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PROGRESS REPORT NO. 6

JANUARY-MARCH, 1984

USAID-ICRAF COOPERATIVE AGREEMENT
NO. DAN-5545-A-00-2075-00
PROJECT NO. 936-5545

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Annex 1.1:	Report on first ICRAF/USAID agro-forestry course	in DIS
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Annex 1.11:	AF Systems description: Forest villages in Thailand	in DIS
Annex 1.12:	AF systems description: Plant species in Kilimanjaro AF systems	in DIS

1. INTRODUCTORY NOTES (B. Lundgren)

This is the sixth quarterly progress report of the USAID-ICRAF Cooperative Agreement, Project No. 936-5545, covering the period January-March, 1984. According to the three-year agreement, which became effective as of 1st September, 1982, ICRAF receives support from USAID for the following three projects:

- Agroforestry Training (Project leader: Dr. E. Zulberti)
- Diagnostic and Design Methodology Development (Project leader: Dr. J.B. Raintree)
- Agroforestry Systems Inventory (Project leader: Dr. P.K.R. Nair).

During the quarter covered by this report a USAID mid-term evaluation mission visited ICRAF for three weeks (March 12-30), making an in-depth assessment of the progress of the three projects. The team was made up of Dr. Robert F. Chandler Jr., Dr. Harlan Davies and Mr. Jim Seyler. A draft report was prepared by the team before leaving Nairobi. Basically, the team was very positive in their evaluation of progress made and they provided a lot of very valuable advice, not only on the continuation of the three projects, but on ICRAF's total work programme.

Also during this period, Dr. Nyle Brady, visited ICRAF to familiarize himself with our work in general and USAID-ICRAF cooperation in particular.

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2. AGROFORESTRY TRAINING (E. Zulberti)

2.1. First ICRAF/USAID Agroforestry Course

Final Report. A report on the first ICRAF/USAID Agroforestry Course, held in Nairobi 1-18 November 1983 was produced during this quarter. It contains a narrative description of activities undertaken week by week, the training materials distributed and the results of the evaluation and recommendations formulated by participants upon completion of the course (see Annex 1). The report was widely distributed to participants and both national and international institutions related to agroforestry research, training and development. Very positive reactions are reaching ICRAF giving an indication of the existing and growing interest in the training activities of the Council.

Follow-up. Efforts are being made to keep in contact with all participants. Two regular communications were sent from the ICRAF's Training Unit on the occasion of the Christmas holidays and announcing the second ICRAF/USAID Agroforestry course. Participants - on the other hand - are sending copies of the reports presented to their respective employing institutions to ICRAF, some of them containing an assessment and recommendations of the agroforestry potentials in their own countries. It is worth mentioning that a mission to Burundi is being considered by ICRAF's Advisory Unit as a result of Mr. R. Baragengana's attendance at the course and subsequent report presented to his government.

A questionnaire was designed to collect feed-back information on how much of the agroforestry knowledge and methods taught at the course participants are being put into use (see Annex 2). The form is under discussion with ICRAF scientific staff.

Mr. Steven Mwihomeke from Tanzania will join ICRAF for a six-month internship to undertake agroforestry study/work on fuelwood and fodder production of multipurpose trees. Mr. Mwihomeke's attendance at the November 1983 course proved crucial in his selection as an ICRAF On-the-job trainee.

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2.2. Second ICRAF/USAID Agroforestry Course

The second ICRAF/USAID Course was announced. A leaflet was produced and distributed to institutions in Africa and COSPRO-related institutions in Kenya Peru and Costa Rica. The deadline for national institutions to submit candidates is April 20, 1984. A sample of the leaflet can be seen in Annex 3. The course is to be held in Nairobi 4-22 June 1984.

The detailed course programme is under revision, following the recommendations of participants and first ICRAF experience. An in-house seminar is to be held at ICRAF during the coming quarter to discuss the proposed changes and approve the final programme scope, content and sequence.

2.3. Third ICRAF/USAID Agroforestry Course

Actions were initiated and an agreement reached with the University Pertanian Malaysia to jointly coordinate the third ICRAF/USAID course. It has tentatively been set to take place in Kuala Lumpur in October 1984. Other collaborating COSPRO institutions in Malaysia which will participate are the Ministry of Agriculture and the Forestry Department. E. Zulberti will undertake a mission to Malaysia in May to start the coordination of the course logistic and support.

2.4. 1985 ICRAF/USAID Agroforestry Course

Contacts have already been initiated with COSPRO collaborating institutions in India to jointly organize one of the ICRAF/USAID courses in 1985. Two training proposals are currently under discussion at the All India Agroforestry Coordinated Project authorities in India. Further developments are expected to occur in the next months.

3. DIAGNOSIS AND DESIGN PROJECT (J.B. Raintree)

Approximately half of the draft methodology manual documents (Working Papers 6&7) have been distributed to people outside of ICRAF for review and comment. Comments received from reviewers to date are generally favourable. Only a few reviewers have made detailed comments and suggestions, but there seems to be a consensus that the presentation of the methodology needs to be simplified (avoiding unfamiliar technical jargon) and somehow streamlined (putting more emphasis on the *process* of diagnosis and design as a procedure which is repeated in a flexible manner throughout the life of an agroforestry project). Providing that the *Guidelines* can be simplified and the flexibility of the procedures emphasized in the revisions, several reviewers (including the AID evaluation team) have expressed enthusiasm for the scope and level of detail contained in the optional resource materials (WP 7) and some have suggested additional modules which they would like to see incorporated into the revised edition (e.g. sections on macroeconomic appraisal methods and criteria, simple guidelines on partial budgeting techniques and assessment of market potential, procedures for feedback and 'quality control' during the implementation of D&D-based projects, etc.). These and other suggested topics will be included in the revised version.

Three new Working Papers in the series on Case Studies in Agroforestry Diagnosis and Design were completed this quarter:

Torres, F. and J.B. Raintree, 1984. Agroforestry systems for smallholder upland farmers in a land reform area of the Philippines: the Tabango case study. Working Paper No. 18. ICRAF, Nairobi (see Annex 4).

Hoekstra, D.A. 1984. Agroforestry systems for the semiarid areas of Machakos District, Kenya. Working Paper No. 19. ICRAF, Nairobi (Annex 5).

Rocheleau, D. and A. van den Hoek. The application of a landscape and ecosystem analysis to agroforestry diagnosis and design: a case study from Kathama, Machakos District, Kenya. (in press as ICRAF Working Paper).

Work on further development and elaboration of the D&D methodology to deal with variable scale applications and monitoring guidelines for the project implementation stage continued this quarter on several fronts, under the supervision of D. Rocheleau.

In Kathama, where the larger-than-farm and intra-household scale work is centering on the activities of six local self-help groups, four nurseries have been established (capacity = 5,000 seedlings each) in preparation for planting out in productive watershed conservation designs. Progress has been made in working out agreements on the land, water, trees and labour rights and responsibilities of group members at this scale of operation which may provide a model for other areas. Followup visits and monitoring of previous group plantings, as well as the on-farm trials, continued during the quarter. The Third Working Paper cited above reports on the analytical work behind these activities, which has been supplemented by detailed mapping and survey work during the quarter.

In Kakuyuni, where the methods developed initially in Kathama are being extended and tested under the COSPRO collaborative project, mapping and survey work progressed with the help of MIDP and KARI personnel, supplemented by the work of two informal student collaborators. Contacts with local self-help group were maintained and nursery work continued in preparation for the watershed and intra-household scale interventions which are being planned for this site.

In Siaya, where ICRAF is collaborating with CARE Kenya to develop and test variable scale approaches and monitoring guidelines for AF projects, field work was initiated during a 3 day visit by Dr. Rocheleau, involving reconnaissance survey and group interviews with project participants.

The *Demonstration value* of the work in progress at the Kenyan D&D sites, particularly Kathama, was heavily exploited during this quarter. Visitors to the Kathama site included: the AID evaluation team (Robert Chandler and Harlan Davies), Prof. F. Mergén (Yale), AID project personnel from Rwanda and Burundi, Arnold Egli (Swiss

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project in Rwanda), Drake Hocking (ICAR, India) Don Thomas (Univ. of Nairobi), Wayne Teel (Mennonite Central Committee), and Terry Hirst (well-known Nairobi cartoonist now illustrating AF-related publications). The Kathama site was also used by a BBC film team for filming a segment of documentary involving ICRAF personnel.

4. AGROFORESTRY SYSTEMS INVENTORY PROJECT (P.K.R. Nair)

4.1. Net-working

The efforts to publicize the project widely (see previous quarterly reports) have resulted in the formation of a global network of individuals and institutions interested in the inventory activity. Several of them have voluntarily provided very useful input to the project. The situation is illustrated in Table 1.

4.2. Data Collection

- The headquarters' staff continued the data collection vigorously. P.K. Nair undertook travels to Indonesia (Java and Kalimantan) and Sri Lanka. In Indonesia, Dr. Sukiman Atmosudaryo, ICRAF Board member, made excellent arrangements with Perum Perhutani and other national organizations, so that questionnaires could be completed and other information (e.g. pictures) gathered on the very interesting AF systems existing there. From Sri Lanka also, informmation could be gathered on several systems with the help of national agencies.

- Reports were received from four Regional Coordinators that data collection was going on in full swing, but that they would not be able to complete the data collection by the deadline of 31 March, 1984.

4.3. Data Bases

- Four sets of data bases have been prepared on microcomputer at Nairobi. These are:
  - field examples of prominent AF systems existing in various ecological regions in different countries;
  - characteristics and uses of the important woody perennials commonly found in different systems;
  - trees and other woody perennials with anti-pest properties;
  - bibliographic references on prominent and promising AF systems and practices.

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These data bases are being up-dated regularly. Examples of the print-outs of these data bases are attached (Annexes 6-9).

- A large number of photographs have been assembled on various agroforestry systems around the world and some of them mounted on display panels at ICRAF.

4.4. System Descriptions

- The first three contributions to the Series on AF System Descriptions (Series editor: P.K.R. Nair), arranged to be published in AF Systems Journal (see previous quarterly report), have been processed and submitted to the journal. These are:

  1. E.C.M. Fernandes, A. O'Kting'ati and J. Maghembe. The Chagga home gardens: a multistoried agroforestry cropping system on Mt. Kilimanjaro (N. Tanzania). Annex 10.

  2. S.A. Boonkird, E.C.M. Fernandes and P.K.R. Nair. Forest villages: an agroforestry approach to rehabilitating forest land degraded by shifting cultivation in Thailand. Annex 11.

  3. A. O'Kting'ati, J.A. Maghembe, E.C.M. Fernandes and G.H. Weaver. Plant species in the Kilimajaro agroforestry system. Annex 12.

4.5. Data Evaluation

Prof. Spedding of Reading, U.K., who has been contracted for data evaluation (see previous quarterly report) has initiated the work. As a first step, a structured and condensed data format is being prepared, that will facilitate the preparation of:

i) standardised/compatible data summaries from Regional Coordinators and other correspondents;

ii) computer storage of data by non-technical people (such as secretaries); and

iii) classification of AF systems depending on the purpose of such classification.

4.6. Project Evaluation

The USAID Evaluation Team which undertook a mid-project evaluation in March has recommended an extension of six months, till March 1986, to complete the project (in view of the enormous magnitude of the project activities over the originally conceived level and the unanticipated problems in data gathering). The team also recommended to USAID that additional funding may immediately be provided for the inventory from the Pacific-PNG region (for which proposals were resubmitted in February 1984 based on the discussion with Mr. Michael Benge, Project Manager, AID/W).

4.7. Major items of work planned during the next quarter

- completion of data collection from all regions (except the Pacific and PNF);
- continuation of data evaluation;
- finalization of more system descriptions under the AF System Description Series.

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TABLE 1:

INTERNATIONAL COOPERATION IN AGROFORESTRY SYSTEMS INVENTORY

Number of active contacts excluding those of/through the Regional Coordinators in different geographical regions (March, 1984)

	SE Asia	S. Asia	Middle East, Mediterranean and N. Africa	E & C Africa and Humid West Africa	Sahel and southern Africa	American Tropics	Pacific	Others
1. No. of people to whom the project details and questionnaires were sent	50	50	20	100	40	150	15	75
2. No. of additional requests for project info. (excluding 1)	15	14	-	30	12	12	4	15
3. Voluntary contributions (completed questionnaires, system descriptions, etc.)	6	8	-	4	2	7	7	2
4. No. of institutions with active contacts	12	10	2	12	8	18	8	several

FINANCIAL STATEMENT (K. Gatamah)

ICRAF
INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY
CONSEIL INTERNATIONAL POUR LA RECHERCHE EN AGROFORESTERIE
CONSEJO INTERNACIONAL PARA INVESTIGACION EN AGROSILVICULTURA
P.O. Box 30677, Nairobi, Kenya. Tel 29867 Telex 22048 Cable ICRAF

7th May, 1984.

Ref: ADM/3841/USAID/KG/43

Regional Financial Management Centre,
Agency for International Development,
P.O. Box 30261,
NAIROBI.

Dear Sir,

RE: REQUEST FOR ADVANCE ICRAF COOPERATIVE AGREEMENT

Enclosed please find project financial implementation report for the above project for your necessary action.

Yours faithfully,
International Council for Research in Agroforestry

K. Gatamah
Secretary/Treasurer

Encls.

/lwg

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Standard Form 1034
Revised January 1980
Department of the Treasury
I TFRM 4-2000
1034-118

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

VOUCHER NO.

U.S. DEPARTMENT, BUREAU, OR ESTABLISHMENT AND LOCATION

Regional Financial Management Centre for International Development,
P.O. Box 30261, Nairobi.

DATE VOUCHER PREPARED: 30th April, 1984

CONTRACT NUMBER AND DATE: DAN-5545-A-00-2076-00

REQUISITION NUMBER AND DATE: Sept. 14, 1982 and amend No. 1 dd Jan. 7, 1983

SCHEDULE NO

PAID BY

PAYEE'S NAME AND ADDRESS

International Council for Research in Agroforestry,
P.O. Box 30677,
NAIROBI.

DATE INVOICE RECEIVED

DISCOUNT TERMS

PAYEE'S ACCOUNT NUMBER

SHIPPED FROM | TO | WEIGHT | GOVERNMENT B/L NUMBER

NUMBER AND DATE OF ORDER	DATE OF DELIVERY OR SERVICE	ARTICLES OR SERVICES (Enter description, item number of contract or Federal supply schedule, and other information deemed necessary)	QUANTITY	UNIT PRICE COST	UNIT PRICE PER	AMOUNT
		Advance payment for estimated expenditures for the period, 1st April, to 30th June, 1984 (see attached signed project implementation report).				US$ 76,076

(Use continuation sheet(s) if necessary) (Payee must NOT use the space below) TOTAL US$76,076

PAYMENT:
- ☐ PROVISIONAL
- ☐ COMPLETE
- ☐ PARTIAL
- ☐ FINAL
- ☐ PROGRESS
- ☐ ADVANCE

APPROVED FOR = $ EXCHANGE RATE = $1.00

BY [2]

TITLE

DIFFERENCES

Amount verified, correct for

(Signature or initials)

Pursuant to authority vested in me, I certify that this voucher is correct and proper for payment.

(Date) (Authorized Certifying Officer)[3] (Title)

ACCOUNTING CLASSIFICATION

PAID BY

CHECK NUMBER ON ACCOUNT OF U.S. TREASURY | CHECK NUMBER ON (Name of bank)

CASH $ DATE | PAYEE [1]

[1] When stated in foreign currency, insert name of currency
[2] If the ability to certify and authority to approve are combined in one person, one signature only is necessary; otherwise the approving officer will sign in the space provided, over his official title
[3] When a voucher is receipted in the name of a company or corporation, the name of the person writing the company or corporate name, as well as the capacity in which he signs, must appear. For example "John Doe Company, per John Smith, Secretary", or "Treasurer", as the case may be

PER

TITLE

Previous edition usable NSN 7540-00-634-4206

PRIVACY ACT STATEMENT

The information requested on this form is required under the provisions of 31 U.S.C. 82b and 82c, for the purpose of disbursing Federal money. The information requested is to identify the particular creditor and the amounts to be paid. Failure to furnish this information will hinder discharge of the payment obligation.

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INTERNATIONAL COUNCIL FOR RESEARCH
IN AGROFORESTRY,
P.O. BOX 30677,
NAIROBI.

PROJECT FINANCIAL IMPLEMENTATION REPORT

PROJECT: 936-5545
COOPERATIVE AGREEMENT NO. DAN-5545-A-00-2076-(
AS OF MARCH 31 1984

APPROVED BUDGET LINE ITEM	AMOUNT	BUDGETED	DISBURSEMENTS (US$)			
	1	2	3	4	5	6
	US$	KSHS	Prior Cumulative	This Period	Cumulative Thro'	Estima Next days
1. Salaries	444,525	-	265,160	48,790	313,950	36.0
2. Consultants	104,000	-	84,265	(5,488)	78,777	5.0
3. Travel & Transportation	103,500	-	39,985	5,135	45,120	-
4. Equip. Materials & Supplies	107,240	-	59,260	5,337	64,597	9.6
5. Participant Training	63,400	-	24 850	-	24,850	18.0
6. Overhead	162,335	-	94,705	9,854	104,559	13.7
7. Evaluation	15,000	-	-	12,568	12,568	-
TOTAL	1,000,000	-	568,225	76,196	644,421	82.3

Estimated disbursements thru (columns 5 & 6) 1984	US$	724.8
Less cash advances received thru/disbursements to	US$	650.7
Cash advance/requested	US$	76.0

I certify that records and supporting payment documents e.g. commercial invoices, receiving reports, inventory and property records are on file at ICRAF Headquarters (Nairobi) and are available for rev by US Government representatives upon request

Signature: Kalamah

Name: KARUGOR GATAMAH

Title: SECRETARY/TREASURER

Date: APRIL 30, 1984

ANNEX 1

REPORT ON THE FIRST ICRAF/USAID

AGROFORESTRY TRAINING COURSE

1983

Title of Course: "Agroforestry Research for Development: Concepts, Practices and Methods."

