry literature, and the organization of agroforestry research, development and training activities.

Study tours and special programmes

ICRAF organizes study tours and special programmes for staff members of national, international and donor organizations. These allow researchers and development workers to exchange views and to obtain first-hand knowledge of agroforestry systems and practices.

In 1990, ICRAF organized a field trip in Malawi for 20 national researchers from Malawi, Tanzania, Zambia and Zimbabwe. ICRAF also organized four field trips in Kenya: for 7 participants from Malawi, 8 participants from Zambia, 5 participants from Thailand, and 10 participants from Ghana.

Special programmes, ranging from 14 days to 2 months, were also arranged at ICRAF headquarters for four visiting scientists. These were staff members from the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) (Costa Rica), Sokoine University of Agriculture (Tanzania), the University of Idaho (USA) and Moi University (Kenya).

Finally, ICRAF arranged a one-day demonstration D&D exercise in Kenya's Embu District for 22 representatives of donor agencies plus members of the Board of Trustees, and another for 9 representatives from SIDA.

Preparation of teaching materials

All training courses at ICRAF headquarters are supported by the compilation of teaching materials, some prepared in both English and French. In 1990, lecture notes were compiled for the course on agroforestry research for development and lecture notes and selected readings were compiled in collaboration with visiting lecturers from ITE and Kenyatta University for the technicians' training course. This activity will be expanded in 1991.

Curriculum development for agroforestry education

A project was launched in 1988 to develop curricula for agroforestry education in African universities, particularly at the M.Sc. level. In 1990, a related programme was introduced to support agroforestry curriculum development at technical colleges.

During the year, ICRAF staff consulted with faculty members at 10 universities and 7 technical colleges in 10 countries participating in the AFRENA programme. ICRAF also organized three workshops on curriculum development, one in Ghana and two in Kenya.

These discussions indicated that several universities in Africa have recently introduced courses in agroforestry at the B.Sc. and M.Sc. levels. There are important opportunities for agroforestry students at both levels to conduct field research in collaboration with AFRENA programmes.

Most of the technical colleges in contact with ICRAF have also recently introduced agroforestry courses, perhaps due to increasing government emphasis on small-scale farmers. Between 50 and 80% of graduates from technical institutions take up employment either as government extension officers or as field staff in non-governmental organizations. This suggests that support for agroforestry education at technical colleges should have an important direct impact on farmers.

Visits and workshops in 1990 resulted in the formulation of model curricula for M.Sc. courses in agroforestry. In addition, curricula were developed for agriculture, forestry and livestock production courses with an agroforestry component. Objectives and course outlines have also been developed for agroforestry courses in technical colleges.

Although instruction in agroforestry is becoming more widespread, most teachers and curriculum-development specialists have never studied agroforestry themselves and they are often uncertain about where to find appropriate teaching material. Thus, important areas for further attention at ICRAF include training in agroforestry for lecturers and teachers and the compilation and development of instructional materials.

An important result of consultations in 1990 was the preparation of a proposal for an African Network for Agroforestry Education (ANAFE). This will be established in 1991, based at ICRAF headquarters.

Information and Documentation

Photo: A. Njenga

ICRAF's library collection and bibliographic database provide the foundation for several information services and products.

The primary objective of ICRAF's Information and Documentation services is to advance agroforestry research and development through the identification, acquisition, processing and dissemination of information. Activities in 1990 focused on meeting the needs of agroforestry researchers collaborating with ICRAF as well as needs arising from other individuals and institutions around the world.

Building up the database

Information staff are continuously adding to ICRAF's unique bibliographic database of information on agroforestry. This involves scrutinizing appropriate publications, international databases and abstracting services on a regular basis. In 1990, staff members scanned more than 300 issues of international journals and 400 books, plus databases of the United States Department of Agriculture (AGRICOLA), FAO's International Information System for Agricultural Sciences and Technology (AGRIS), and CAB International (CABI).

The ICRAF library acquired 530 books and 3000 reprints during the year, bringing the total collection to more than 6000 books and 13,500 reprints. The library also currently subscribes to 104 periodicals. Out of the new acquisitions, more than 3000 documentary units were catalogued, indexed and entered into the bibliographic database, bringing the total number of records to 17,600.

Photo D G Peden

AFRENA staff in Uganda occasionally provide training and assistance to groups of women farmers. In the process, the scientists have the opportunity to learn more about farming practices in the region

Information services and products

The library collection and associated bibliographic database provide the foundation for a number of information services and products. First, ICRAF produces a *Bimonthly Accessions List*, distributed to 365 individuals and libraries worldwide. Information staff also responded to nearly 700 requests for bibliographic searches during the year. About half of these came from institutions and individuals in Africa, including a quarter from scientists and field workers collaborating with ICRAF through the AFRENA programmes. Searches were carried out using ICRAF's own database plus those of AGRICOLA and AGRIS.

ICRAF provides a selective dissemination of information (SDI) service currently based on the in-house database. This service, which was fully automated during the year, alerts individual users to the most recent additions to the database directly relevant to their research interests. During 1990, the number of scientists who have asked to receive this service increased from 175 to 230. Primarily as a result of ICRAF's search and SDI services, scientists requested and received full copies of nearly 2000 documents identified from the database.

Information staff are preparing a specialized bibliography on agroforestry and fuelwood, with 150 records already identified and analysed. They also began work in 1989 on a computerized directory of agroforestry researchers, which now has more than 450 entries. This directory should provide useful information on current agroforestry research projects and 'who-is-doing-what' to facilitate collaboration and help avoid duplication of effort.

Collaborative activities

During the year, ICRAF's information staff continued cooperative work with international agricultural research centres, United Nations agencies, and other organizations to improve the utilization of information resources. ICRAF contributed to the CGIAR Compact International Agricultural Research Library (CIARL) CD-ROM project. ICRAF also serves as a distribution point for Micro CDS/ISIS, a software package developed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) for bibliographic database management on microcomputers. In 1990, ICRAF issued this software to 11 organizations.

Other collaborative activities included participation in the environmental information network—INFOTERRA—of the United Nations Environment Programme (UNEP). ICRAF functions within INFOTERRA as a special information source on agroforestry. ICRAF information staff also participated in meetings of AGRIS/CARIS (Current Agricultural Research Information System), CGIAR information officers, and the International Association of Agricultural Information Specialists.

Finally, ICRAF is a member of the Kenya Micro CDS/ISIS Users Group and the Nairobi Information Group, an informal association of information services from the many national and international research institutions with offices in Nairobi.

Training and institution building

An important mechanism for strengthening national agroforestry research systems is the provision of training for information personnel. In 1990, two information officers—one from BARC in Bangladesh and one from CARE Kenya—received on-the-job training at ICRAF.

Information staff also helped develop an important information component in the collaborative agroforestry research project for the semi-arid lowlands of West Africa, with funding from CIDA. The objective is to strengthen the information-handling capacities of selected national institutions in Burkina Faso, Mali, Niger and Senegal. ICRAF will play an active role in training and advising the information personnel of these institutions.

Finally, in 1990 as in other years, ICRAF's information staff received large numbers of visitors wishing to learn about ICRAF's Information and Documentation services and to use the ICRAF library.

Communications

ICRAF scientist discusses agroforestry with His Excellency, Dr Kenneth Kaunda, President of Zambia (left), and the Minister of Agriculture, Hon. J.J. Mukando (right), at the 64th Zambian Agricultural and Commercial Show in August 1990.

Communications activities at ICRAF include publication, translation, distribution, audiovisual and graphic production and services, and public affairs. The objective is to communicate agroforestry information to a range of audiences, primarily in support of ICRAF's research and training programmes.

Publications in 1990

ICRAF staff contribute to the international literature on agroforestry through journal articles, chapters in scholarly books and conference papers. In 1990, staff members authored 12 chapters in books, 10 articles in international refereed journals, and 10 articles in ICRAF's magazine, *Agroforestry Today*. One ICRAF staff member also edited the proceedings of a workshop on soil management and agroforestry sponsored jointly by ICRAF and the International Board for Soil Research and Management (IBSRAM). ICRAF's own major periodical publications are the quarterly magazine, *Agroforestry Today*, and the annual report.

Produced for a broad audience, *Agroforestry Today* serves both a communications and a promotional function. Articles cover the field of agroforestry as a whole, not just activities at ICRAF, with a growing proportion of the contents from outside contributors. Half of the magazine is devoted to feature articles and the other half to departments, including letters from readers, news items, a question-and-answer section, and notices of conferences and training courses. In 1990, *Agroforestry Today* added a book-review section.

The annual report contains information for audiences concerned more specifically with ICRAF. As more 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.

Another important publication resulted from a major strategic planning exercise that took place in 1990—*ICRAF: strategy to the year 2000*. ICRAF's strategy document was created through an intense participatory process involving management, staff and the Board of Trustees, as well as representatives from collaborating institutions and the donor community.

ICRAF publishes monographs, computer programs, conference proceedings and annotated bibliographies on different aspects of agroforestry. One major publication was completed in 1990, *SCUAF: soil changes under agroforestry*, an interactive computer model with user's handbook, which estimates the effects on soils of specified agroforestry systems within given environments. ICRAF also published a short general brochure.

Rapid and inexpensive dissemination of research results is achieved through informal publications. These 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 1990, ICRAF published 8 Working Papers, 11 AFRENA Reports, 3 Training and Education Reports, and 1 report in the Source Materials and Guidelines series.

Copublications

ICRAF copublishes an international scholarly journal, *Agroforestry Systems*, with Kluwer Academic Publishers in The Netherlands. In addition to major participation in the peer review and editorial policy-making functions, ICRAF provides 120 subscriptions of the journal to selected 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 helps identify authors of overview articles. ICRAF provides 500 free subscriptions to key agricultural libraries in developing countries and to collaborating researchers in Africa. The Asian Development Bank (ADB) pays for 150 subscriptions to agricultural libraries in ADB member countries.

Translation and publication in French

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, ICRAF is strongly committed to translating major publications into French. In 1990, the annual report and all issues of *Agroforestry Today* were translated and published in French. The French edition of the magazine, *L'agroforesterie aujourd'hui*, is more than a simple translation: it is increasingly tailored for a francophone audience with relevant news items, letters, announcements, calendar notes and book reviews.

In 1990, ICRAF also published one Working Paper, six AFRENA Reports, and various instructional materials, posters, brochures and course notices in French. In addition, translation staff started work on a computerized English-French glossary and thesaurus of agroforestry-related terms, which now contains about 1700 multiple entries and definitions. Translation work is complemented by a continuous effort to verify and expand ICRAF's distribution list of francophone readers.

Distribution

An important accomplishment in 1990 was the completion of an exercise to update the *Agroforestry Today* mailing list. Readers were given two opportunities to return postcards indicating their continued interest in the magazine, and all who failed to reply were deleted from the list. At the same time, a substantial number of new readers asked to receive the magazine. By the end of the year, the mailing list included more than 6200 confirmed addresses.

ICRAF publications are announced in *Agroforestry Today*, and copies are sent out on request. Prices are set on a cost-recovery basis but are waived for many readers in developing countries. In 1990, 1600 copies of ICRAF publications were distributed on request. In addition, all publications are distributed to outposted staff, members and former members of the Board of Trustees, representatives of donor organizations, and specialized libraries.

Audiovisual and graphic production and services

ICRAF's computerized database of colour slides increased from 1500 to 5000 in 1990, reflecting a major effort over the course of the year. The collection of black-and-white photographs increased from 3000 to 5000. More than 150 slides and black-and-white photographs were distributed on request, primarily for use in outside publications, and more than 200 copies of ICRAF's slide sets were sold or given away during the year.

ICRAF photographs, posters and publications were featured in several exhibitions, and ICRAF's video presentation, *The Promise of Agroforestry*, was shown at national agricultural shows in Zambia and Malawi, in training courses organized by the Kenya Government, and at meetings and conferences in Europe.

Communications staff provided technical support for all ICRAF conferences, supplied artwork, desktop-publishing and paste-up services for all ICRAF publications, and prepared overheads and slides for conference presentations by ICRAF staff. Communications staff also helped ICRAF scientists make photographic records of agroforestry systems and experimental work.