Date : 1 - 18 November 1983

Place : Nairobi, KENYA.

Ester Zulberti

January 1984

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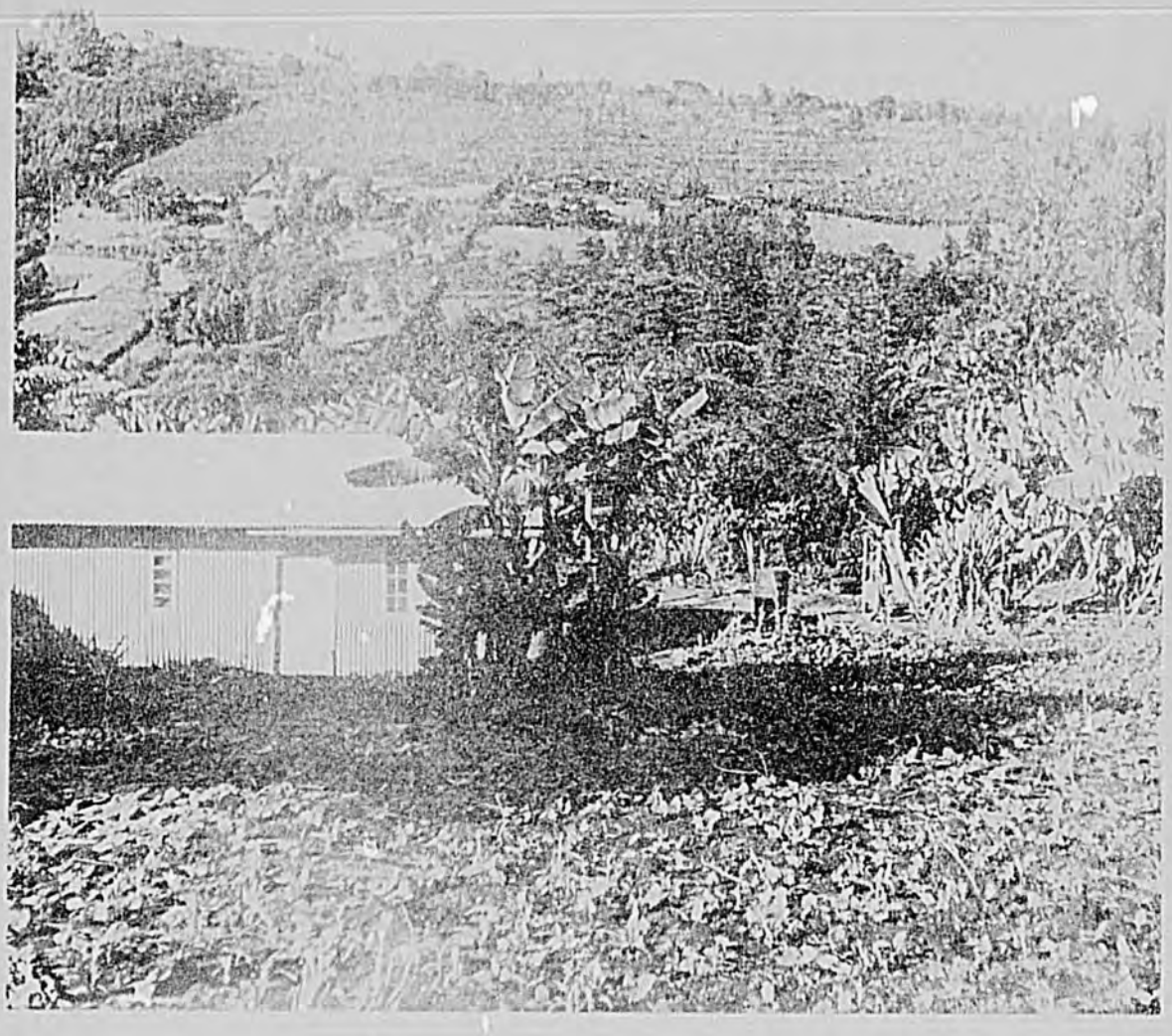


A look at agroforestry systems: bananas and beans in the foreground and fruit trees, woody perennials, living fences and woodlots in the back

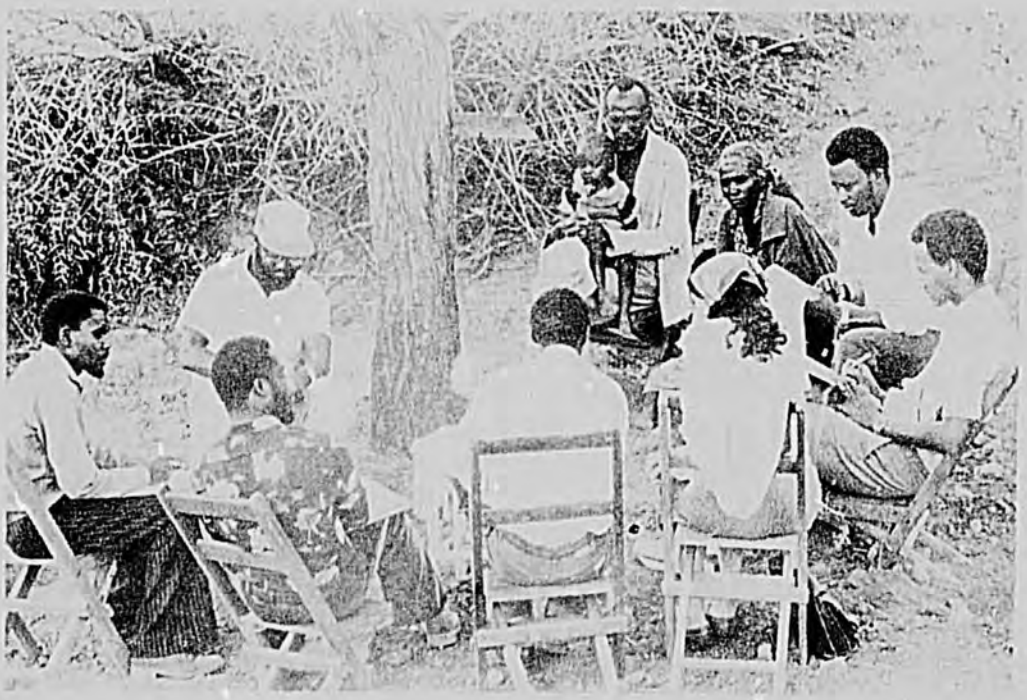
A VISIT TO ICRAF FIELD STATION IN MACHAKOS

Touring the Field station grounds.

At a demonstration plot for tree-crop interface.

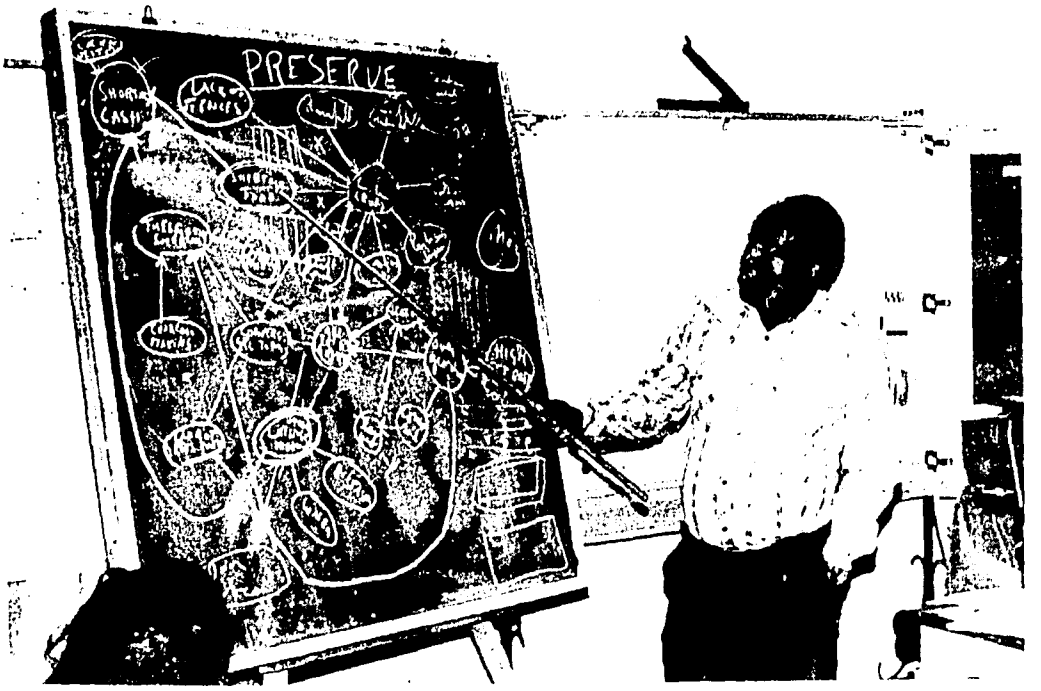
THE DIAGNOSTIC AND DESIGN EXCERCISE

A reconnaissance of the grazing land in a Kathama household.

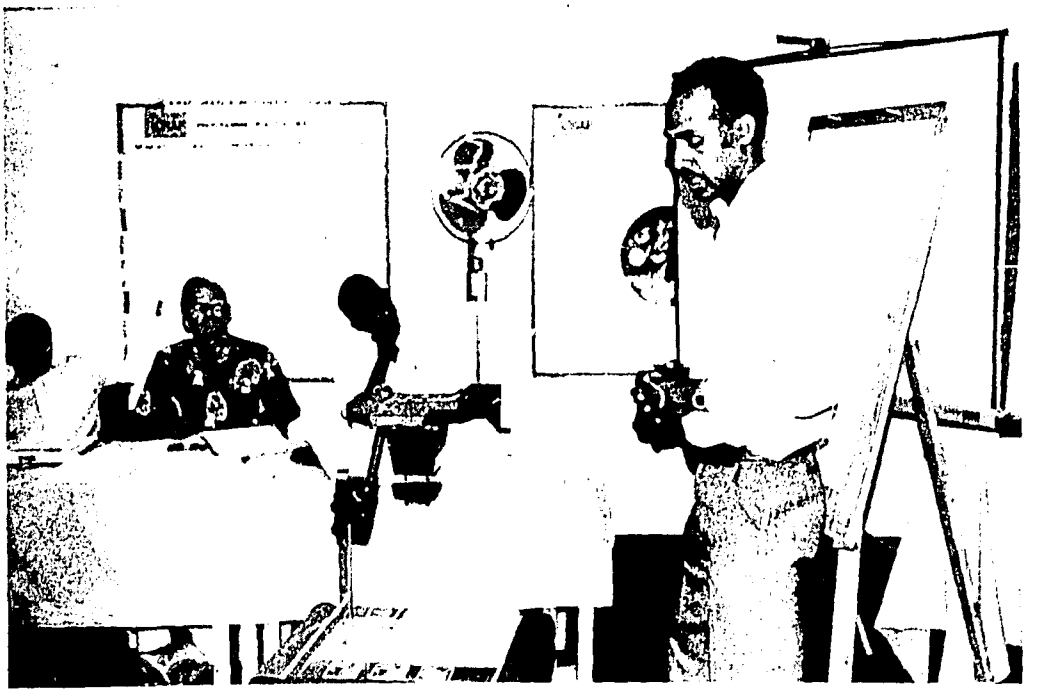


Informal interviews with family members.

PARTICIPANTS PRESENTING RESULTS



Analysing the D & D excercise. It really wasn't as complicated as it looks !



Conclusions of a small group assembled to work on a simulated research proposal.

1. INTRODUCTION

1.1 BACKGROUND

The ICRAF/USAID Training Course on Agroforestry Research for Development was held in Nairobi, Kenya, from 1 to 18 November 1983. It was carried out as part of a series of training courses launched by ICRAF to disseminate available knowledge on agroforestry practices and systems, and on methods for assessing land use problems and evaluating agroforestry potentials. The course was made possible through a Cooperative Agreement between ICRAF and the United States Agency for International Development. It was organized by ICRAF.

ICRAF's multidisciplinary scientific and professional team participated in the development of the training programme which covered a wide range of conceptual, methodological and practical aspects of agroforestry. The Coordinator of the Course was Dr. Ester Zulberti, ICRAF's Training Officer.

1.2 PARTICIPATION

Twenty-two participants from the following countries took part in the Course: Burundi (1), Cape Verde (1), Ethiopia), Ghana (1), Kenya (6), Malagasy (1), Malawi (1), Mauritius (1), Niger (1), Nigeria (1), Tanzania (3), Uganda (2) and Zambia (1).

Disciplines represented among participants were: forestry(9), agriculture (5), animal husbandry (2), soils (2), geography (1), farm management (1), agroforestry (1) and plant genetics (1).

A complete list of participants, invited speakers, and members of ICRAF is given in Annex 1 of this report.

1.3 OBJECTIVES

The overall objective of the Course was "to enhance the professional capabilities of research scientists and development planners from developing countries from initiating

and implementing agroforestry research, leading to the development of systems and technologies that are both suited to local conditions and adoptable by farmers."

This objective was accomplished by:

(1) introducing the concepts and procedures of ICRAF's methodology to diagnose agroforestry related land use problems and potentials and design appropriate agroforestry systems (D&D).

(2) discussing key conceptual, organizational and operational aspects of ICRAF's programme of work and,

(3) analyzing available agroforestry research information and relevant experimental approaches.

2. PROGRAMME

2.1 INAUGURATION

The three-week course meeting site was at ICRAF Headquarters in Nairobi. Participants reported to ICRAF on Monday 31 October for registration. The opening session took place on the morning of Tuesday 1 November. Dr. Bjorn Lundgren, Director of ICRAF, welcomed the participants and briefly explained the background of the Course they were about to begin.

The Course Coordinator then provided the participants with a technical overivew of the programme outlining the objectives of the event and the steps that had been arranged to reach goals, as well as the administrative procedures to be followed.

Participants were requested to introduce themselves and give a brief description of their current professional activities and agroforestry interests.

2.2 STRUCTURE AND CONTENT

The Course programme was organized in three phases. The objective of the first phase (one week long) was to present and discuss the conceptual and technical background of agroforestry as well as to introduce participants to ICRAF's programme of work. An invited speaker and ICRAF collaborator, Dr. Amare Getahun, from Energy Development International (EDI) in Kenya presented information on Agroforestry Systems in the African Highlands. Two field trips undertaken to complement the presentations provided the opportunity to observe a wide range of land-use systems - from the fertile uplands of the Kiambu District to the semi-arid regions of Machakos District.

The second phase of the Course focussed on ICRAF Diagnostic and Design Methodology. It began with an introduction to approaches to Farming Systems Research (FSR). Dr. M. Collinson and Dr. P. Anandajayasekeram from the International Maize and Wheat Center (CIMMYT) and Dr. R. Kirkby from the International Development Research Centre (IDRC) highlighted the potentials and constraints of the FSR approach to assist rural communities in development. Even though participants were exposed to all the stages and steps involved in the D&D methodology they did not actually spend the time required to complete the full exercise (2-3 weeks) due to time constraints. This limiting factor was balanced out by gathering all pre-diagnostic information well in advance as well as by using previous work experience in the Machakos area. The sequence of activities - as they occurred during this week and a half long period was as follows:

- Introduction to the D&D conceptual framework and methodological procedures.
- Analysis of two case-studies where ICRAF has undertaken D&D exercises, specifically in Costa Rica and Malaysia
- Preparation for the D&D field exercise. It included: a) review of baseline information on the Machakos area,

b) selection of land use systems of interest,
c) review of field survey methods,
d) identification of farmers, and
e) assembling of four small multidisciplinary groups.

- Field exercise. Two field groups worked in the highlands and two in the lowlands of the Machakos District. It began with a reconnaissance of the area followed by 16 diagnostic farmers' interviews.

- Simultaneous workshops. They were held at ICRAF in four small groups to:

  a) evaluate diagnosed land use problems,
  b) design specifications for problem-solving interactions,
  c) analyze technology options to address the identified design specification, and
  d) evaluate design alternatives and select 'best bet' options.

- Plenary sessions. They took place after the workshops to present and discuss the recommendations of the small groups.

- Consultation with rural population. Participants returned to the field to discuss with the farmers interviewed at the diagnostic phase the benefits or constraints of the proposed problem solving technologies.

- Wrap up session. ICRAF staff presented the results of a real and full time D&D mission undertaken by ICRAF in the Machakos District. Results, even though obviously not identical to those produced during the Course D&D exercise due to several constraints e.g. time, number of farmers interviewed, etc, did point in the same direction. Thus bringing to the participants' attention the value of the D&D procedures.

Moving on in the development of the programme, the logical next step and follow-up to the D&D exercise was to identify research needs to generate required technologies, if not already available. This was the beginning of the third and last phase of the Course. Specific research problems were

defined and attention focussed on the planning and implementation of investigations to generate agroforestry technology. Small groups were assembled to work on simulated research proposals in "alley cropping", a problem solving technology identified for the Machakos area during the D&D exercise. The groups' deliberations led to a brief overview on experimental designs and experimental measurements in agroforestry. The pre-established focus of the Course on ICRAF's multidisciplinary approach to diagnose land use problems and potentials and design appropriate agroforestry systems did not allow for further involvement in technology generation issues which rightly justifies a Course in its own. A detailed day - to - day account of the programme of activities will be found in Annex 2.

2.3 MONITORING

Monitoring procedures were applied throughout the development of the Course with the aim of detecting programme difficulties, if any, and to apply corrective measures on time. The Course Coordinator carried out review sessions at the end of the first and second weeks of the Course as part of the programme of activities. No changes were requested by participants. Minor adjustments were made by ICRAF staff during the last two days to fit better the activities of the programme to the participants' interests in agroforestry experimental approaches. Largely, the programme of activities and general coordination was followed as originally planned.

2.4 SPECIAL ACTIVITIES

During the course the participants were guests of different ICRAF staff on several occasions. Fun-tours to wild animal reserves were also organized.

A film on "Remote Sensing" kindly lended to ICRAF by the Kenya Resource Evaluation and Monitoring Unit (KREMU) was shown as an after programme activity. Participants expressed their appreciation to update knowledge in this field. Three UNEP films on world experimental issues were also available.

2.5 COURSE FOLLOW-UP ACTIONS

On the afternoon of Friday, 18 November, ICRAF staff met with the participants to discuss follow-up actions to the Course. A double channel of communication between ICRAF and the participants was identified as highly desirable to: a) provide feed-back information on the impact of ICRAF's training programme b) update participants on agroforestry research developments, and c) identify possible cooperative activities between ICRAF and national institutions as well as to facilitate cooperation between countries. Agreement was reached on the following specific actions:

- ICRAF will include all participants in the distribution list of the Council's Newsletter and special announcements of future training opportunities.

- ICRAF will prepare and send a follow-up questionnaire to all participants 3-4 months after the course in an attempt to determine how much agroforestry information/ methods are being put into use as a consequence of Course attendance.

- Participants will send to ICRAF a copy of the reports presented to their respective institutions with detailed recommendations on possible agroforestry alternatives in the light of issues discussed during the Course.

- Participants will collaborate with ICRAF in the identification of qualified colleagues who would benefit the most by participating in ICRAF's training activites.

2.6 CLOSING SESSION

The closing session of the course took place in the early afternoon of 18 November. Following a brief oral evaluation of the Course, Dr. Jairaj Ramkissoon gave a speech of thanks to ICRAF on behalf of the pariticipants for making the event possible. The official closing address was given by Dr. Peter Huxley, Acting Director of ICRAF in the absence of Dr. Lundgren.

Course participants were then presented with certificates of attendance by ICRAF staff. A farewell reception was then held for participants as well as for ICRAF scientific, professional and support staff involved.

3. TRAINING MATERIALS

3.1 TRAINING PACKAGE

Since agroforestry training is a new area, so is the development of appropriate training materials. A systematic method is being followed by ICRAF to develop such training materials, essentially the same as in developing research methods, viz. collation and evaluation of relevant information from cognate disciplines, integration of such information into a new format and testing during the training courses.

An Agroforestry Training Package was compiled of existing knowledge and selected information about agroforestry principles, practices and methods gathered from different sources and arranged to follow the course programme of activities. Training materials were placed in a two-ring binder to be used as a portable system to add and revise important information.

Four dividers were established to identify modules on: ICRAF's Role and Programme, Agroforestry Conceptual and Technical background, A Diagnostic Approach to the Design of Agroforestry, and Experimental Approaches. Each module included the main notes and/or key articles, practical exercises, (case studies, field trips) and a list of recommended reading or references. Additional information was provided on the Course day-to-day programme activities, the participants and the final evaluation of the event. A description of the training package content is presented in Annex 3.

3.2 VISUAL AIDS

Visual aids were prepared to complement speakers' presentations, to present general information or to start up discussion sessions. Among the most frequently used were slide series, overhead transparencies, display boards, posters and

documents/books exhibitions.

4. EVALUATION AND RECOMMENDATIONS

As was called for at the beginning of the Course, participants were requested to evaluate and formulate recommendations on specific aspects of the programme, at the end of the three-week programme. An evaluation form was enclosed in the training package handed out to participants. A copy of this form will be found in Annex 4 of this report.

Twenty-one evaluation forms were filled and returned. In general, participants expressed very positive comments towards this first agroforestry course organized by ICRAF with the USAID support. Particularly appreciated was the friendly atmosphere and easy relationship established among participants and ICRAF staff and the effort made to provide a coherent and professionally stimulating programme on agroforestry research issues. As one participant put it... "With the limited time, ICRAF has made a lot of effort to acquaint us with upto date information and development in respect of agroforestry. The course was excellent for it gave the theoretical and practical aspects of agroforestry and at the same time we were exposed to the Diagnostic and Design Methodology, which is a new approach..."

It should be rightly pointed out that ICRAF staff, on the other hand, expressed equally positive comments on the general performance of the participants. This professionally interested and inquisitive group kept discussion sessions alive and field exercises an active experience. Attendance at daily training sessions was very high throughout the three-week programme.

A summary of participants' views and recommendations are given below on: pre-course arrangements, structure of the Course, objectives, physical resources and facilities, organization of training sessions and general coordination

and participants. General comments are also included.

4.1 PRE-COURSE ARRANGEMENTS

Invitations to submit candidates' nominations were mailed to institutions in the region five months prior to the start of the Agroforestry Course. Participants acknowledged having first learnt about anywhere between five and one month before the start of the event. It is difficult to single out the cause for delays. The regular inter-country mailing system may account for some, while the intra-institutional channel of communications may account for the rest e.g. in Kenya some participants were informed about the Course in June and others in October.

A hundred per cent of the "ICRAF selected participants" acknowledged having received the set of pre-course information before coming to Nairobi (the only exception was the USAID official from Cape Verde) and all of them agreed that the information was adequate. Among the suggestions to improve the pre-course arrangements were:

- add more information about ICRAF and agroforestry
- request participants to prepare a descriptive report on agroforestry activities in their respective countries.

4.2 STRUCTURE OF THE COURSE

Participants' views were requested on the adequate duration/length of the Course, the daily working sessions, the field exercises and the independent/study sessions. Aspects above were evaluated in terms of: "too long," adequate" and "too short." A summary of the information expressed in percentages of the total number of participants is presented in Table 1 of this report. In general, a higher percentage of the total number of participants thought that "the Course" and the "independent/study sessions" were too short while the "daily working sessions" and "field exercises" were adequate. Recommendations to increase the course length vary from 1 to 4 months.

Table 1. Summary of the Participants' Views on the Course Structure *

ASPECTS TO EVALUATE	TOO LONG	ADEQUATE	TOO SHORT
The length of the Course	0	43	57
Daily working sessions	29	67	04
Field exercises	0	67	33
Independent study/work	0	38	62

* As measured in terms of length/duration. Results are expressed in percentages of the total number of participants.

4.3 Objectives

Participants were requested to express their views on the "appropriateness" and "effectiveness" of the course objectives using a measuring scale from 1 to 5, where 1 = less appropriate/effective and 5 = very appropriate/effective. Terms were defined as follows:

Appropriateness - the relevance and usefulness of the course objectives to the participant's work.

Effectiveness - whether appropriate or not, the extent to which the objectives were fulfilled.

Final results are presented in Table 2. All four objectives were assigned "higher than 4" average values in relation to the appropriateness and average values between "3.6 and 4.7" in relation to the effectiveness. Comments formulated by participants clearly relates to the lowest 3.6 value (effectiveness of objective 4) when they said:

- ICRAF has connections with numerous research agencies all over the world. I would have liked to be more informed on who those agencies are and what they do.

- more time for literature review and AF information.

- the whole exercise was fine except that too much information was given in such a short time.

4.4 Physical Resources and Facilities

They were evaluated using a 1 to 5 value scale, where 1 = not adequate and 5 = very adequate. Information is summarized in Table 3. All aspects evaluated were given higher than 4.0 values. It was mentioned several times that the time factor was the constraint to use the library and computer services, but facilities as they exist, are quite adequate.

Table 2. Summary of Information on the Appropriatness and Effectiveness of the Course Objectives *

Objectives	Appropriatness	Effectiveness
(Main) 1. To become familiarized with the concepts and procedures of ICRAF's methodology to diagnose AF related land use problems/ potentials and design appropriate AF systems.	4.6	4.3
(Complementary) 2. To become acquainted with institutional organization and programme of work.	4.5	4.7
3. To develop/enhance an undertaking of the concepts of AF as a land use system, its potentials and contraints.	4.6	4.5
4. To become updated on available AF research information and appropriate experimental approaches.	4.1	3.6

* expressed in average of the total number of participants using 1 to 5 scale, where 1= less appropriate/effective and 5= very appropriate/ effective.

Table 3 Summary of Information on Physical Resources and Facilities*

Physical Resources and Facilities	X
- Transportation arrangements during field exercises	5.0
- Hotel accommodation	4.9
- Secretarial assistance	4.9
- Travel arrangements	4.6
- Meal arrangements in the field	4.5
- Conference room	4.5
- Meeting rooms	4.5
- Per diem payments	4.4
- Library services	4.2
- Computer services	4.2

* expressed in average of the total number of participants using a 1 to 5 scale, where 1 not adequate and 5 = very adequate.

Table 4 Summary of Information on the Organization of the Training Sessions and General Co-ordination*

ASPECTS TO EVALUATE	$\bar{X}$
Training materials and written information handed-out to participants	4.8
Availability of visual equipment and training aids	4.8
Availability of staff for consultations	4.3
Quality of presentations (clarify) of speaker, use of visual aids, time)	4.2

* expressed in average of the total number of participants using a 1 to 5 scale, where 1 = not adequate and 5 = very adequate.

4.5 Organization of Training Sessions and General Coordination

Participants opinions were requested regarding the adequateness of training materials/written information, the quality of presentations, the availability of visual equipment/training aids and the availability of ICRAF staff for consultations. Again, a scale from 1 to 5 (1 = not adequate and 5 = very adequate) was used. As shown in Table 4 all aspects evaluated were given a "higher than 4" average value. Once more, the time factor was considered a constraint to consult with ICRAF staff.

The main suggestions for improvement were:

- leave a half day free to arrange for individual meetings with ICRAF staff.
- limit number of speakers in individual presentations.
- rectify some focusing problems in overheads and slides.
- have a list of relevant AF books, and if possible have them available for purchasing.

4.6 Participants

They were requested to express their views about the size of the group of participants attending the course, the various disciplines represented and the interaction among participants as well as with ICRAF staff. A five numeral scale was used where 1 = not satisfactory and 5 = very satisfactory. A summary of information on this section is presented in Table 5.

Results indicate that in general the group of participants was considered to be very adequate even though some suggestions were made regarding the need to balance out the representation of disciplines and avoid the bias towards foresters.

Table 5. Summary of Information about the Participants*

Aspects to Evaluate	$\bar{X}$
The size of the group	4.6
The interaction among participants	4.2
The interaction of participants with ICRAF staff	4.2
The various disciplines represented	4.0

expressed in average of the total number of participants using a 1 to 5 measuring scale where 1 = not satisfactory and 5 = very satisfactory.

4.7 General Comments

Participants contributed their general comments about the Course and recommendations for future similar events. This is what they said:

- Excellent - keep it up please
- The course has been very interesting and important. It goes along way to introduce proper understanding of AF and Systems. Also the role of ICRAF has been properly defined to help in any future collaboration with different institutes from the participants countries. But the Course was too short for the work covered. For this reason I am sure questions may be asked in writing later on to ICRAF.
- 1st and 2nd week course presentations and materials were very good and informative. The last week, especially last three days needed more definitive material on experimental designs and development of AF technology.
- Personally I have gained a lot of knowledge from presentations, papers and interaction with the participants. There seems to have been a lot of organization work for a number of modern ideas about Agroforestry have come up. I am sorry for missing the 1st week due to other inevitable commitment.
- A rather long time was given for basic concepts on AF, there by depriving valuable time for the core topic. The course could well assume prior knowledge and familiarization with these, and hence allowing more time for desk and field sessions on the D&D methodology. The volume of papers presented though comprehensive, tended to discourage even the most enthusiastic readers. Perhaps the handouts could be reduced only to essential material.
- The Course was very interesting and beneficial but the time constraint was number one while I envisage the impossibility of keeping people away from their stations for much longer than 3 weeks, I would suggest that ICRAF, either should plan for a followup course to evaluate the actual effectiveness or increase the course period to at least 2 months. More fellowships and 6 months training should be offered to more people in all fields. If possible a few more on-station trials should be considered in different eco-zones.
- Just take the opportunity to recognize how the course was good in coordination of activities and the ideas given. But the socioeconomic views has taken a long time. We generally have already spoken to many farmers and it isn't necessary to spend 3 days of asking questions to a small amount of farmers. When we were at Machakos we

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should also have talked to the farmers in Diagnostic and Design so that the amount of farmers would have been more significant. But in general, the course was so good that I take the opportunity to thank the ICRAF staff for their effort to make the course successful.

- Everyone on the ICRAF staff was quite friendly and helpful, much more so than one might have expected. The presentation by Patrick Robinson was superior, with a good temp and concise, blending in a good balance of background, description, supposition, results and conclusions. The field trip arrangements were perfectly tailored to the group size. Field exposure to local circumstances by the interview method was an ideal technique, however, the interview format was too lengthy to utilize efficiently, as written. The questionnaire put uneven emphasis on various subsystems, for better or for worse; yet lacking a changed or re-structured format; it was followed in a more-or-less routine sequence. For example, the social subsystem did not wave any pre-formulated questions, so the investigators had difficulty using it and, in fact none of the teams gave the subsystem any mention in the group analysis, perhaps as a result. Hopefully, individual participants now have a solid appreciation for the Diagnosis and Design Technique. However, the Monday (Nov. 14) exercise in group discussion and analysis was not very fruitful because:

  1) of the time constraint in preparation by individual teams,

  2) because of the incompleteness of the analysis and,

  3) because of the inability to anyone to test the hypothesis (factual and/or for linkages) of the diagnosis of others - or of their own.

  The great amount of written material will be of inmense value when one is able to read and analyse it more fully. Funds permitting, it might be appreciated if the documents could be mailed out to participants at the end of the course, for future courses. There were reservations about the experiments on Machakos Farm. It was felt that the plots in the litter experiment were too small to get more than a cursory idea of maize production. Also, six maize plants per plot, in a straight line - with an entry cell between each plot is too few maize plants for a proper biological response. Of more concern is that each line of maize has distinct border effect possibilities, thus would not be comparable to maize production monitored elsewhere. It appears that labour costs would be very expensive in the hedgerow experiment, given the very deep trenches and circular holes. One wonders whether such an expensive and slow means of land preparation would be undertaken by the average farmer. There was one logiscic bottleneck that was bothersome: Breakfast at the hotel, or at any nearby coffee shop is not served before 7.00 a.m. As a consequence, it was difficult to get a good breakfast down before the 7.30 departure time. On field trip days. It really was a great course! and top-quality people.

- In general, with the limited time ICRAF has made a lot of effort to acquaint us with upto date informations and development in respect of AF. The facilities provided to us were also adequate. However, it is realized by me that if the period had been extended for two weeks more, I should have been able to clear my doubt in respect of experimental approaches and design which I could have gained a bit from it because this is the field which has a great deal of relevance to my present duty as an agorofrestry expert.

- The organization of the course was quite in order although the content of the course was too much to be accomplished within the duration of the course. Subsequent courses may be allowed to run for say four weeks so that participants will have some to themselves which will enable them to use the library. The time constraints affected mostly the field exercises and the time available for data analysis. More time should be allocated to this in subsequent courses.

- The course was very satisfying and, as I complement ICRAF for the success of this first course, I wish that they can expand on what we were taught. ICRAF possesses some world reknown specialists and I think, it would have been worthwhile to give them enough time to talk about their views on specific subjects. As an example: M. Baumer knows a lot about arid countries; others may know as much about other climatic zones, or about specific topics. But in all, I am pleased to have participated in this 1st course in AF training. Thank you!

- The course was very well-organized but the time was too short for course material covered. A 4-5 week course would be more appropriate with a maximum of 6 hours of sessions per day. Provisions should be made for a one-day weekday break during the course for participants to do business of their choice that they can do only during the week.

- Overall, I am totally satified with the course structure and organization, especially the coordination aspect and I would wish to record my congratulations to Ester. The only snag has been the feeling of "incompleteness" of the last section which dealt with the experimentation aspects (as was well accepted by ICRAF staff themselves). This section actually is the most important bit as it is the one part of the course that could be out to immediate practice (resources and other factors permitting)in our country. But I think this could be remedied in 2 ways: by constant communication and interaction between the participants and ICRAF staff after our return home and through the participation of the same actual participants to your next course programmed on "Research and Experimental Methodology" to be held next year. It would be most interested to attend to this course as I think that it would be an essential complement and followup to this course. Also, it would enable a re-gathering of most of the participants and a feedback to the progress and constraints experienced by each during application of the knowledge gained.