Public affairs

Many ICRAF staff members are involved in promotional activities to increase public awareness of agroforestry and of ICRAF. These include interviews with journalists, preparation of press releases, and appearances on local radio and television. ICRAF is also an active participant in the global public-awareness campaign sponsored by the CGIAR.

One important activity in 1990 was the production of a poster in English and French describing the leucaena psyllid, *Heteropsylla cubana*, and giving instructions to scientists and field workers on how to identify and report any incidence of psyllid infestation in Africa. This project was undertaken in collaboration with the International Institute of Biological Control (IIBC) and the OAU's Inter-African Phytosanitary Council.

Agricultural Show Features Agroforestry

'Plan and Prosper' was the theme of the 64th Zambian Agricultural and Commercial Show, held in Lusaka in August. The Department of Agriculture invited the Agroforestry Research Project ... to participate in the show.

The project staff constructed a stand and designed posters explaining objectives, initial research results and training activities. The exhibit included live seedlings of several multipurpose trees with good potential for Zambia.... Visitors also saw samples of prunings and fuelwood harvested from *Sesbania sesban*, *Leucaena leucocephala* and *Eucalyptus camaldulensis*.

Hundreds of visitors were attracted to the exhibit, including small-scale and commercial farmers. Perhaps the most exciting moment for project staff was the visit of His Excellency, Dr Kenneth Kaunda, President of Zambia.... Dr Kaunda found the agroforestry exhibit so interesting that his aides had to urge him to move on to visit the rest of the show. He took with him copies of ICRAF publications, including *Agroforestry Today*.

—*Agroforestry Today*
October–December 1990

Training and institution building

As resources allow, communications staff provide training and support in the form of editing, translating, audiovisual services and graphic design to other sections of ICRAF and to collaborating institutions. In 1990, a member of ICRAF's communications staff led workshops on scientific writing for the African Association of Science Editors (AASE) at the association's annual conference in Ibadan, Nigeria, and helped plan a series of science-writing courses for WARDA and OAU/SAFGRAD. Training sessions in aspects of scientific writing were also conducted for ICRAF headquarters and outposted staff.

ICRAF Publications in 1990

Photo: A Njenga

Participants in ICRAF's course on field experimental methods and data collection measure light interception in a woodlot of young Grevillea robusta *at the Machakos field station.*

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ICRAF Staff in 1990

Name	Position/Discipline (Nationality)	Date Joined (Left)	Duty Station
Office of the Director-General			
Dr B. Lundgren	Director-General (Sweden)	1.9.81	Nairobi
Mr E.G.C. Barrow	Senior Scientist/Agroforestry (Ireland)	9.1.90	Nairobi
Dr P. Huxley	Principal Research Advisor (UK)	4.1.79	Nairobi
Mr S. Kanani	Technical Coordinator (Kenya)	13.6.83 (19.2.90)	Nairobi
Dr W. Migongo-Bake	Research Officer/Range Management (Kenya)	12.11.90	Nairobi
Mr R.B. Scott	Senior Director/Economics (Canada)	1.1.88	Nairobi
Mrs J. Kasyoki	Secretary (Kenya)	13.2.89	Nairobi
Miss A. Kinyanjui	Bilingual Secretary (Kenya)	10.9.90	Nairobi
Mr A. Kirima	Messenger (Kenya)	1.7.87	Nairobi
Miss T. Knudsen	Principal Secretary (Kenya)	1.11.83	Nairobi
Mrs F. Mboya	Principal Secretary (Kenya)	1.9.78	Nairobi
Mrs L. Munge	Cleaner/Tea Lady (Kenya)	1.6.88	Nairobi
Finance and Administration			
Mr D.M. Sickelmore	Director, Finance and Administration (UK)	1.1.86	Nairobi
Mr A. Aghaulor	Head of Finance (Nigeria)	1.8.89	Nairobi
Mr R. Bhabra	Head of Operations (Kenya)	17.9.90	Nairobi
Mr J.B. Granados	Information Systems Manager (Colombia)	1.12.90	Nairobi
Mrs V.H. Guerrero	Head of Human Resources (Venezuela)	1.4.89	Nairobi
Mr G. Maina	Management Accountant (Kenya)	1.10.89	Nairobi
Mrs N. Sood	Associate Travel and Conference Officer (Iran)	1.11.89	Nairobi
Miss A. Achungo	Senior Secretary (Kenya)	9.8.90	Nairobi
Mr J. Akhatsika	Cleaner (Kenya)	1.11.85	Nairobi
Mrs F. Chege	Tea Lady/Cleaner (IUFRO) (Kenya)	1.7.87	Nairobi
Mrs M.M. de Souza	Personnel Assistant (Kenya)	1.10.87	Nairobi
Mr L. Gakombe	Cleaner (Kenya)	1.7.87	Nairobi
Mr E. Gatoru	Assistant Accountant/Projects (Kenya)	1.9.88	Nairobi
Mr J. Gitau	Mail/Filing Clerk (Kenya)	1.3.84	Nairobi
Mr B.B. Hware	Photocopy Operator (Kenya)	15.7.87	Nairobi
Mr T. Ivati	Mechanic (Kenya)	1.7.81	Nairobi
Mrs M. Kabaya	Tea Lady/Cleaner (Kenya)	1.6.90	Nairobi
Mr J. Kagiri	Photocopy Operator (Kenya)	1.10.85	Nairobi
Mrs D. Kamaan	Receptionist/Telex Operator (Kenya)	1.8.87	Nairobi
Mr T. Kamundi	Computer Operator (Kenya)	1.8.88	Nairobi
Mr P. Kang'ethe	Driver (Kenya)	1.6.87	Nairobi
Mr P. Kanyasya	Assistant Accountant/General Ledgers (Kenya)	15.9.89	Nairobi
Ms C. Kanyeki	Building Superintendent (Kenya)	17.1.80 (19.11.90)	Nairobi
Mr J. Kariuki	Driver (Kenya)	1.7.87	Nairobi
Mrs B. Kedeng'e	Principal Secretary (Kenya)	1.3.86	Nairobi

Name	Position/Discipline (Nationality)	Date Joined (Left)	Duty Station
Mr K. King'aru	Administrative Assistant/ Transport (Kenya)	1.9.87	Nairobi
Mr M. Kuria	Storekeeper (Kenya)	1.9.83	Nairobi
Mr H. Luvinzu	Cleaner (Kenya)	1.8.88	Nairobi
Mr A. Makindu	Cashier (Kenya)	1.1.88	Nairobi
Mr J. Mbugua	Messenger (Kenya)	1.11.85	Nairobi
Mr W. Mburu	Accounts Clerk/Disbursements (Kenya)	20.2.90	Nairobi
Mr D. Michino	Accounts Clerk/Receivables (Kenya)	1.8.88	Nairobi
Miss J. Moraa	Filing Clerk (Kenya)	1.7.87	Nairobi
Mr J.M. Muli	Carpenter (Kenya)	1.10.87	Nairobi
Mr D.M. Musili	Cleaner (Kenya)	1.10.87	Nairobi
Miss M. Mutua	Computer Operator (Kenya)	1.10.85	Nairobi
Mr F. Ndungu	Senior Messenger (Kenya)	1.2.85	Nairobi
Mrs T.K. Ng'ang'a	Secretary (Kenya)	1.8.86	Nairobi
Miss F. Ngari	Tea Lady/Cleaner (Kenya)	1.6.83	Nairobi
Mrs G. Ngugi	Receptionist/Telex Operator (Kenya)	1.8.87	Nairobi
Mrs I. Njiraini	Assistant Account/Projects (Kenya)	1.3.90	Nairobi
Mr C.D. Nyaga	Messenger (Kenya)	1.12.87	Nairobi
Mr B. Nyachienga	Driver (Kenya)	1.5.88	Nairobi
Mr A.N. Okello	Electrician (Kenya)	1.11.87	Nairobi
Mrs M. Oluoch	Accounts Assistant/Payroll (Kenya)	19.9.83	Nairobi
Miss C. Omega	Cleaner (Kenya)	19.3.90	Nairobi
Mr S. Omondi	Junior Carpenter (Kenya)	1.10.90	Nairobi
Mr J.O. Opande	Driver (Kenya)	1.10.87	Nairobi
Ms R. Thuo	Senior Secretary (Kenya)	24.8.87	Nairobi
Mrs L. Wambua	Procurement Clerk (Kenya)	1.4.83	Nairobi
Ms L. Wanjau	Receptionist (Kenya)	1.6.87	Nairobi
Mr H. Wanjohi	Cleaner (Kenya)	1.11.88	Nairobi

Research Division

Name	Position/Discipline (Nationality)	Date Joined (Left)	Duty Station
Dr P.J.M. Cooper	Director of Division/Agronomy (UK)	1.11.90	Nairobi
Mr E. Akunda	Research Officer/Crop Physiology (Kenya)	1.1.86	Nairobi
Dr E. Akyeampong	Scientist/Agronomy (Ghana)	1.1.87	Burundi
Dr Amare Getahun	Principal Scientist/Agroforestry (Ethiopia)	1.9.88 (30.6.90)	Nairobi
Dr M. Avila	Principal Scientist/ Agricultural Economics (Belize)	13.7.87	Nairobi
Dr Bahiru Duguma	Scientist/Forestry (Ethiopia)	1.2.87	Cameroon
Mr Bashir Jama	Research Assistant I (Kenya)	1.9.86	Nairobi
Dr M. Baumer	Senior Scientist/Range Management (France)	1.9.83	Nairobi
Dr E. Bonkoungou	SALWA Regional Coordinator/Ecology (Burkina Faso)	1.7.90	Burkina Faso
Ms E. von Capeller	Research Associate/Agronomy (Switzerland)	6.11.89	Cameroon

Name	Position/Discipline (Nationality)	Date Joined (Left)	Duty Station
Mr P. von Carlowitz	Senior Research Scientist/Forestry (GTZ) (FRG)	26.6.82	Nairobi
Mr R. Coe	Senior Scientist/Biometry/Statistics (UK)	15.10.90	Nairobi
Dr T. Darnhofer	Senior Scientist/Agrometeorology (Austria)	15.7.82 (1.7.90)	Nairobi
Dr M. Djimde	Scientist/Animal Science (Mali)	1.5.85	Nairobi
Mr E. Franz	Visiting Scientist/Ecology (USA)	2.8.89 (30.5.90)	Nairobi
Mr D. Gatama	Research Assistant (Kenya)	8.7.85 (18.1.90)	Nairobi
Mr A. Heineman	Research Associate/Forestry (Netherlands)	17.11.87	Maseno
Mr D. Hoekstra	Regional Coordinator/Agricultural Economics (Netherlands)	1.3.82	Nairobi
Dr C. Kamara	Scientist/Soil Science (Sierra Leone)	1.9.88	Zambia
Miss I. Kamau	Research Officer/Biology (Kenya)	1.9.84 (30.6.90)	Nairobi
Dr M. Karachi	Scientist/Agronomy (Kenya)	1.8.88	Tanzania
Mr P. Kiepe	Research Associate/Soil Science (Netherlands)	12.10.87	Nairobi
Dr F. Kwesiga	Scientist/Forestry (Uganda)	1.4.85	Zambia
Dr D.O. Ladipo	Scientist/Tree Breeding and Improvement (Nigeria)	1.11.90	Nigeria
Dr J. Maghembe	Senior Scientist/Forestry (Tanzania)	1.6.87	Malawi
Dr S. Minae	Scientist/Socioeconomics (Kenya)	1.8.85	Malawi
Mr P. Muraya	Research Officer/Computer Applications (Kenya)	1.5.85	Nairobi
Dr D. Ngugi	Regional Coordinator/Agronomy (Kenya)	1.11.85	Malawi
Mr A. Niang	Scientist/Forester (Senegal)	15.1.89	Rwanda
Mr P. Oduol	Associate Research Officer/Forestry (Kenya)	1.10.85	Nairobi
Ms E.L. Ohlsson	Research Associate/Agronomy (Sweden)	1.1.90	Maseno
Dr F. Owino	Senior Scientist/Tree Breeding (Kenya)	10.8.87	Nairobi
Mr B. Owuor	Associate Research Officer/Tree Breeding (Kenya)	1.1.89	Maseno
Mrs G. Patel	Associate Administrative Officer (Kenya)	26.1.88	Nairobi
Mr D. Peden	Senior Scientist/Range Management (Canada)	21.4.89	Uganda
Mr I. Pegorie	Research Associate/Forestry (CTFT) (France)	14.12.88 (21.12.90)	Nairobi
Mr A. Pinney	Graduate Fellow (UK)	9.5.87	Nairobi
Mr H. Prins	Research Associate/Forestry (Netherlands)	1.1.88	Malawi
Dr J. Raintree	Principal Scientist/ Social Scientist (USA)	18.12.80 (1.8.90)	Nairobi
Dr M.R. Rao	Senior Scientist/Experimental Agronomy (India)	1.6.88	Nairobi
Dr J.H. Roger	Senior Scientist/Biometrics and Statistics (UK)	1.4.88 (31.5.90)	Nairobi
Dr S. Scherr	Senior Scientist/ Socioeconomics (USA)	1.12.85 (30.6.90)	Nairobi
Dr K. Shepherd	Scientist/On-farm Agronomy (Rockefeller) (UK)	14.12.89	Nairobi