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- Course preparations, content and presentations was satisfactory except that time factor was limited and hence resulted in making the programme very tight. Participants would like more time to utilize ICRAF resources and exchange more ideas with ICRAF staff.

- The course was well organized. Duration of the course was fairly short.

- The course was very well organized but time could be increased upto 2 months. Field exercises could get more time. If possible doing the diagnosis and design could get more time. Time for planning a TRIAL should be more especially playing with micro-computers.

- With the limited time ICRAF has made a lot of effort to acquaint us with upto date information and development in respect to AF. The course was excellent for it gave the theoretical and practical aspects of Agroforestry and at the the same time the participants were exposed to the Diagnosis and Design Methodology which is a new approach before any experiments can be laid out or before new ideas for improving the standard of living of any particular individual or community using AF can be suggested by AF experts.

- Increase duration of course so as to give more attention to particular aspects of interest.

- Too short a course but too many ideas for dissemination to participants. In fucure more multidisciplinary staff should attend the deliberations of groups in order to bring up more comments on designs. In future choose a humid area for field trip demonstration in addition to semi-arid. (Unless this is not existing in Kenya). this will give an idea on the two sides of the coin.

- It would have been very useful if arrangements were made to visit one of the National Forestry fields and get explanations about the overall activities to understand the level of work and also to relate ICRAF activities. The course is very well organized and conducted.

- The course has generally been a success and I am sure it has brought home the agroforestry concept to participants. ICRAF staff deserves congratulations for this first effort.

ANNEX 1

The List of Participants

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ANNEX 2

TIMETABLE AND DAILY PROGRAMME OF ACTIVITIES

Training Course - "AGROFORESTRY RESEARCH FOR DEVELOPMENT: Concepts, Practices and Methods" 1-18 November 1983 Nairobi

		MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SAT.	SUN.
FIRST WEEK	Morning	October 31 Participants arrive-	November 1 Introduction to the course . ICRAF's Role and Programme	November 2 . Global Overview of Agroforestry Systems and Practices	November 3 Agroforestry	November 4 .Technology for Agroforestry	Nov. 5	Nov. 6
	Afternoon	and Registration	. The Concept of Agroforestry . AF Field trip to Kiambu District	. Agroforestry Potentials and Constraints	Field Day	(continued)	FREE	FREE
	Evening	Reception		Independent Work		Independent Work		
SECOND WEEK	Morning	November 7 . Approaches to Farming Systems Research . Diagnostic Approach to the Design of AF Technologies	November 8 . Field Study Preparation . Field Survey Methods	November 9 Field	November 10 Field	November 11 . Diagnostic Analytis (in 4 simultaneous workshops)	Nov.12	Nov. 13
	Afternoon	. Case Study Review in Costa Rica	. Case Study Review in Malaysia	Excercise	Excercise		FREE	FREE
	Evening	Independent Work	Independent Work			Independent Work		
THIRD WEEK	Morning	November 14 . ICRAF's Summary of Diagnosis and Design Specifications . Technology Appraisal	November 15 . Design Evaluation Survey (Field Activity)	November 16 . Detailed ex-ante evaluation of the design	November 17 . Research Objectives and Research Planning	November 18 . Proposals for Experimental measurements	Nov.19	Nov. 20
	Afternoon	. Information & Documentation in AF . ICRAF's Design Proposal for Kathama	. Visit On-Site Experiments	. Planning & Implementing Investigations to generate Technology.	. Proposals for experimental designs	.Course Review and Evaluation	Participants Leave	
	Evening	Independent Work		Independent Work	Independent Work			

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 1 (Tuesday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
08.30 - 08.45	Introduction and general objectives of the course.	Bjorn Lundgren
08.45 - 09.15	Course structure and organization. Announcements.	Ester Zulberti
09.15 - 10.15	Participants introductions and brief description of current professional activities and AF interests.	
10.15 - 10.45	Coffee Break	
10.45 - 11.45	Continued.	
11.45 - 12.30	ICRAF's Role and Programme	Bjorn Lundgren
12.30 - 14.00	Lunch	
14.00 - 15.30	The concept of Agroforestry	Filemon Torres
15.30 - 15.45	Coffee Break	
15.45 - 18.00	Agroforestry field trip to Kiambu District	Peter Huxley

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 2 (Wednesday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
08.30 - 09.30	Global overview of Agroforestry systems and practices	P.K.R. Nair
09.30 - 10.15	Agroforestry systems in arid and semi-arid regions	Michel Baumer
10.15 - 10.40	Coffee Break	
10.40 - 11.00	Agroforestry systems in African Highlands	Amare Getahun/ E. Fernandes
11.00 - 12.30	General discussion	P.K.R. Nair
12.30 - 14.00	Lunch	
14.00 - 14.45	Agroforestry potentials and constraints for land use	Bjorn Lundgren
14.45 - 15.30	Group discussion on "Actions needed for AF development at international, regional and national levels"	
15.30 - 16.00	Coffee Break	
16.00 - 16.45	Continued	

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 3 (Thursday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
07.30 All day	Agroforestry Field Day	
	. Observations on on-farm and on-station agroforestry trials (Kakuyuni and Katumani) and the role of woody vegetation in the semi-arid regions.	Dirk Hoekstra Michel Baumer
	. A visit to ICRAF's Field Station in Machakos	P.K.R. Nair Till Darnhofer P.v. Carlowitz

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 4 (Friday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
08.30 - 09.00	Technology for Agroforestry Introduction	Peter Huxley
09.00 - 09.45	The environmental data base	Till Darnhofer
09.45 - 10.30	Soils aspects of AF Research	P.K.R. Nair
10.30 - 10.45	Coffee Break	
10.45 - 11.30	Climate and climatic measurements in AF	Till Darnhofer
11.30 - 12.30	Multipurpose trees. Opportunities and limitations.	P.v. Carlowitz & Peter Wood
12.30 - 14.00	Lunch	
14.00 - 14.30	Characteristics of crop species for AF	Willem Beets
14.30 - 15.30	Animal production in AF systems	Filemon Torres & P. Robinson
15.30 - 15.45	Coffee Break	
15.45 - 16.45	Tree/crop mixtures - the benefits (or otherwise) of mixed marriages	Peter Huxley
16.45 - 17.00	General review of the first week of the course and brief overview of the programme of activities for the second week	E. Zulberti

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 7 (Monday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
08.30 - 09.00	Approaches to Farming Systems Research	Roger Kirkby IDRC
09.00 - 09.20	CIMMYT's Conceptual and Methodological approach to On-Farm Research	P. Ananda CIMMYT
09.20 - 09.40	CIMMYT's experience to date in Africa	M.P. Collinson CIMMYT
09.40 - 10.00	Coffee Break	
10.00 - 11.00	Group discussion	Filemon Torres
11.00 - 11.10	Short break	
11.10 - 12.30	Diagnostic approach to the design of AF technologies	John Raintree
12.30 - 14.00	Lunch	
14.00 - 15.30	An example of a diagnostic and design application: Case study review in Costa Rica. Case study review in Costa Rica. (Example 1 of a diagnostic and design application)	D. Rocheleau
15.30 - 15.45	Coffee Break	
15.45 - 16.45	Continued	

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 8 (Tuesday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
08.30 - 09.00	Field Study Preparation	
	Introduction to the case study exercise in Kathama	John Raintree
09.00 - 10.30	Pre-diagnostic overview of the Kathama study area.	Dirk Hoekstra Till Darnhofer
10.30 - 11.00	Coffee Break	
11.00 - 12.30	Field survey methods	D. Rocheleau
12.30 - 14.00	Lunch	
14.00 - 15.30	Case study review in Malaysia. (Example 2 of a diagnostic and design application).	P.v. Carlowitz & D. Hoekstra
15.30 - 15.45	Coffee Break	
15.45 - 16.45	Continued	

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 9 (Wednesday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
07.30 onwards	Field Exercise in Kathama	John Raintree D. Rocheleau Filemon Torres Dirk Hoekstra E. Zulberti Interpreters Japheth Kyengo Veronica Ndunge L. Kyongo R. Mwendandu

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 10 (Thursday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
07.30 onwards	Field Exercise in Kathama Continue	(same as previous day)

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 11 (Friday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
08.30 - 10.00	Diagnostic Analysis (in four simultaneous workshops)	John Raintree D.Rocheleau Filemon Torres Dirk Hoekstra
10.00 - 10.30	Coffee Break	
10.30 - 12.30	Continued	
12.30 - 14.00	Lunch	
14.00 - 15.30	Continued	
15.30 - 15.45	Coffee Break	
15.45 - 16.30	Preparation of posters for group presentations on Monday.	
16.30 - 16.45	General review of the second week of the course and brief overview of the programme of activities for the third week.	E. Zulberti & John Raintree

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ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 14 (Monday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
08.30 - 09.30	Groups presentations of diagnosis. Discussion session.	Group leaders
09.30 - 10.00	ICRAF's summary of diagnosis and design specifications in Kathama	John Raintree
10.00 - 10.30	Coffee Break	
10.30 - 12.30	Technology appraisal exercise in small groups	Group leaders
12.30 - 14.00	Lunch	
14.00 - 15.15	Information resources in AF	Richard Labelle
15.15 - 15.30	Coffee Break	
15.30 - 16.45	Design and Evaluation	
	. suggested design procedures	John Raintree
	. ICRAF's design proposal for Kathama	
	. introduction to design evaluation survey	D. Rocheleau

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 15 (Tuesday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
07.30 onwards	Field Exercise	
	Design Evaluation Survey (in consultation with farmers interviewed before)	Group leaders & interpreters
	Lunch in Kathama	
	Visit on - site experiments	

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 16 (Wednesday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
08.30 - 09.00	Detailed ex-ante evaluation of the design. (Technology evaluation score sheets)	John Raintree
09.00 - 10.30	Some relevant examples (ecological, physical, social, biological, economic aspects)	Michel Baumer P.K.R. Nair D. Rocheleau Filemon Torres Dirk Hoekstra
10.30 - 11.00	Coffee Break	
11.00 - 12.15	Continued	
12.15 - 12.30	Summary of Diagnostic Approach to the Design of AF Technology	John Raintree
12.30 - 14.00	Lunch	
14.00 - 15.00	Defining specific research problems	Peter Huxley
15.00 - 15.30	Coffee Break	
15.30 - 16.45	Planning and implementing investigations to generate technology: The Alley Cropping Case	Peter Huxley

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 17 (Thursday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
08.30 - 10.00	Choosing MPT species	Peter Wood
	Some implications for intercropping research	Willem Beets
10.00 - 10.30	Coffee Break	
10.30 - 12.30	Predicting productivity and sustainability for mixtures of trees and agricultural crops	Peter Huxley
	Abstract criteria	Till Darnhofer
12.30 - 14.00	Lunch	
14.00 - 15.15	Systematic spacing designs for AF	Peter Huxley
15.15 - 15.30	Coffee Break	
15.30 - 16.45	General discussion on field layouts	(All above)
	(Candidates split into two working groups to plan an alley cropping experiment Group A - High level of research resources Group B - Low level of research resources	

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 18 (Friday)

TIME	SUBJECT/ACTIVITY	PRESENTED/ COORDINATED BY
08.30 - 09.30	Proposals for experimental measurements Appropriate data collection for: - Plant characteristics	Peter Huxley
09.30 - 10.30	- Environmental characteristics (soils/ climate)	Till Darnhofer
10.30 - 11.00	Coffee Break	
11.00 - 12.30	Data analysis and summaries. Plenary session	Peter Huxley & ICRAF staff
12.30 - 14.00	Lunch	
14.00 - 15.30	Overall course review and evaluation	Ester Zulberti & ICRAF staff
15.30 - 16.30	Farewell to participants COURSE ENDS	

ANNEX 3

THE TRAINING PACKAGE

On Registration Day participants received a binder containing an initial set of training materials (approximately 200 pages). By the end of the Course the material nearly tripled in size. A general description of the training package content by section and a list of document titles/authors is presented below.

DESCRIPTION OF SECTION CONTENT

Preface - By Dr. Bjorn Lundgren

Introduction - By Dr. Ester Zulberti

Provides an overview of the Course objectives and programme of activities as well as a description of the organisation and content of the training package.

Section 1 - ICRAF Role and Programme

Specifies ICRAF's mandate and objectives and identifies the seven programmes of work.

Section 2 - Agroforestry Conceptual and Technical Background

Is a compilation of key articles/notes dealing with the definition of the agroforestry concept, its potentials and constraints for land use. It provides background information on ICRAF Global Inventory of Agroforestry Systems. Introduces the newly established concept of 'agroforestry research' focussing on woody perennial species and land use. It outlines ICRAF's approach to agroforestry technology. Hand-outs used for two field study tours are included. Suggested readings on various aspects of Technology for Agroforestry are recommended, e.g. on environmental, economic, animal production, andother issues.

Section 3 - A Diagnostic Approach to the Design of Agroforestry

This Section presents two background articles on approaches to Farming System Research followed by an introduction to ICRAF interdisciplinary Diagnostic and Design Methodology for agroforestry. Documents included cover the logical framework of the methodology, an outline and description of the step-by-step procedures, a discussion of manpower requirements, the scale and timing of D&D activities, institutional considerations, etc. Two case studies (Costa Rica and Malaysia) are given as examples of a D&D application. Information resources in AF is provided. Practical field exercise tools, readings on survey methods and general information on economics and ecological descriptions of land use systems are included, among others, as supplementary materials.

Section 4 - Relevant Experimental Approaches

It provides background information on research planning considerations with emphasis on relevant agroforestry experimental designs and plant management.

SECTION 5 - course Evaluation

It contains the course evaluation forms.

APPENDICES

I Participants Names and Addresses

II List of ICRAF Staff, Invited Speakers and Interpreters

III Time Table and Detailed Programme of Activities

LIST OF TITLES

Section 1 - ICRAF Role and Programme

- An Introduction to ICRAF

Section 2 - Agroforestry Conceptual and Technical Background

2.1 Main Notes

- Agroforestry: Concepts and Practices (F. Torres)
- The use of Agroforestry to Improve the Productivity of Converted Tropical Land (B. Lundgren)
- Agroforestry - Developing a New Research Discipline (P. Huxley)
- Woody Plants and Land Use (P. Huxley)

2.2 Practical Exercises (Hand-outs)

- Agroforestry Field Trip to Kiambu District (P. Huxley and F. Owino)
- Map of Machakos Soils
- Maize Mulch/Green Manure Trials, Beans Mulch/Green Manure Trials, and Hedgerow Trial (D. Wambugu)
- ICRAF Field Station (P.K.R. Nair)

2.3 Supplementary Materials

- Project Proposal for Agroforestry Systems Inventory (P.K.R. Nair)
- Global Inventory of Agroforestry Systems: Data Collection Guidelines.
- Agroforestry Systems in Arid and Semi-arid Regions (M. Baumer)
- Ecological Aspects of Agroforestry in the Highland Ecosystem of Tropical Africa (A. Getahun).

- ICRAF's Programme on Agroforestry Technology (P. Huxley)
- The Environmental Basis of Agroforestry (A. Young)

- Meteorological Elements and Their Observations (T. Darnhofer)
- The Process of Collection, Storage, Evaluation and Dissemination of MPT Data and Information (P. von Carlowitz)
- The Multipurpose Tree Data Sheet (P. von Carlowitz)
- Limitations of Multipurpose Trees (P. Wood)
- Rome Aspects of Multiple Cropping Systems (W. Beets)
- The Role of Woody Perennials in Animal Agroforestry (F. Torres)
- Animal Production in Agroforestry Systems (F. Torres and P.J. Robinson)
- The Tree/Crop Interface, (P. Huxley)
- Technology Design and Management Guidelines - Some proposals for comment.

Section 3 - A Diagnostic Approach to the Design of Agroforestry Systems

3.1 Main Notes

- Guidelines for Agroforestry Diagnostic and Design (J. Raintree)
- Resources for Agroforestry Diagnosis and Design (J. Raintree)

3.2 Practical Exercises

- Case Study Review in Costa Rica
- Case Study Review in Malaysia
- Economic Analysis of Agroforestry Models - Selangor Forest Reserve (D. Hoekstra)
- Ex-Ante Economic Evaluation of Alley Cropping systems (D. Hoekstra)
- Map of Kathama with identification of diagnostic interviews farmers' plots.

3.3 Supplementary Material

- On-Farm Experimentation - New Method for an old Concept? (R. Kirkby)
- An Overview of Farming Systems Research (H. Zandstra)
- Overview of an Integrated Research Program (CIMMYT)

- Pre - Diagnostic Information on Kathama Site (R. Vonk)
- An Inventory of Trees and Shrubs in the Northern Division of Machakos District (E. Flievoet)
- Selected Bibliography of Agroforestry (L. Majisu and R. Labelle)
- ICRAF's Publications List September 1983
- Combining Disciplines in Rapid Appraisal: The Sondeo Approach (P. Hildebrand)
- Some Notes on the Art of Informal Interviewing (R. Rhoades)
- The Use of Economics in Agroforestry (D. Hoekstra)
- Choosing the Discount Rate for Analysing Agroforestry Systems/Technologies from a Farmer's Point of View (D. Hoekstra)

Section 4 - Relevant Agroforestry Experimental Approaches

Notes Hand-outs and Supplementary Material

- Comments on Agroforestry Classifications with Special Reference to Plant Aspects (P. Huxley)
- The Role of Trees in Agroforestry: Some Comments (P. Huxley)
- Assessment of Experimental Sites*
- The Scope and Design of Field Trials*
- Plant Population and Yield of Tree and Herbaceous Crops (M.G. Cannell)
- Rapid Appraisal Methodology for Priority Species Selection by Use and Ecology and for Prioritizing Research Requirements (P. von Carlowitz)
- Some Characteristics of Trees to be considered in Agroforestry (P. Huxley)
- The Tree/Crop Interface*
- Plant Management in Agroforestry: Manipulation of Trees, Population Densities and Mixtures of Trees and Herbaceous Crops (M.G. Cannell)
- Phenology of Tropical Woody Perennials and Seasonal Crop Plants with Reference to their Management in Agroforestry Systems (P. Huxley)

** from a Manual Methodology for the Exploration and Assessment of MPT's by P. Huxley et.al.

- Systematic Designs for Field Experimentation with Multipurpose Trees* (P. Huxley)
- Notes on the Microclimatic Effects and Design of Shelterbelts (T. Darnhofer)
- Considerations when Experimenting with Changes in Plant Spacing* (P. Huxley).

ICRAF/USAID AGROFORESTRY COURSE
Nairobi, 1-18 November 1983

ICRAF

EVALUATION SHEET

The purpose of the present evaluation sheet is to seek participants' opinions about the general structure, organisation and coordination of the course as well as suggestions to improve the design of similar ones.

SECTION 1. This Section is intended to gain information about Pre-Course Arrangements.

1.1 When did you learn about the course? Indicate the approximate date.
Your country is _____

DAY	MONTH

1.2 Did you receive the pre-course information before coming to Nairobi?

TICK

YES	NO

1.3 Was pre-course information adequate?

TICK

YES	NO

1.4 Suggest any pre-course improvements.

_____

_____

_____

_____

SECTION 2. Please give us your views on the Structure of the Course. Were the following adequate?

TICK IN APPROPRIATE BOX

COURSE STRUCTURE	TOO LONG	ADEQUATE	TOO SHORT
2.1 The length of the course			
2.2 Daily working sessions			
2.3 Field excercises			
2.4 Independent work/study sessions			
2.5 Other (Please, specify)			

SECTION 3. The main Objectives of the course are shown below. Indicate how appropriate you believe they were and how effectively they were achieved. Before completing this section note these meanings:

Appropriatness: the relevance and usefulness of the course objectives to your work.

Effectiveness: whether appropriate or not, the extend to which the objectives were fulfilled.

1 = less appropriate/effective 5 = very appropriate/effective

OBJECTIVES	APPROPRIATNESS					EFFECTIVENESS				
	1	2	3	4	5	1	2	3	4	5
(Main) 3.1 To become familiarized with the concepts and procedures of ICRAF's methodology to diagnose AF related land use problems/potentials and design appropriate AF systems.										
(Complementary) 3.2 To become acquainted with ICRAF's institutional organisation and programme of work.										
3.3 To develop/enhance an understanding of the concepts of AF as a land use system, its potentials and constraints.										
3.4 To become updated on available AF research information and appropriate experimental approaches.										

3.5 Suggested improvements.

_____

_____

_____

_____

_____

SECTION 4. We would like your views on the Physical Resources and Facilities for the course. Were they adequate?

from 1-not adequate to 5-very adequate

Physical Resources and Facilities	1	2	3	4	5
4.1 Conference room					
4.2 Meeting rooms					
4.3 Library services					
4.4 Computer services					
4.5 Secretarial assistance					
4.6 Per diem payments					
4.7 Travel arrangements					
4.8 Hotel accommodation					
4.9 Meal arrangements in the field					
4.10 Transportation arrangements during field excercises					
4.11 Other (please, specify					

4.12 Suggested improvements.

_____

_____

_____

_____

SECTION 5. Indicate your opinion about the Organisation of Training Sessions and General Coordination of the course.

from 1-not adequate to 5-very adequate

	1	2	3	4	5
5.1 Training materials, written information given to participants					
5.2 Quality of presentations (clarity of speaker, use of visual aids, time)					
5.3 Availability of visual equipment, training aids, stationery.					
5.4 Availability of staff for consultations					
5.5 Other (please, specify)					

5.6 Suggested improvements.

SECTION 6. What is your opinion about the Participants of the course?

from 1-not satisfactory to 5-very satisfactory

	1	2	3	4	5
6.1 The size of the group of participants					
6.2 The various disciplines represented					
6.3 The interaction among participants					
6.4 The interaction between participants and ICRAF staff					
6.5 Other (Please, specify)					

6.6 Suggested improvements.

CASE STUDIES IN AGROFORESTRY DIAGNOSIS AND DESIGN NO. 2

18

AGROFORESTRY SYSTEMS FOR SMALLHOLDER UPLAND FARMERS IN A LAND REFORM AREA OF THE PHILIPPINES: THE TABANGO CASE STUDY

by

Filemon Torres and John B. Raintree

with

M.V. Dalmacio and T. Darnhofer

In Collaboration with

SEARCA, FORI, VISCA,
UNIVERSITY PERTANIAN MALAYSIA
and KASETSART UNIVERSITY

INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY

March 1984

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Acknowledgements

In addition to those scientists who contributed to the writing of this case study, several others contributed to the effort behind the report. Participants in the diagnostic field survey and subsequent technology design exercise included Peter von Carlowitz of ICRAF, Kamis Awang of the Universiti Pertanian Malaysia, Somsak Sukwong of Kasetsart University in Thailand, and Dominador Gonzal of the Visayas State College of Agriculture. Special thanks is also due to the Mayor of Tabango municipality, without whose dilligent efforts in support of the field exercise, the regional team's work would not have been as smooth and successful as it was. The team also gratefully acknowledges the logistical support of VISCA, the contribution of the participants at the Southeast Asian Regional Seminar-Workshop on Agroforestry, where the case study was first presented and discussed, and the continuing involvement of SEARCA in support of these collaborative activities.

F O R E W O R D

As part of its programme of work ICRAF has established a Collaborative and Special Projects Programme (COSPRO) to strengthen the capability of national institutions to develop agroforestry systems. In order to cover a wide spectrum of agroecological and socioeconomic conditions, COSPRO is organized on the basis of geographical regions, on the assumption that regional land management systems share broadly similar cultural conditions. Within each of these regions, three or four major ecological zones are selected, to build a geographical/ecological framework in which a network of potential research sites are to be located. Southeast Asia is one of such geographical regions.

This second case in the ICRAF series on Case Studies in Agroforestry Diagnosis and Design is the result of collaborative activities undertaken by scientists from ICRAF, the Forest Research Institute (FORI) of the Philippine Council for Agriculture and Resources Research and Development, the Visayas State College of Agriculture (VISCA), University Pertanian Malaysia, and Kasetsart University, who joined together under the sponsorship of the Southeast Asian Regional Center for Graduate Studies and Research in Agriculture (SEARCA) to do the field work on which this case study is based. The findings of the field exercise were presented at the Southeast Asian Regional Seminar-Workshop on Agroforestry held at SEARCA in October, 1982. This led to the formulation of proposal for a research project to be implemented by the Philippine Institutions with the technical back-stopping of ICRAF.

The aim of the proposed research project is to develop improved systems of land management for upland farming systems in the Southeast Asian region, with special attention to the farming circumstances of the beneficiaries of a land reform programme in the study area on the island of Leyte in the Philippines.

The case study is the result of an application of ICRAF's Diagnostic and Design methodology (D&D) by a multidisciplinary team of scientists from the participating institutions. The purpose of the initial 'rapid appraisal' D&D exercise was to diagnose existing and future land management constraints and agroforestry potentials, design appropriate agroforestry systems and formulate plans for research to develop the candidate agroforestry technologies through a combination of on-farm and field station research. As the project progresses, the iterative D&D process will be repeated in modified form to take stock of project experience, refine the diagnosis and design, and introduce appropriate modifications into the research plan in order to optimize the productivity, sustainability and adoptability of the experimental technologies.

In due course, prototype agroforestry technologies and land management systems arising from this process will be evaluated for extension and adaptive research throughout a wider recommendation domain in Southeast Asia and in similar farming situations in other parts of the world.

Filemon Torres
COSPRO Programme Coordinator

John B. Raintree
Case Studies Series Editor
Systems Programme Coordinator

1. UPLAND FARMING AND LAND REFORM IN THE PHILIPPINES

The hazards of upland farming in the Philippines, as elsewhere in Southeast Asia, are notorious. Problems range the whole spectrum from shifting cultivation to permanent upland farming systems. In areas of high population density where permanent arable cropping has been the predominant form of land use for many generations of peasants, continuous cultivation without the possibility of fallow results in soil mining, accelerated erosion and diminishing yields. Although the system may eventually stabilize at a very low level, it holds little prospect of being able to meet a future of increased human population which cannot be realistically absorbed into the urban economy. Low cash incomes of peasant farmers and lack of adequate input supply and marketing infrastructures create a situation which offers little hope for improvement of the rural economy through conventional high-input approaches to agricultural intensification.

Land tenure issues compound the problem. Unlike among the shifting cultivators, where the main issue is insecurity of tenure over ancestral lands in the face of restrictive forest laws and increasing pressure from land-grabbing outsiders, the main problem in peasant farming is unequal distribution of land and other productive resources between smallholders, often tenant, farmers and large, often absentee, landowners. In some cases the traditional systems of rights and obligation safegurded a reasonably stable symbiosis. With modernization and the breakdown of these traditions, however, landlord-tenant relations have become increasingly exploitative in many areas. In response to mounting political pressures, the government has sought to implement land reform through various programmes. One such programme is "Operation Land Transfer," which is being implemented in the Tagbango case study area on the island of Leyte.

In Tabango the relationship between ecological and tenure problems in upland farming systems takes on a particularly interesting and challenging form to developers of agroforestry technologies. There are basically two main forms of land use in the area: coconut-based perennial tree crop systems and permanent upland cultivation of field crops. As presently practiced, the coconut-based farming system, with or without additional tree crops and livestock grazing in the understorey, appears to be a productive and sustainable land use system, but permanent upland cultivation is not. Although the tree crop system is feasible for farmers with upwards of 5 hectares at their disposal, the major part of the coconut system is held by a small number of large landowners.

In areas not designated as "land reform areas" large landowners are expanding their tree crop holdings using the labour of landless farmers to plant the trees in return for the right to cultivate annual crops until the canopy closes and forces them out. Eviction, in this case, is accomplished by the tree rather than the landlord. While they do have the option of remaining on the large haciendas as wage labourers, most farmers would prefer to be independent smallholders, or at least permanent share-croppers on open land.

To meet the small farmers' need for land the Operation Land Transfer (OLT) programme, in areas where it is being implemented, buys out the landlord and offers the farmers eventual title, after a specified pay-back

period, to the land they have traditionally cultivated as tenants. The problem faced by many of the beneficiaries of this programme is that the amount of land to which they can thus lay claim is quite small, usually under two hectares. This is too small to contemplate a transition to the tree crop systems for farmers who must meet their families' daily subsistence needs. They are left, then, with the upland field crop system which, under traditional technology, is only marginally productive and highly subject to a severe form of the upland degradation syndrome.

In Tabango we are confronted with the land use paradox of sustainability without equity and equity without sustainability. If land reform is to succeed in Tagbango, and similar situations throughout the Philippines, new technologies will have to be developed to place smallholder upland farming on a sustainable footing. This is where agroforestry may have a role to play. The specific form which that role could take is the subject of this case study.

2. DESCRIPTION OF THE STUDY AREA

2.1 Site Location

Tabango Municipality is located in the northern part of the island of Leyte in the Philippines, about 159 km from Tacloban City, between the municipalities of Villaba and San Isidro. Comprising an area of some 129 km^2, the municipality is traversed by unpaved all-weather roads. Coastal areas along the Visayan Sea are accessible by boat. Tabango has a total of 13 local administrative units known as barangays. Due to the inaccessibility of some of the barangays during heavy rains, the study was confined to five barangays: Poblacion, Catmon, Omaganhan, Tabing and Campokpok.

2.2 Topograhy

Mostly hilly with moderate to steep slopes draining to the Visayan sea. The highest peak is Mt. Canturaw with an elevation of 362 ft above sea level. Level lowland areas are limited to about 25 percent of the total land area.

2.3 Climate

The Project area is situated in the humid tropics, with an annual average rainfall between 2000 and 2500 mm. The water balance is usually positive (rainfall in excess of evaporation) through 9 of 12 months, from May/June to Feb/March. The growing period is approximately 270 days/year. As the rainfall is to a large extent influenced by tropical depressions and storms (2-4 per year) its inter-annual variabillity is considerable. This results in temporary drought situations as well as heavy rains representing high erosion hazards.

The mean temperature at sea level is around 27°C, with little annual variation (2.5°). The absolute maximum and minimum range between 34° and 22°C respectively. The elevation effects the mean temperature with a loss rate of 0.55°C per 100 m.

Nebulosity follows the seasonal changes in rainfall distribution and is accordingly high. The average duration of bright sunshine is between 40 and 50% of the astronomical day length.

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High relative air humidity (70-80%) is again in accordance with the general climatic pattern.

The prevailing wind directions change from NE in January to WSW in July. The mean windspeed is generally 2.0 m/s.

2.4 Population

As of 1980 the total population of Tabango Municipality was 29,356. Males comprise 50.41 percent and females 49.59 percent of the population. The annual grude population growth rate is 1.6 percent and the average population density is 234/km^2.

2.5 Economy

The major minicipal products are maize, coconuts and rice. Employment and monthly income are as follows:

EMPLOYMENT

Self-employed farmers	- 45 percent
Labourers	- 40 percent
Other employed	- 15 percent

MONTHLY INCOME

Less than 100 pisos	- 14 percent
100 to 300 pisos	- 68 percent
more than 300 pisos	- 18 percent

2.6 Agroecological Zones within the Study Area

a) level topography (0-5% slope) or Class A cropland which can be cultivated using ordinary methods of farming; erosion hazzard very slight to nil

b) sloping cropland (5-60% slope) which should be cultivated using special conservation practices since the soil is subject to moderate erosion hazzards

2.7 Criteria for Differentiation of Farming Systems

Farms in the study area can be classified into different farming system types on the basis of land tenure, farm size and production emphasis. The main classes are as follows:

Land tenure

- owner cultivators
- beneficiaries of a government land reform programme known as Operation Land Transfer (OLT); according to the Ministry of Agrarian Reform about 3000 ha. in the area are now under the land reform programme, benefiting some 1,887 tenants
- leaseholders; this category is reportedly being phased out by the OLT (the survey team only encountered one farmer in this category)

Owner cultivators and OLT beneficiaries constitute about 90 percent of the farmers.

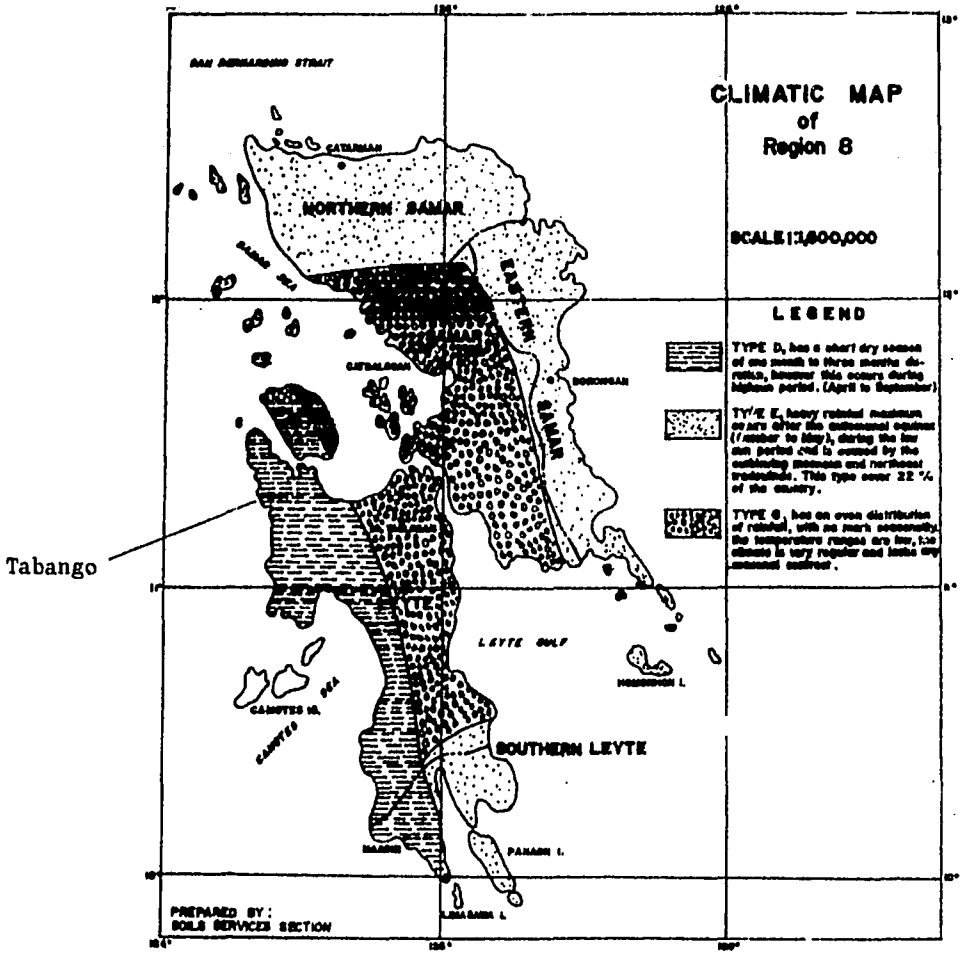

Figure 1. Site location and climatic map of the study area on the island of Leyte in the Philippines.