Name	Position/Discipline (Nationality)	Date Joined (Left)	Duty Station
Ms E. Styger	Research Associate/Entomology (Switzerland)	15.1.90	Rwanda
Mr R. Swinkels	Research Associate/Agricultural Economics (Netherlands)	12.5.89	Maseno
Mr R. Thijssen	Associate Expert/Agriculture (Netherlands)	5.6.88	Nairobi
Dr E. Torquebiau	Senior Scientist/Forest Ecology (France)	9.10.87	Nairobi
Mr D. Wambugu	Associate Research Officer/Agronomy (Kenya)	1.12.82	Nairobi
Mr G.V. Wolf	Scientist/Forestry (GTZ) (FRG)	4.11.86	Nairobi
Dr A. Young	Principal Scientist/Soil Science (UK)	4.1.83	Nairobi
Mrs Z. Dossa	Senior Secretary (Kenya)	7.5.90	Nairobi
Mrs K. Gilani	Senior Secretary/GTZ (Kenya)	15.6.84 (30.4.90)	Nairobi
Miss H. Gitere	Tea Lady/Cleaner (Kenya)	1.8.87	Nairobi
Miss P. Hassan	Bilingual Secretary (Kenya)	1.5.90	Nairobi
Ms M. Kiarie	Secretary (Kenya)	1.6.90	Nairobi
Mrs B. Kibe	Principal Secretary (Kenya)	1.6.81 (11.5.90)	Nairobi
Mrs J. Kimotho	Secretary (Kenya)	1.9.86	Nairobi
Mrs T. Lohay	Administrative Assistant (Kenya)	1.6.84	Nairobi
Mr A. Mageto	Messenger (Kenya)	15.7.87	Nairobi
Miss S. Muasya	Secretary (Kenya)	26.8.82	Nairobi
Ms C. Muniafu	Bilingual Secretary (Kenya)	1.3.88	Nairobi
Mrs J. Muriuki	Secretary (Kenya)	1.1.89	Nairobi
Miss L. Mwandawiro	Bilingual Secretary (Kenya)	1.2.88	Nairobi
Miss M. Mwangi	Secretary (Kenya)	23.3.87 (5.2.90)	Nairobi
Miss R. Mwangi	Bilingual Secretary (Kenya)	3.8.89 (5.8.90)	Nairobi
Mrs J.W. Njagi	Secretary (Kenya)	1.1.89	Nairobi
Mr J. Obande	Field Attendant (Kenya)	10.2.89	Maseno
Mrs S. Okoth	Secretary (Kenya)	1.8.87	Nairobi
Mrs J. Waweru	Senior Secretary (Kenya)	1.3.80	Nairobi
Mr P. Waweru	Senior Driver (Kenya)	1.1.79	Nairobi

Field Station—Machakos

Mr P.M. Kurira	Assistant Research Officer/Farm Manager (Kenya)	1.8.81	Machakos
Mr M. Mathuva	Associate Research Officer/Agronomy (Kenya)	1.6.89	Machakos
Mr P. Ambani	Senior Field Assistant (Kenya)	1.9.88	Machakos
Mr K. Chondo	Labourer (Kenya)	1.1.88	Machakos
Mr B. Kamba	Labourer (Kenya)	1.1.88	Machakos
Mr G. Kiilu	Labourer (Kenya)	1.1.83	Machakos
Mr G. Kilonzo	Gardener (Kenya)	1.9.88	Machakos
Mr M. Kioko	Labourer (Kenya)	1.1.88	Machakos
Mr J. Kyengo	Field Attendant (Kenya)	1.5.89	Kathama
Mr W. Kyule	Labourer (Kenya)	8.9.81	Machakos
Mr E. Letaulo	Labourer (Kenya)	1.1.88	Machakos

Photo: A. Njenga

ICRAF staff in the courtyard of the headquarters building, Nairobi, Kenya.

Mr J. Malonzah	Labourer (Kenya)	1.7.88	Machakos
Mr P. Mbiti	Field Assistant (Kenya)	1.9.86	Machakos
Mr Z. Musembi	Labourer (Kenya)	1.7.88	Machakos
Mr M. Muthoka	Labourer (Kenya)	1.1.88	Machakos
Mr E. Mutinda	Labourer (Kenya)	8.1.88	Machakos
Mr P. Mutua	Labourer (Kenya)	20.1.88	Machakos
Mr L. Mutunga	Labourer (Kenya)	1.1.88	Machakos
Mr G. Mwasambu	Field Assistant (Kenya)	1.12.82	Machakos
Mr M. Ndambuki	Labourer (Kenya)	1.1.88	Machakos
Mr P. Nzioka	Labourer (Kenya)	1.7.88	Machakos
Mr T.O. Ondieki	Labourer (Kenya)	1.1.88	Machakos

Training and Information Division

Dr E. Zulberti	Director of Division/Education (Argentina)	26.4.82	Nairobi
Dr E.O. Asare	Senior Visiting Fellow/Agronomy (SIDA) (Ghana)	19.2.89	Nairobi

Name	Position/Discipline (Nationality)	Date Joined (Left)	Duty Station
Mr J. Beniest	Scientist/Horticulture (Belgium)	16.1.89	Nairobi
Mr B. Bondole	Associate Information Officer (Zaire)	7.3.88	Nairobi
Mr D.A. Brett	Editor/Writer (Australia)	4.8.90	Nairobi
Mr G. de Chatelperron	Associate Information Officer (France)	1.7.88 (30.6.90)	Nairobi
Mr B. Hansson	Research Associate/Curriculum Development (Sweden)	1.3.90	Nairobi
Mr R.D. Huggan	Divisional Director/Communications (Canada)	1.8.87 (31.7.90)	Nairobi
Ms K. Kebaara	Assistant Editorial Officer (Kenya)	3.12.84	Nairobi
Mr R. Labelle	Head/Information and Documentation Unit (Canada)	1.7.81 (21.9.90)	Nairobi
Ms A. Leymarie	French Translator/Reviser (France)	1.9.88	Nairobi
Mrs M. Mbindyo	Associate Administrative Officer (Kenya)	19.9.88	Nairobi
Mr S. Mburu	Associate Information Officer/ Computer Programmer (Kenya)	1.1.89	Nairobi
Mrs H. Munyua	Associate Information Officer (Kenya)	1.5.86	Nairobi
Mr A. Njenga	Assistant Audiovisual Officer (Kenya)	1.2.88	Nairobi
Ms D.A. Odanga	Assistant Graphic Arts Officer (Kenya)	5.10.88	Nairobi
Ms Chang Soh Kiak	Senior Visiting Fellow/Audiovisual Producer SIDA (Singapore)	1.2.89 (28.2.90)	Nairobi
Ms L. Teemba	Associate Information Officer (Kenya)	1.3.79	Nairobi
Mr J. Wahome	Research Officer/Animal Science (Kenya)	1.8.84	Nairobi
Ms S.B. Westley	Head/Communications Unit (USA)	1.8.88	Nairobi
Mrs H. Abdalla	Senior Secretary (Kenya)	1.7.88	Nairobi
Mrs A. Aduol	Senior Secretary (Kenya)	1.9.86	Nairobi
Mr B. Alenga	Graphic Technician (Kenya)	18.8.90	Nairobi
Mrs L. Chege	Secretary (Kenya)	1.1.85	Nairobi
Mrs E.K. Gimode	Principal Bilingual Secretary (Kenya)	9.11.87	Nairobi
Ms M. Kanyugo	Production Secretary/English (Kenya)	18.10.89	Nairobi
Mrs C. Kimwemweh	Bilingual Secretary	1.7.90	Nairobi
Mrs M. Kimenye	Secretary (Kenya)	1.8.86	Nairobi
Mr S. Maina	Messenger (Kenya)	1.11.85	Nairobi
Mrs J.B. Muga	Secretary (Kenya)	1.1.88	Nairobi
Miss E. Muhenge	Secretary (Kenya)	1.9.86	Nairobi
Mr A. Mureithi	Library Assistant (Kenya)	1.1.89	Nairobi
Ms M. Mwangi	Senior Bilingual Secretary (Kenya)	1.11.88	Nairobi
Miss D. Ogonda	Bilingual Secretary (Kenya)	10.9.90	Nairobi
Mr S. Okemo	Library Coordinator (Kenya)	25.1.82	Nairobi
Ms L. Ular	Bilingual Secretary (Kenya)	12.10.87 (11.10.90)	Nairobi
Mrs P. Wandhala	Tea Lady/Cleaner (Kenya)	1.11.85	Nairobi

Financial Statements for 1990

CORE FUND—REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31 DECEMBER 1990

	1990 (US$'000)	1989 (US$'000)
Revenue		
Grants	4050	2960
Recharges	1122	1624
Sundry income	251	181
Total revenue	**5423**	**4765**
Expenditure		
Personnel costs	3216	3010
Supplies and services	1011	1094
Travel	251	187
Purchase of fixed assets	194	259
Total expenditure	**4672**	**4550**
Surplus (deficit) of revenue over expenditure for the year before the following items:	751	215
Extraordinary item	—	(431)
Provision for budget deficit	(250)	—
Surplus (deficit) for the year	**501**	**(216)**
Statement of accumulated core funds		
Balance as at 1 January	(666)	(450)
Surplus (deficit) for the year	501	(216)
Balance as at 31 December	(165)	(666)

Note: The complete 1990 audited financial statements will be supplied upon request.

BALANCE SHEET AT 31 DECEMBER 1990

	1990 (US$'000)	1989 (US$'000)
Fixed assets	**4205**	**3782**
Current assets		
Stocks	70	42
Donor debtors	949	443
Other debtors and prepaid expenses	707	639
Bank balances and cash	1026	407
	2752	**1531**
Current liabilities		
Restricted projects fund	773	1266
Donations received in advance	784	—
Creditors and accrued charges	1223	751
	2780	2017
Net current liabilities	**(28)**	**(486)**
Net assets	**4177**	**3296**
Funded by:		
Capital funds	4205	3782
Core funds	(165)	(666)
Long-term loan	137	180
	4177	**3296**

STATEMENT OF CHANGES IN FINANCIAL POSITION FOR THE YEAR ENDED 31 DECEMBER 1990

	1990 (US$'000)	1989 (US$'000)
Source of funds		
Surplus (deficit) for the year	501	(216)
Adjustment for items not involving movement of funds:		
Write-off of headquarters fund deficit	—	431
Funds generated from operations	501	215
Funds from other sources		
Increase in capital funds	423	133
Increase in donations received in advance	784	—
Decrease in debtors and prepaid expenses	—	139
Increase in creditors	472	338
	2180	**825**
Application of funds		
Increase in fixed assets	423	133
Decrease in long-term loan	43	40
Increase in stock and goods in transit	28	42
Increase in donor debtors	506	—
Increase in debtors and prepaid expenses	68	—
Decrease in restricted projects fund	493	227
Decrease in donations received in advance	—	150
	1561	**592**
	619	**233**
Changes in net liquid funds		
Increase in cash and bank balances	619	233