Farm size

- less than 2 ha
- 2 to 5 ha.
- more than 5 ha
- large hacienda

Most farmers cultivate no more than 5 ha. The majority of these operate farms of 1.5 to 2 ha.

2.8 Production Emphasis

Table 1. Production emphasis of the predominant farming systems in the Tabango study area.

	Primary Production Emphasis	Secondary Production Emphasis
Annual Crops	subsistence staples rice maize cash crops peanuts mung beans	supplementary foods & cash crops cassava sweet potato & other roo bananas
Perrenial Crops	cash crop coconut	cash crop Leucaena leucocephala (ipil-ipil) for leaf-meal and fuelwood
Farm Animals	draught power carabao (water buffalo) cash income pigs	subsistence consumption chickens

2.9 Characteristics of the Selected Farming System

The following information summarizes the salient characteristics of a typical farm in the farming system selected for priority emphasis by the diagnostic and design team:

Agroecological characteristics

- topography: upland slopes ranging from 10-60 percent (avg = 30%)
- soil: clay to clay loam, generally deep
  pH = 7.7
  % N (total) = 0.06 - 0.14%
  % OM = 0.4 - 2.5%
  P (available) = trace, particularly in upper slopes, 22 - 32 ppm in lower slopes
- erosion hazzard: sheet and rill erosion notable on many farms

Tenure status

- OLT beneficiaries

Farm size

- 1-2 ha.

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Production system

Table 2. The role of major crop and livestock components in the selected farming system and their associated cultural practices. Where two or more purposes are served the primary one is underlined.

CROP/ANIMAL	PURPOSE	CULTURAL PRACTICE
Primary		
maize	subsistence, cash, animal feed	monocrop in rotation
rice	subsistence, cash, animal feed	monocrop in rotation
peanut	cash	monocrop in rotation
mung bean	cash	monocrop in rotation
Secondary		
sweet potato	subsistence, cash	monocrop in rotation
cassava	subsistence	monocrop
banana	subsistence, cash, feed	boundary planting
ipil-ipil	cash, fuelwood	scattered rows and clusters on farm
Animals		
carabao	draught animal	grazing on roadsides and neighbouring coconut plantations
pigs	cash, social consumption	scavenging and supplementary feed
chickens	subsistence	scavenging and supplementary feed

Cropping schedule for major crops:

	Planting	Harvesting
Maize	April-May	July-August
peanut	Sept	Dec-January

Average crop yields:

Maize	5 sacks/ha (250 kg/ha)
peanut	10 sacks/ha

3. DIAGNOSIS OF MAJOR LAND USE PROBLEMS AND POTENTIALS

The results of the diagnostic survey and analyses carried out by the regional D&D team are presented in Fig. 2. This is a combined causal network and flow diagram which depicts, from left to right, the major household supply problems. The flow of related inputs and outputs (unbroken lines), and the causal factors which contribute (broken lines) to the creation of the identified problems.

3.1 Problems in the Household Supply System

Contrary to initial expectations, the diagnostic survey revealed that there are no presently perceived problems in the staple food and fuelwood

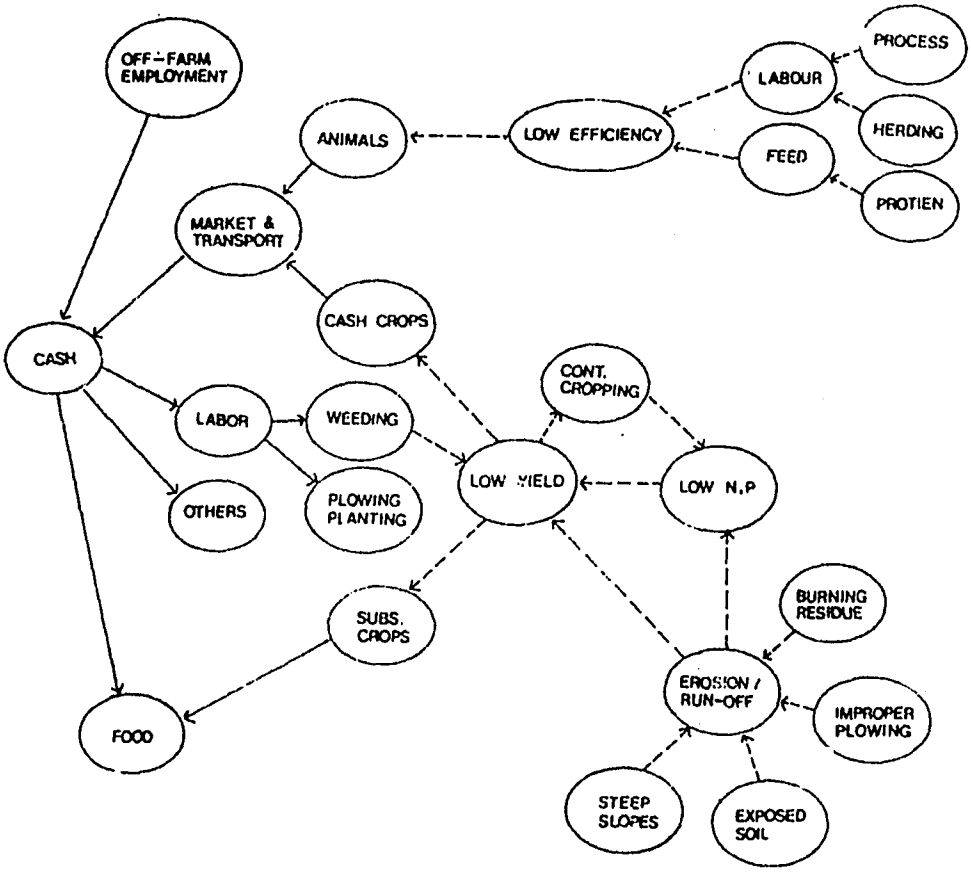

Figure 2. Combined causal network and flow diagram of the farming system problematique in Tabango, Leyte. Depicted from left to right are the major household supply problems, the flow of related inputs and outputs (unbroken lines), and the causal factors which contribute to the creation of the identified problems (broken lines).

supply subsystems of households in the target farming system. Domestic needs for fuelwood are reported to be adequately met by the ready supply of coconut fronds in the general area together with farm plantings of *Leucaena leucocephala*. Although, farm produced staple foods are in most cases insufficient to meet the annual needs of some households, the dominant strategy of the household economy is one of mixed subsistence and cash crop production, supplemented by income from off-farm labour (mainly agricultural labour on other farms in the area). Since cash income is sufficient to meet the needs for supplemental purchase of food, food shortage *per se* is not felt to be a problem. This does, however, constitute a drain on household cash resources.

Inadequate cash income

Insufficient cash for purchase of other household needs (clothing, educational expenses, and non-food consumer items) and for capitalization of farm improvements emerges, therefore, as the main household supply problem in the survey area. The main sources of cash income are proceeds from the sale of cash crops (mainly peanuts and mung bean), livestock (pigs) and earnings from off-farm employment, as shown in Table 3.

Table 3. Sources of cash income

Source of Income	Percentage of Farmers Surveyed (N=10)
Off farm employment	90
Peanuts	90
Pigs	80
Mung bean	50
Maize	20
Rice	20
Sweet potato	20
Banana	10
Ginger	10
Onion	10

The main drains on household cash resources are food purchases to supplement farm production of staples and hired labour for weeding, land preparation and planting. Some 50 percent of the household surveyed own no carabao and must spend an average of ₱250 per crop (2 crops/year) to hire the services of a ploughman and carabao. This lack of a draught animal is a severe capital constraint which, given the low net income, is very difficult to remedy.

Income from sale of cash crops and livestock is generally insufficient to meet the cash needs of the household and most farmers resort to off-farm employment to supplement farm earnings. Of the 10 farmers surveyed who fall into the category of the target farming system, 8 engage in off-farm agricultural labour and one is self-employed as a maker of wooden ploughs. All farmers expressed interest in increased income from farm sources, but the survey team did not detect a notably high level of entrepenurial aspiration among this group of farmers.

3.2 Causal Factors Responsible for Household Cash Problems

On the income side, the main factors associated with low on-farm cash production are shown in Fig. 2 as causal complexes or "syndromes" responsible for *low yield* of field crops and *low-efficiency* of the pig production enterprize.

Low Yield Syndrome

Continuous permanent cropping without mineral nutrient inputs and inadequate soil conservation practices have resulted in low nutrient status of the soils and low and declining yields of both subsistence and cash crops (e.g. 250 kg/ha of maize). The small farm size and low productivity of the land necessitates a permanent cultivation regime with no opportunity to rest portions of the land in order to restore soil fertility, thus perpetuating the low yield syndrome. The non-use of mineral fertilizers is attributable both to the lack of cash resources and the lack of a local infrastructure for supply of agricultural inputs.

Sheet and rill erosion processes further exacerbate the degradation syndrome on these farms through continued nutrient losses and poor crop stands. Erosion hazards are substantial under the prevailing conditions of steep slopes and cropping practices which leave the soil exposed to heavy rains following field preparation. Improper ploughing practices and the burning of agricultural residues are major contributing factors in soil erosion. The fact that the farming system is still operational at all, even at low levels of yields, is attributable to the depth and only moderate erodibility of the soil. Nevertheless, at an estimated rate of loss of 1 cm of soil per year, this system of poor husbandry cannot be sustained indefinitely.

The prevailing tillage practice is to plough the field in lines perpendicular to the main slope. However, since the fields typically exhibit an undulating topography with minor slopes in variation to the main slope, the ploughing pattern usually deviates substantially from recommended contour ploughing practices, with the result that severe erosion occurs in areas of downslope furrows. From discussion with farmers it is clear that the decision to plough perpendicular to the main slope is mainly based on the desire to conserve the energy of the draft animals and not specifically intended to prevent erosion. Although proper contour ploughing would more efficiently satisfy both erosion control and energy conservation purposes, no cases of contour ploughing by smallholders were observed in the entire survey area.

The retention of agricultural residues on the fields would also tend to mitigate both erosion and low-fertility problems, but all farmers surveyed reported a strong inclination to gather up crop residues and burn them. The main reason given for removal of crop residues from the fields was to avoid interference with ploughing operations, since with the traditional chisel plough used in the area maize stalks and other residues tend to bunch up in front of the plough, making tillage difficult. The expressed reason for burning the gathered residues was not any conscious desire to release nutrients to the soil, but rather to destroy potential habitats for rodent pests.

All of this is done without any evident consideration for erosion control and maintenance of soil fertility, although both of these factors are acknowledged by farmers as major contributing causes of declining yields. The only notable fertility conserving measure practiced by the majority of farmers is the rotation of cereal crops with grain legumes.

Low Efficiency of the Livestock Enterprise

The low time-use efficiency of carabaos (water buffalo) as draft animals is a noteworthy latent constraint on agricultural production, but not one which admits of an easily conceivable and feasible solution. These

animals, unlike oxen, must be rested and allowed a cooling-off period in water after brief periods of draught labour. Nevetheless, the slow work pace of the carabao seems to accord quite well with the somewhat leisurely attitude to work of the local farmers, and there seems to be little scope at present for any attempt to disrupt this congenial symbiosis by substitution of more efficient draught animals.

The main addressable livestock constraint, therefore, is the low efficiency of the pig production enterprise, which is present as a source of cash income and socially expendable wealth (fiesta contributions, etc.) on most farms. Inefficiency arises in connection with the labour requirements of the present system of feeding and the nutritional inefficiency of the present diet. Free range pig feeding is not possible on most farms because of the danger of damage to one's own and neighbour's crops. Consequently, labour is required to move and tether pigs from time to time. Supplemental feeding of rice bran and shredded banana stalk is commonly practiced, but this does not make up for the lack of high quality protein in the diet. The resulting slow rate of live weight gain yields rather low returns to labour invested in the pig enterprise.

4. DERIVATION OF DESIGN SPECIFICATIONS

The following list of design specifictions may, for convenience, be divided into *functional specifications* derived from analysis of intervention points in the system suggested by the combined causal network/flow diagram (Fig. 2) and *other design specifications* derived from the general understanding of resource constraints and farmers' strategies gained in the course of the diagnostic survey exercise.

4.1 Functional Specifications

To reduce the outflow of cash:

a) Reduce the need for hired labour by reducing

   -- the amount of tillage required for field preparation
   -- the level of labour required for weeding

b) Reduce cash expenditure on supplementary food purchases by increasing on-farm production of staples by removing or mitigating the yield-reducing constraints. This could be done by:

   -- improving the availability of nutrients (mainly N&P)
   -- reducing erosion by

      - adopting proper contour ploughing practices
      - instituting a feasible system of organic matter maintenance on the fields

To increase the inflow of cash:

a) Incorporate new cash crops into the farming system

b) Improve the productivity of existing cash crop enterprizes (see b above)

c) Improve the efficiency of the main livestock enterprise by

   -- producing a more balanced pig ration from potential farm feed sources
   -- reducing the labour requirements of pig feeding by

      - introducing improved processing technology
      - substituting the current tethering practice by an efficient pen feeding regime

4.2 Additional Design Specifications:

To be appropriate and *adoptable* by farmers in the context of their existing farming system (i.e. without major infrastructural or motivational changes) candidate technologies must:

a) have low capital requirements and must not rely on inputs which are not generally accessible to small farmers in the area,

b) be efficient in the use of available labour resources (i.e at prevailing levels of effort acceptable to the majority of farmers) and must not exacerbate labour bottlenecks in the farming system,

c) make efficient and intensive use of scarce land resources

d) not contribute unduly to increased pest problems,

e) be consistent, in the case of new cash crops, with marketing potentials in the area.

5. ALTERNATIVE TECHNOLOGIES

Cash deficit was identified at the diagnostic stage as the main symptom of the farming systems in the Tabango area, a problem that motivates farmers to look for off-farm income. The causal diagram in Fig. 2 indicates that this deficit stems mainly from factors in the operation of cropping and animal production enterprises within the farm. Of the two a higher priority should be placed on improvement of cropping enterprises, since they constitute the main source of both food (maize) and cash (peanuts).

Low soil fertility and soil erosion were singled out as the main causes of low crop yields, indicating the most promising points for technological interventions in the system. Table 4 summarizes some of the alternative practices, of an agroforestry and non-agroforestry nature, envisaged by the multidisciplinary team as having the potential to overcome those constraints.

5.1 Non-agroforestry Alternatives

Although a thorough discussion of these options vis-a-vis the identified constraints is beyond the scope of this document, it is worth mentioning some of the reasons leading to the selection of an agroforestry alternative, most of them linked to the design specifications discussed above.

In the field of soil nutient deficiency the introduction of inorganic fertilizers would most certainly overcome the biophysical constraint. However, such an input would further strain the already scarce cash resources available at the farm level. Even if a credit programme were made available, there is no existing infrastructure for distributing fertilizers. Compost could be an interesting alternative, particularly to avoid residue burning. However, lack of knowledge and labour requirements may prevent its adoption.

Green manuring with appropriate herbaceous species has been shown to improve soil fertility, but land and labour scarcity and local attitudes against growing a crop solely for the purpose of improving the soil, would tend to prevent the acceptance of conventional green manuring practices by farmers.

One of the problems farmers would face in trying to incorporate residues is the type of ploughing equipment in use, which does not have a mould-board to turn the soil over. Substituting the existing chisel plough by

Table 4. Possible non-agroforestry and agroforestry interventions to solve or mitigate the diagnosed problems.

PROBLEMS	INTERVENTIONS	
CASH OUTFLOW	NON-AGROFORESTRY	AGROFORESTRY
1. Low Yield		
- N.P. deficiency	- Mineral fertilizer - Composting - Green manure	- Legume tree mulching
- Residue burning	- Mould-board ploughing - Composting - No-tillage	- Mulching for minimum tillage
- Water erosion		
.Steep slopes	- Terracing	- Hedges across slopes
.Improper ploughing	- Contour ploughing - No-tillage	- Contour hedges
.Exposed soils	- Perennial crops - Relay cropping - Mulching	- Mulching
2. Tillage		
- Carabao		
.Hired ploughing	- No-tillage	- Mulching for minimum tillage
.Working capacity	- Oxen - No-tillage	- Mulching for minimum tillage
- Weeding	- Mulching	- Mulching
CASH INFLOW		
1. Low Yield (Peanuts)		
Same as outflow	- Same as outflow	- Same as outflow
2. Swine Production		
- Feed sources	- Balanced ration	- Gabi & leaf meal in hedgerow intercropping
- Feed processing	- Mechanical shredder	
- Management	- Appropriate housing	
3. Cash Sources		
- Crops	- Pineapple - Black pepper - Ginger	- Hedgerow intercropping of: .Pineapple .Black pepper + Ipil[2] Leaf Meal .Ginger
- Livestock	- Cattle Fattening	

a mouldboard plough would be a relatively costly option, possibly requiring stronger animal traction. It is known that no-tillage methods will improve soil and water conservation as well as reduce traction energy and labour requirements, but the specialized knowledge and equipment required, together with high cost and problems with the supply of herbicide may again prevent its widespread adoption. There is a need, moreover, to provide for a source of mulch which should not compete unduly with the main crops for light, moisture, nutrients and space and/or time in the cropping regime.

The investment required for construction of proper bench terraces would seem to rule them out as a locally adoptable alternative. Contour ploughing would certainly be a feasible erosion mitigating alternative, to which farmers ought to be introduced. At the moment there is a kind of "across the slope" ploughing, not precisely as a soil conservation practice but to avoid having the carabao go up and down the slope.

A permanent vegetation cover would certainly decrease the impact of erosive factors. However, establishing perennial crops (like coconuts) would compete with food and cash crops for the use of scarce land, depriving the smallholder family of its livelihood for quite a few years (it could become a viable alternative, however, for holdings of 5 ha or larger). Relay cropping would also provide a permanent protective cover, but its efficiency may be impaired by the low soil fertility level.

The efficiency of tillage operations could possibly be improved by substituting the carabao (short effective working time) by oxen, but this may be a very difficult change to introduce and it may disrupt a cherished symbiosis between Visayan farmers and carabaos. At any rate, it would appear that in the medium to long run land pressure may tend to displace animal traction from smallholdings, particularly if and when free access to grazing under the coconuts of the larger plantation owners is restricted.

Cash income could be increased by substituting alternative cash crops for peanuts, but the rate of adoption may be slow under existing marketing conditions. Cattle fattening does not appear as a sustainable alternative for smallholders, since fodder production will compete with food and cash crops for land and labour.

5.2 Agroforestry Alternatives

Collumn 3 in Table 4 summarizes the interventions of an agroforestry nature which were considered by the team for addressing specific constraints in the diagnosed system From the discussions at the design stage of the D&D process there emerged a general design concept for an agroforestry land management system which appears to have the potential to remove or mitigate several of the most limiting constraints. The team decided, therefore, to focus its attention on the elaboration of this design concept as a prelude to the planning of a research project to develop and test the proposed agroforestry system. The results of the teams' thinking, as developed initially in the rapid appraisal mission and later in the followup phase of the D&D process are presented below.

5.2.1 Design concept: hedgerow intercropping or alley cropping system

The use of mulch from a nitrogen-fixing tree as a source of organic fertilizer for the predominant field crops appeared to the team as a promising technique for restoring and maintaing soil nitrogen at an increased level. The possibility for arranging such trees in hedgerows

along contour lines in the field suggested itself as a way of forming vegetative barriers capable of arresting soil erosion which in time would result in the development of natural terraces. The existence of contour hedgerows would also force farmers to plough along contour lines, thus reducing inter-row erosion.

The food and/or cash crops normally grown by farmers could be intercropped between the hedges with the expectation that, if such a system were perfected, the increase in productivity from organic fertilization would more than offset the reduction in cropping area alloted to the main crops. Moreover, if the hedges were composed of leucaena or other fodder-producing trees or shrubs, the tops could be used to produce leaf-meal during those times of the year when the prunings were not being used for mulching. Firewood could also be produced as a by-product of other management practices. It was further envisaged that the space alloted to the hedgerows could be intercropped in a two-storey arrangement with shade tolerant root crops grown at the side of the hedge, and vine crops (such as black pepper) grown within the hedgerow by planting self-pruning tree species at 10 meter intervals or more in the hedgerow to serve as live supports for the vines. See Fig. 3 for an artist's conception of the proposed system.

This design concept will be recognized as a variation on the "alley cropping" theme found in the literature (Parera, 1976; Guevarra, 1976, 1978; Benge, 1979; de la Rosa, 1980; IITA, 1980a, 1980b; Wilson and Kang, 1980; Wilson and Raintree, 1980; Raintree and Turay, 1981; Kang, Wilson and Sipkens, 1981; Metzner, 1981; Evensen, 1982). As a form of "zonal cropping" (Huxley, 1980), alley cropping is a type of agroforestry system which may allow simplification of management procedures by dealing with each zonally arranged component largely as a sole cropping enterprise within the cropping system.

Evaluation of different alley cropping system, however, has shown (Verinumbe, 1981; Balasubramanian, 1983) or predicted (Hoekstra, 1983; Torres, in press) variable results in different environments, indicating the need to generalize with caution and distinguish clearly between specific design variations on the general alley cropping theme. The concept of alley cropping or, more generally, hedgerow intercropping implies a "family of technologies" often linked to each other only by the shared attribute of some form of zonal arrangement of woody and herbaceous components.

The specific hedgerow intercropping system depicted in Fig. 3 is only a *design prototype*, intended to convey the general idea of the team's proposal and to serve as a starting point for the research envisaged as necessary to develop an optimal system for the farming conditions of the Tagbango area. The product of such research, assuming the project is successful in developing an optimal site-specific system, would itself revert in the dissemination phase to the status of a prototype for adaptive research throughout the potential recommendation domain.

Although various hedgerow intercropping systems of this general type are known to exist in the Philippines and in other forms elsewhere in Southeast Asia, it is doubtful whether any such system has gone through the process of reiterative development and refinement which would be characteristic of a systematic and cost-effective approach to the development of system-specific agroforestry technology (ICRAF, 1983a, 1983b). At the

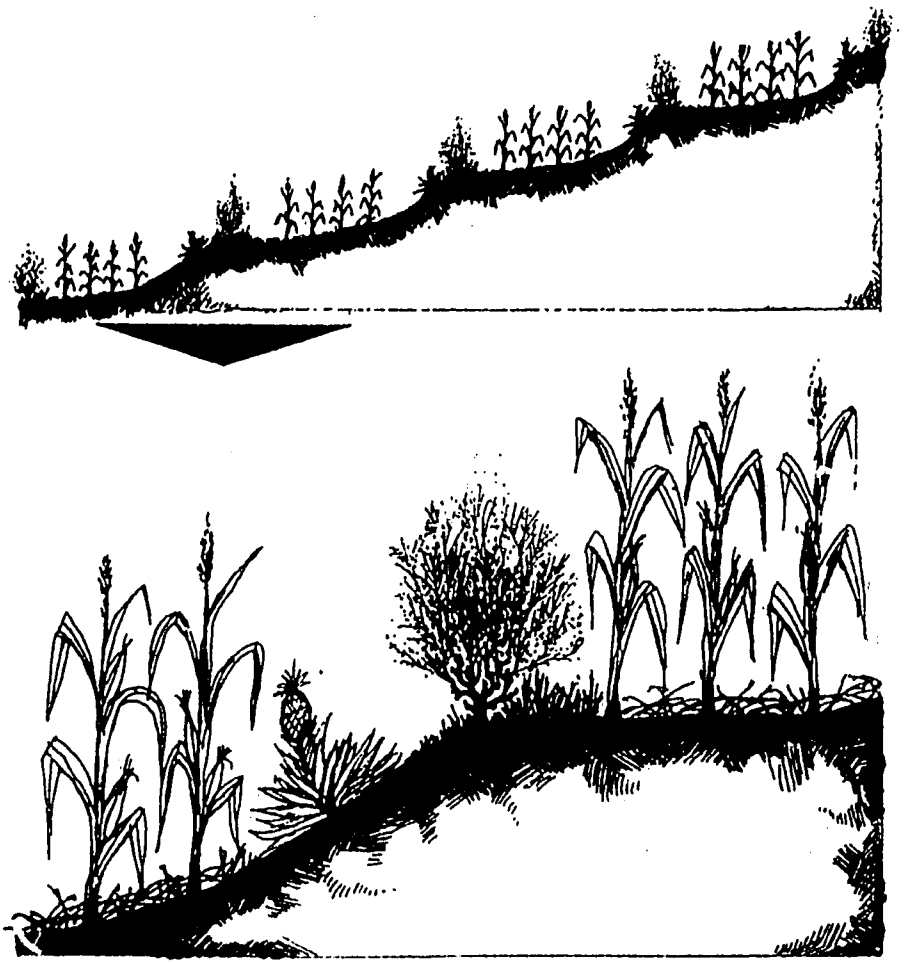

Figure 3. Artist's conception of the experimental hedgerow intercropping system proposed for research at the Tabango site.

outset of such a process it is essential to set forth the desirable characteristics of the eventual technological product (i.e. the design specifications) which would make it appropriate and adoptable in the context of the target land use system.

In addition to addressing the functional requirements of soil fertility improvement (mainly increased nitrogen) and erosion control, an appropriate alley cropping system for the target group in Tabango would also possess the following desirable characteristics:

a) be efficient in the intensive use of land
b) be efficient in the use of labour and not create labour bottlenecks
c) not increase pest problems beyond an acceptable level
d) be flexible as regards management for different products on different farms and at different times of the year
e) allow for the possibility of minimum tillage management in the eventuality of reduced draught power on the smaller farms
f) not involve management complexities which the local farmers, after a sufficient demonstration and trial period, would not be willing to accept.

5.2.2 Plant ideotype for the tree/shrub component of the system

Although maize is virtually a "given" as a component of any widely adoptable alley cropping system developed for the Tabango site, the choice of the most appropriate tree/shrub component for the system is an *open question for research*. In addition to specifying the desirable characteristics of the proposed system, it is helpful to set forth the desirable characteristics of plant components prior to screening (Raintree, 1981). The following characteristics have been identified as features of the ideotype for the ideal tree/shrub component of hedgerow intercropping systems of the type proposed for Tagbango:

a) high N-fixation capacity
b) fast-growing
c) able to coppice vigorously and yield required volume of suitable mulch material under acceptable cutting regime
   - vigor and yield requirements will vary with cutting frequency deemed acceptable to user (which will be affected by labour availability shading effects and mulch requirement to achieve desired benefits)
   - suitability of mulch material determined by various characteristics (e.g. rapidly decomposing leaves for quick release fertilizer, slowly decomposing leaves for weed and runoff control, desirability of insect-repellent properties, nutritional quality and palatability if herbage to be managed for fodder by-product, etc.)
d) deep rooting habit for drought resistance, recycling of subsoil nutrients, and minimal surface root competition with associated arable crops
e) easy and economic establishment
f) high yields of economic by-products (feed and firewood)

It is difficult to assign priorities to the various characteristics prior to on-farm trials to assess performance in terms of features desired by the end-user. Other, more detailed plant physiological characteristics may be identified as the research progresses. It may also be necessary

to think of satisfying the total package of requirements by a *combination* of hedgerow species if they are not optimally combined in a single species.

5.2.3 Ex ante evaluation of the proposed system

The basic hypothesis behind the proposal of the experimental hedgerow system is that the increments in crop yield due to organic nitrogen inputs from the nitrogen-fixing woody component would increase the productivity per unit of intercropped land. Available information was analysed to evaluate the potential contribution of leucaena hedgerows and to formulate a more quantitative hypothesis on the impact on grain and fuelwood yields of the intercropping of leucaena hedgerows with maize (Torres, in press).

The use of data on *Leucaena leucocephala* in the following computations is made without prejudice to the eventual selection of other woody components for the hedgerow role, although the choice of leucaena as an initial "best bet" component for the prototype system is justified on several grounds: 1) leucaena does possess most of the characteristics of the plant ideotype for the tree/shrub component of the system (although it does not have slowly decomposing leaves, which might be desired if a more durable mulch is required for a minimum tillage variant of the system); 2) the giant "Salvador type" leucaena varieties are a well-established feature of the existing farming system (though not in the arrangement envisaged in the proposed design); 3) sufficient data on the performance of leucaena and associated crops exist in the literature to allow a *first order approximation* of its performance under the proposed conditions (this is not the case for most of the woody species often mentioned as having potential for agroforestry). The following calculations, therefore, give an approximate indication of the performance of *one variant* of the prototype system.

Based on production data from the humid tropics it was assumed that a linear meter of leucaena closely planted in a hedgerow would produce about 1 kg of "leafy" dry matter per year with a nitrogen content of 3.5%. and around 650 g of fuelwood. It was further assumed that an increase of 5.3 or 6.3 kg of maize per kg of nitrogen applied as leucaena mulch would be obtained from such practice. Results of this speculation in terms of kg of maize per ha of intercropped land for different baseline maize productions are shown in Table 5. Increases in grain yield expressed as percentage of baseline production are shown in Fig. 4. (Torres, in press).

Table 5. Estimated yields of maize per hectares of intercropped land, as affected by baseline production of maize

Leucaena inter-row spacing (cm)	maize baseline production (kg ha^{-1}) 500	1000	1500	2000
– Applying ratios derived from *observed* yields				
150	2310	2120	2110	2170
300	1405	1560	1805	2085
450	1103	1373	1703	2056
600	953	1280	1653	2043
– Applying ratios derived from *reduced* yields (75% of observed)				
150	1800	1710	1770	1880
300	1150	1355	1635	
450	933	1236	1589	
600	825	1178	1568	

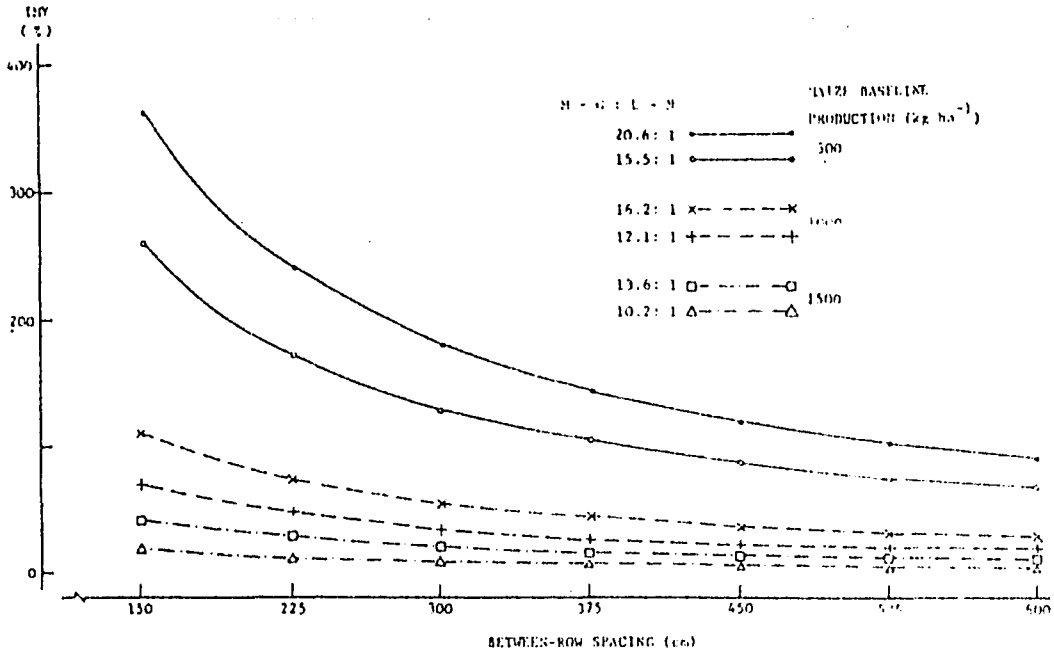

Figure 4. Increase in maize yield per unit of intercropped land (IMY)

As mentioned above, the existing production level at Tagbango appears to be in the order of 250 kg ha^{-1}. Under these circumstances the hypothetical relationships shown in Fig. 4 indicate that even at the wider inter-row spacing, increases in physical production is higher than 30%. Should those relationships be supported by experimental evidence, espacement would still depend on economic considerations, particularly in relation to the labour cost: maize price ratio. The proposed practice would obviously require higher labour inputs than the present system, but it should be noted that at the 150 cm spacing and 1: 6.3 ratio the increase in maize yield would be equivalent to about 60 man days (assuming 1.1 pesos per kg of maize and a salary of 7 pesos day^{-1}) which could be expected to offset the increased labour input.

Table 6. Estimated potential fuelwood production per hectare of intercropped land.

Leucaena between-row spacing (cm)	Stem production kg ha^{-1}	m^3 ha^{-1}
150	1610	3.50
300	805	1.75
450	537	1.17
600	403	0.88

In addition to the potential benefit to be derived from an increase in maize production, a hectare of hedge intercropping at 150 cm spacing would supply enough fuelwood to satisfy annual requirements of 8 persons (Table 6), and the equivalent value of another 40 man-days of labour could be obtained if one of the hedgerow harvests is sold for leafmeal production (assuming that 50% of the "leafy" portion would be accepted for leafmeal at a price of 500 pisos per ton of leafmeal).

It should be emphasised, however, that *the potential of this technology must still be tested under field conditions* before being considered for dissemination to farmers. That, in fact, is what is envisaged as part of the research proposed in the next section of this report.

6. RESEARCH PROPOSAL

Accepting that the quantitative hypothesis formulated in the previous section is based upon some experimental evidence, the designed technology prototype could already be tested on-farm, while more controlled experiments are carried out concurrently to test hypothetical relationships (to allow for a better understanding of fundamental processes) and to try alternative components.

It is proposed, therefore, that research activities be carried out at 3 sites: on farmers' fields, in a local field station (to be developed on land generously offered by the Tabango Mayor) and at the VISCA campus. In general, information emerging from those sites will reach the development stage in the short (2 years), medium (4 years) and long (6 years) term, respectively (meaning the period of elapsed time before they are ready to be disseminated by the extension system).

In this context it is suggested that the following research activities be implemented in the different sites.

6.1 Intercropping with leucaena hedges (1)

Site: Farmers' field
Period: Immediate (short term).
Problems to Overcome:

i) Low N and P
ii) Soil erosion
iii) Improper ploughing

Objectives

General: Utilization of leguminous trees in croppings with contour hedges to reduce water run-off, and increase N and P availability to the interplanted crops

Specific: (i) To examine the effect of between hedge distances on the yields of crops established on farms with different baseline productions and slope gradients

(ii) To examine the effect of cutting frequencies on the leucaena yield and labour input

(iii) To examine the overall effect of the proposed system on water run-off, erosion, and soil and chemical properties.