CORE DONORS FOR 1989 AND 1990

	1990 (US$'000)	1989 (US$'000)
Canada (CIDA)	825	753
World Bank (IBRD)	460	460
Japan	415	—
Netherlands	399	357
Norway	309	295
Finland (FINNIDA)	294	235
Switzerland	290	251
African Development Bank	250	200
Sweden (SAREC)	244	198
Australia	183	—
Belgium	162	—
Ford Foundation	150	150
France	69	61
Total	**4050**	**2960**

RESTRICTED PROJECT GRANTS FOR 1989 AND 1990

	1990 (US$'000)	1989 (US$'000)
United States of America (USAID)	1123	572
Canada (CIDA)	946	854
Sweden (SIDA)	635	529
International Fund for Agricultural Development (IFAD)	500	507
German Ministry for Economic Cooperation and German Agency for Technical Cooperation (BMZ/GTZ)	279	238
International Development Research Centre (IDRC)	270	111
Swedish Agency for Research Cooperation with Developing Countries (SAREC)	245	255
Direct Support to Training Institutes in Developing Countries (DSO)—Government of The Netherlands	185	220
Norwegian Agency for International Development (NORAD)	170	8
Switzerland	125	68
Ford Foundation	98	325
France	75	54
Australia (AIDAB)	42	107
Rockefeller Foundation	34	365
The Netherlands	—	21
Nitrogen Fixing Tree Association (NFTA)	—	16
International Foundation for Science (IFS)	—	15
Total	**4727**	**4265**

ANALYSIS OF RESTRICTED PROJECT FUNDS AT 31 DECEMBER 1990

	Balance at 1.1.1990	Income Received 1990	Income Accrued 1990	Total Available 1990	Personnel Cost	Supplies and Services	Travel	Fixed Assets	Total Expenditure	Balance
Ford Foundation										
Graduate Training	22 860	19 000	—	41 860	27 658	—	—	—	27 658	14 202
India—Bangladesh	160 277	—	—	160 277	35 900	36 443	36 949	—	109 292	50 985
Research Trainee	31 109	—	—	31 109	4 781	47	633	1 067	6 528	24 581
On-Farm Research Workshop	18 611	26 000	—	44 611	—	8 567	21 436	—	30 003	14 608
On-Farm Research Publication	—	28 000	—	28 000	9 380	231	—	—	9 611	18 389
CIDA										
Southern Africa AFRENA	51 137	894 524	51 047	996 708	693 468	201 274	74 892	27 074	996 708	0
GTZ										
MPT Germplasm	110 026	273 372	—	383 398	135 826	94 107	45 794	3 552	279 279	104 119
Fellowships	—	—	1 996	1 996	1 200	65	731	—	1 996	0
SIDA										
Field Station	47 267	310 006	—	357 273	153 252	53 998	2 840	90 337	300 427	56 846
Fellowship—Audiovisual	19 363	—	—	19 363	7 321	12 042	—	—	19 363	0
Fellowship—Special Studies	16 585	101 954	—	118 539	62 206	18 433	15 820	—	96 459	22 080
Agroforestry for Development in Kenya	136 685	—	—	136 685	82 024	9 351	141	—	91 516	45 169
Macro D&D—Ethiopia	—	11 828	—	11 828	6 800	1 484	3 545	—	11 828	0
Associate Expert (1)	—	55 695	—	55 695	10 500	13 215	4 250	1 225	29 190	26 505
Curriculum Development	—	58 772	—	58 772	4 392	22 641	31 739	—	58 772	0
Associate Expert (2)	—	55 695	—	55 695	10 500	12 712	3 452	3 098	29 762	25 933
Publications	—	44 437	—	44 437	—	24 200	—	—	24 200	20 237
SAREC										
ICRAF/Zambia Agroforestry Research	170 767	244 536	—	415 303	112 494	68 541	12 216	38 781	232 032	183 271
USAID										
Eastern and Central Africa AFRENA	—	798 177	192 639	990 816	499 020	345 736	81 400	64 660	990 816	0
ICRAF/OSU/IITA MPT Evaluation	74 517	—	—	74 517	6 622	5 331	18 938	21 000	51 891	22 626

ANALYSIS OF RESTRICTED PROJECT FUNDS AT 31 DECEMBER 1990, CONTINUED

	Balance at 1.1.1990	Income Received 1990	Income Accrued 1990	Total Available 1990	Personnel Cost	Supplies and Services	Travel	Fixed Assets	Total Expenditure	Balance
IDRC										
IRA/ICRAF—Cameroon	—	114 790	—	114 790	50 908	31 653	16 158	16 071	114 790	0
Humid Lowlands—Ghana	—	33 300	—	33 300	16 000	1 350	8 429	—	25 779	7 521
Technician Training Course	—	56 445	—	56 445	6 200	15 145	20 484	14 616	56 445	0
The Netherlands—DSO										
ICRAF/DSO Training Course 1990	—	160 799	—	160 799	45 825	13 668	101 306	—	160 799	0
ICRAF/DSO Training Course 1991	—	—	1 440	1 440	1 200	240	—	—	1 440	0
IFAD										
SALWA	76 972	500 000	—	576 972	248 821	38 653	250 084	—	537 558	39 414
AIDAB										
Grevillea Robusta Workshop	—	42 411	—	42 411	5 000	11 853	19 016	—	35 869	6 542
Rockefeller Foundation										
On-Farm Research	297 749	—	34 149	331 898	191 706	57 189	21 041	61 962	331 898	0
Switzerland										
Associate Expert Cameroon	32 275	45 467	—	77 742	43 466	14 246	—	—	57 712	20 030
Associate Expert Rwanda	—	73 788	—	73 788	43 490	12 300	—	—	55 790	17 998
NORAD										
Agroforestry in Arid Areas	—	162 202	—	162 202	77 442	25 410	266	6 708	109 826	52 376
OTHERS										
Strategy 2000	—	53 495	—	53 495	22 898	10 223	20 374	—	53 495	0
Consultant	—	43 260	—	43 260	37 647	4 912	701	—	43 260	0
TOTAL	**1 266 200**	**4 207 953**	**281 271**	**5 755 424**	**2 653 947**	**1 165 259**	**812 635**	**350 151**	**4 981 993**	**773 431**

Acronyms and Abbreviations

AASE: African Association of Science Editors (Ibadan, Nigeria)
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 (Beltsville, Maryland, USA)
AGRIS: International Information System for the Agricultural Sciences and Technology (Rome, Italy)
AGRITEX: Agricultural Technical Extension Services (Harare, Zimbabwe)
AIDAB: Australian International Development Assistance Bureau (Canberra, Australia)
ANAFE: African Network for Agroforestry Education (coordinated from ICRAF)
BARC: Bangladesh Agricultural Research Council (Dacca, Bangladesh)
BARI: Bangladesh Agricultural Research Institute (Joydebpur, Bangladesh)
BMZ: Bundesministerium für Wirtschaftliche Zusammenarbeit/German Ministry for Economic Cooperation (Bonn, FRG)
B.Sc.: Bachelor of Science
CABI: CAB International (Wallingford, U.K.)
CARIS: Current Agricultural Research Information System (Rome, Italy)
CASAWAC: Committee for Agroforestry, Soil and Water Conservation (Harare, Zimbabwe)
CATIE: Centro Agronómico Tropical de Investigación y Enseñanza (Turrialba, Costa Rica)
CD-ROM: compact disk—read-only memory
CDS/ISIS: Computerized Documentation System/Integrated Set of Information Systems
CGIAR: Consultative Group on International Agricultural Research (Washington, D.C., USA)
CIARL: Compact International Agricultural Research Library (Washington, D.C., USA)
CIDA: Canadian International Development Agency (Hull, Quebec, Canada)
cm: centimetre
CSIRO: Commonwealth Scientific and Industrial Research Organization (Canberra, Australia)
D&D: Diagnosis and design
DAP: di-ammonium phosphate
DM: dry matter
DSO: Direct Support to Training Institutes in Developing Countries (The Hague, Netherlands)
FAO: Food and Agriculture Organization of the United Nations (Rome, Italy)
FINNIDA: Finnish International Development Agency (Helsinki, Finland)
FRG: Federal Republic of Germany
g: gram
GTZ: Gesellschaft für Technische Zusammenarbeit/German Agency for Technical Cooperation (Eschborn, FRG)
ha: hectare
HQ: headquarters
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)
IFS: International Foundation for Science (Stockholm, Sweden)
IIALD: International Association of Agricultural Information Specialists (Wageningen, The Netherlands)
IIBC: International Institute of Biological Control (Ascot, UK)
IITA: International Institute of Tropical Agriculture (Ibadan, Nigeria)
ILCA: International Livestock Centre for Africa (Addis Ababa, Ethiopia)
INFOTERRA: International Referral System for Sources of Environmental Information, United Nations Environment Programme (Nairobi, Kenya)
INRAN: Institut national de recherches agronomiques du Niger (Niamey, Niger)

INSAH: Institut du Sahel (Bamako, Mali)
IRA: Institut de la recherche agronomique (Yaoundé, Cameroon)
IRAZ: Institut de recherche agronomique et zootechnique (Gitega, Burundi)
IRNR: Institute of Renewable Natural Resources (Kumasi, Ghana)
IRRI: International Rice Research Institute (Los Baños, Philippines)
IRZ: Institut de recherches zootechniques (Yaoundé, Cameroon)
ISABU: Institut des sciences agronomiques du Burundi (Bujumbura, Burundi)
ISAR: Institut des sciences agronomiques du Rwanda (Butare, Rwanda)
ISNAR: International Service for National Agricultural Research (The Hague, Netherlands)
ISRA: Institut sénégalais de recherches agricoles (Dakar, Senegal)
ITE: Institute of Terrestrial Ecology (Cambridge, UK)
JICA: Japan International Cooperation Agency (Tokyo, Japan)
K: potassium
KARI: Kenya Agricultural Research Institute (Nairobi, Kenya)
KEFRI: Kenya Forestry Research Institute (Muguga, Kenya)
KENGO: Kenya Energy and Environment Organizations (Nairobi, Kenya)
kg: kilogram
km: kilometre
m: metre
MIDP: Machakos Integrated Development Project (Machakos, Kenya)
mm: millimetre
MPT: multipurpose tree
MPTS: multipurpose tree and shrub
M.Sc.: Master of Science
N: nitrogen
NDFRC: National Dryland Farming Research Centre (Katumani, Kenya)
NFTA: Nitrogen Fixing Tree Association (Waimanolo, Hawaii, USA)
NGO: Non-governmental organization
NORAD: Norwegian Agency for International Development (Oslo, Norway)
OAU: Organization of African Unity (Addis Ababa, Ethiopia)
OSU: Oregon State University (Corvallis, Oregon, USA)
P: phosphorus
Ph.D.: Doctor of Philosophy
SACCAR: Southern African Centre for Cooperation in Agricultural Research (Gaborone, Botswana)
SADCC: Southern African Development Coordination Conference (Gabarone, Botswana)
SAFGRAD: Consultative Advisory Committee on Semi-arid Food Grains Research and Development (Ouagadougou, Burkina Faso)
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)
sq: square
t: tonne (metric)
TARO: Tanzania Agricultural Research Organization (Dar-es-Salaam, Tanzania)
TAC: Technical Advisory Committee, CGIAR (Rome, Italy)
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)
UST: University of Science and Technology (Kumasi, Ghana)
WARDA: West African Rice Development Association (Bouaké, Côte d'Ivoire)
wt: weight

Board of Trustees

Members

Meetings during 1990

20th Programme Committee meeting: 29–30 April
13th Executive and Finance Committee meeting: 30 April
1st Audit Committee meeting: 30 April
17th Board of Trustees meeting: 3–4 May
21th Programme Committee meeting: 3–4 October
18th Board of Trustees meeting: 6 October

Board decisions in 1990

- The Board appointed a Search Committee chaired by Dr Holmes to identify a short list of candidates for the post of Director-General, to replace Dr Lundgren who will resign in 1991.
- The Board reacted positively to an invitation for ICRAF to become a member of the Consultative Group on International Agricultural Research (CGIAR).
- The Board discussed and approved ICRAF's Programme of Work for 1990.
- The Board discussed and approved ICRAF's *Strategy to the Year 2000.*
- The Audit Committee established its terms of reference.

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