Research Design

a) Technology components and management:

i) Leucaena cultivars - local giant K8 or K28 (best bet)
ii) In-row planting distance of leucaena - 15 cm, along contour lines
iii) Height of cutting of leucaena - 15 cm (best bet) after allowing 6 months for establishment
iv) Lemon grass to be planted on the uphill sites of hedges
v) Crop cultivars - local

b) Treatment Variables:

i) Distance between hedges

- 3 inter-row spacings to be tested on different farms, according to existing maize production levels: Farms with 250 kg ha^{-1}: 1, 3 and 5 maize rows between hedgerows; Farms with 500 kg ha^{-1}: 1, 2 and 3 maize rows between hedgerows

ii) Slope gradient - 20%, 40%
iii) Frequency of cutting of hedges

- 2 frequencies will be tested

(1) Farmer's way
(2) 6 cuttings as shown (first cutting 10 days before planting maize)

May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1		2		3		4		5		6		7

iv) Replications: 3

c) Criteria for Farm Selection

i) Field extending from ridge to lower slope
ii) Uniform major slope
iii) Minimum width of 50 m

Total farms required: 12

d) Parameters to be Monitored

i)	Yield of crop	Field Researchers
ii)	Yield of leucaena	" "
iii)	Labour input	" "
iv)	Farmer's observations	" "
v)	Rainfall measurement	" "
vi)	Soil chemical and physical properties	VISCA scientists
vii)	Run-off and erosion control	" "

6.2 Intercropping with leucaena hedgerows (2)

Site: Field Station (in Tagbango)
Period: Medium term
Problems to Overcome:

i) Low N and P
ii) Soil erosion
iii) Improper ploughing

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Objectives

General: Utilization of leguminous trees in croppings with contour hedges to reduce water run-off, and increase N and P availability to the interplanted crops.

Specific: (i) leucaena cultivar
(ii) height of cutting hedges
(iii) within row tree spacing in hedges, and
(iv) rate of green manure application in terms of:
- leucaena leaf production
- crop yield
- labour input, and
- nutrient (N and P) cycling

Research Design

a) Technology components and management similar to 6.1
b) Treatment Variables

i) Leucaena cultivars: 2, (i) giant and (ii) local
ii) Height of hedge cutting - 2 treatments
iii) Within row spacing of leucaena trees - 3 spacing

i) 15 cm
ii) < 15 cm
iii) > 15 cm

iv) Rate of green manure application (mulching) - 3 treatments (separate leucaena stand to be established, to supply needs for additional mulch)

v) Replications: 2

c) Parameters to be Monitored

i)	Yield of crop	Field Researchers
ii)	Yield of leucaena	" "
iii)	Labour input	" "
iv)	Nutrient (N & P) cycling	VISCA Scientists

6.3 Hedgerow intercropping of cash crops

Site: Field Station (in Tagbango)
Period: Medium term
Problems to Overcome:

a) Cash shortages

Objectives:

General: To examine the feasibility of introducing some cash crops as components of hedgerows

Specific: (i) To examine the effect of cash crop inclusion in the hedgerow on labour input

(ii) To examine the effect of cash crop inclusion in the hedgerow on the yields of leucaena agronomic crops and cash crops

Research design

a) Technology components and management

i) Hedgerow species, distance between plants, height of cutting and frequency of cutting, similar to 6.1

ii) Lemon grass to be planted on the uphill side of hedgerow

iii) For pepper, 10 m distance between supporting poles

iv) All cash crops to be planted on the downwhill side of hedgerow

b) Treatment Variables:

i) Types of cash crops

a) Black pepper (*Jacaranda copaia, Gliricidia, Erythrina, Sesbania* as poles at intervals within the hedgerow)

b) Ginger
c) Pineapple
d) Gabi

c) Parameters to be monitored:

i) Labour input
ii) Yield of leucaena
iii) Field of cash crop
iv) Yield of agronomic crop

6.4 Mulch farming with contour hedges of other species

Site: Research Station (VISCA Campus)
Period: Long term
Problems to Overcome:

i) Low N and P
ii) Soil erosion
iii) Labour requirements for cultivation and weeding

Objectives

General: Utilization of trees in farming with contour hedges to reduce water run-off, tillage and weeding while increasing N and P.

Specific: (i) To examine the possibility of using other N-fixing and coppicing woody perennials as hedge species for providing mulch and nutrient (N & P) e.g. *Erythrina).*

(ii) To determine the most suitable cutting height and within row spacing for sufficient leaf production

(iii) To determine the required quantity of mulch for effective control of weeds and soil erosion.

Research Design

a) Technology components and management:

i) Species, selected on the basis of:

1) N-fixing, P-pumping capability
2) Broad and slow decomposing leaves (non-deciduous)
3) Deep rooting
4) Fast growing and good coppicer (e.g. *Erythrina, Gliricidia* and *Sesbania)*

b Treatment Variables:

i) Height of hedge cutting - 2 levels
ii) Within row spacing of Erythrina trees - 2 spacings
iii) Mulch rate of application - 3 rates (based on potential production)

c) Parameters to be Monitored:

i) Leaf production
ii) Content of N and P in leaves
iii) Weed growth
iv) Crop yield
v) Erosion

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ANNEX 5

CASE STUDIES IN AGROFORESTRY DIAGNOSIS AND DESIGN NO.3

Working Paper

19

AGROFORESTRY SYSTEMS FOR THE SEMIARID AREAS OF MACHAKOS DISTRICT, KENYA

by

Dirk A. Hoekstra

with

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In Collaboration with

THE KENYA AGRICULTURAL RESEARCH INSTITUTE,
THE NATIONAL DRYLAND FARMING STATION, KATUMANI,
and THE MACHAKOS INTEGRATED DEVELOPMENT PROGRAMME,
MINISTRY OF AGRICULTURE

INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY

March 1984

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F O R E W O R D

As part of its programme of work ICRAF has established a Collaborative and Special Projects Programme (COSPRO) to strengthen the capability of national institutions to develop agroforestry systems. In order to cover a wide spectrum of agroecological and socioeconomic conditions, COSPRO is organized on the basis of geographical regions, on the assumption that regional land management systems share broadly similar cultural conditions. Within each of these regions, three or four major ecological zones are selected, to build a geographical/ecological framework in which potential research sites are to be located. Sub-Saharan Africa is one of such geographical regions.

This third case in the ICRAF Series on Case Studies in Agroforestry Diagnosis and Design is the result of such collaborative activities between scientists from ICRAF and the Kenya Agricultural Research Institute, the National Dryland Farming Station at Katumani, and the Machakos Integrated Development Programme. The joint exercise led to the formulation of a research project, which is now being implemented by the Kenyan Institutions with the technical back-stopping of ICRAF and the sponsorship of IDRC.

The aim of the research project is to develop improved systems of agroforestry land management which are appropriate to the mixed farming systems characteristic of Kenya's semiarid zone, with particular attention to the farming situation in Machakos district.

The case study is the result of an application of ICRAF's Diagnostic and Design methodology (D&D) by a multidisciplinary team of scientists from the participating institutions. The purpose of the initial 'rapid appraisal' D&D exercise was to diagnose existing and future land management constraints and agroforestry potentials, design appropriate agroforestry systems and formulate plans for research to develop the candidate agroforestry technologies through a combination of on-farm and field station research. As the project progresses, the iterative D&D process is repeated in modified form to take stock of project experience, refine the diagnosis and the design, and introduce appropriate modifications into the research plan in order to optimize the productivity, sustainability and adoptability of the experimental technologies.

In due course, prototype agroforestry technologies and land management systems arising from this process will be evaluated for extension and adaptive research throughout a wider recommendation domain in Kenya and in similar farming situations in other parts of the world.

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1. THE SEMIARID LANDS OF KENYA

Rapid population growth in Kenya (approx. 3.8-4.0 percent per annum), limited arable land and a shortage of employment opportunities in the industrial and service sectors have led to a substantial growth in the number of small-holders farming and ranching on Kenya's marginal lands. This trend is expected to continue into the twenty-first century. While increased settlement and exploitation of these lands provide a basis for the livelihood of small-scale farmers, the results are mixed. The soils, especially those on the steeper slopes, are subject to serious erosion. Much of the range land has been overgrazed and the ground cover in some areas is badly degraded. Also, rainfall in the semi-arid zone is low (600 to 800 mm on average) and subject to considerable variability These factors, combined with traditional methods of farming and ranching, have led to a low standard of living for many of the rural populace in these areas. During times of rainfall deficiency the Government of Kenya has had to divert scarce Treasury funds to famine relief for those most seriously affected. Moreover, the resulting depletion of the natural resources (forestry included) does not augur well for future generations who are expected to live on these marginal lands.

A pre-investment inventory study of the marginal/semi-arid lands in Kenya was conducted during 1977 and 1978 by the Consortium of International Development, the U.S. Soil Conservation Service (U.S.D.A.) and staff of the Ministries of Agriculture, Water Development and Natural Resources. The principal theme running throughout this study is that major investments in soil conservation works, farm production technology and infrastructure are needed to reverse the rapid decline in the quality of life and the condition of the physical environment in the semiarid lands.

Several institutions are now geared to fulfil this goal. The Katumani Research Station in collaboration with a team of F.A.O. experts and KARI in collaboration with U.S.A.I.D. experts are presently engaged in researching appropriate agricultural systems for the semi-arid areas while the European Development Fund sponsors an integrated development programme in Machakos District (M.I.D.P.). So far, most research is focused on purely agricultural and/or livestock systems, although the potential role of trees, expecially in solving the imminent energy shortage, has been clearly recognised by each of these institutions.

It is in this context that the formulation of an agroforestry research project is an important and appropriate contribution to the overall development of the semi-arid lands. The research plan discussed in this case study report proposes the refinement of results of on station species and provenance studies so far accumulated at Kibwezi, Hola, Ramogi and elsewhere through application to the farming situation, at Kakuyuni, Machakos District, Kenya.

2. METHODOLOGY

The identification of appropriate agroforestry systems and research needs for the target area was based on an application of ICRAF's diagnosis and design methodology (D&D), which is described in greater detail in Lundgren and Raintree (1983) and ICRAF (1983a, 1983b). A summary of the methodological steps taken in the preparation of this case study is presented below.

The first step was to select a specific study area, followed by an analysis of existing baseline data and a 'windshield' reconnaissance survey of the area coupled with preliminary interviews with qualified informants (articulate farmers, local officials, researchers, etc.) in the area. The output of this step was a basic structural-functional understanding/description of the area and its predominant land use systems.

The next step was to conduct a brief farm classification survey to identify one or two farming system types on which subsequent research would focus and to choose a sample of representative farms.

Subsequent to the selection of the focal system(s), a diagnostic survey of representative farms was conducted, followed by a diagnostic analysis of problems, constraints and potentials for agroforestry interventions to improve the performance of the selected farming system(s).

This led to the formulation of design proposals for agroforestry systems and technologies and, subsequently, to the identification of research needed to generate and test the candidate technologies and systems.

3. BIOPHYSICAL AND SOCIOECONOMIC CHARACTERISTICS OF THE TARGET AREA

3.1 Location of the target area

The Kakuyuni catchment area is located in Machakos District on the Yatta Plateau. It falls within agroclimatic zone 5 (Sombroek *et al.*, 1982), which comprises about one million hectares (i.e. 69% of the district's land area), and supports 465,000 persons (1979 census), i.e. 43% of the district's population. Kakuyuni is considered to be representative of the more densely populated areas of zone 5, where farmers are more dependent on agriculture than grazing (see Figure 1).

3.2 Terrain and Soils

The catchment area is about 1,200 meters above sea level and the terrain is gently to moderately sloping.

Soils in the catchment area are described as well drained, shallow to deep dark red, friable clay in many places rocky (nito rhodic ferralsols and nito chromic cambisols, including lithic and bouldery phases). In some depressions a poorly drained, very dark greyish-brown to black, very firm, slightly calcereous, cracking clay can be found, in many places with a saline and sodic deep subsoil (pellic vertisols, partly saline - sodic phase, with eutric or vertic gleysols) (Sombroek *et al.*, 1982).

The ferralsol cambisol soil association, including lithic phases, suffers from low inherent fertility once the organic matter content is lowered, as it quickly is by arable cropping, and also has a low capacity to retain added nutrients (although this is still worth doing). Maintaining or raising the organic matter content is particularly important.

The dark vertisols found in poorly drained depressions are very difficult to cultivate because clays are heavy, sticky and stiff when wet and hard when dry. The poor drainage also causes problems for most crops other than rice.

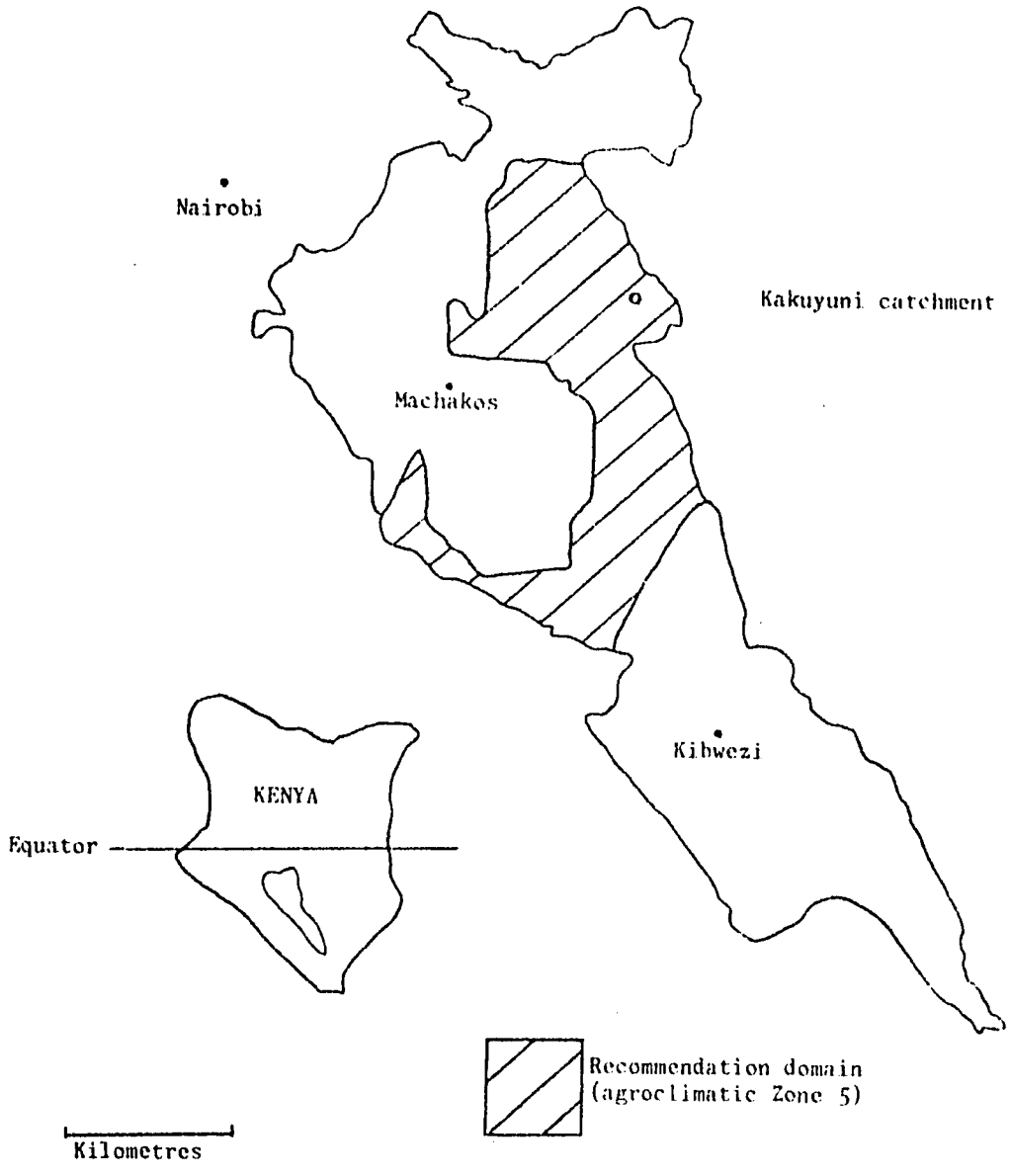

Figure 1. Location of the research site and recommendation domain in Machakos District, Kenya

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3.3 Climate

The main climatic parameters for the target area, derived from climate maps and formulas published by Woodhead (1968) and the Kenya Meteorological Department, are presented in a climate diagram (Fig. 2).

It can be seen that optimal water requirements (E_T), on average, are only met in November, while the lower limit of normal plant water needs (0.4 Eo) is exceeded by precipitation in April, November and December only.

These already unfavourable climatic conditions are further aggravated by the variation in rainfall from one season and one year to the next (see Table 1).

Table 1. Seasonal rainfall probability for the project site (Jätzold, 1979).

	Percent probability of receiving more than:				
	100 mm	150 mm	200 mm	250 mm	300 mm
March-May (Mean 195 mm)	75%	54%	38%	23%	15%
October-November (Mean 305 mm)	96%	90%	74%	58%	39%

The projected onset and cessation of the rains in the project area are as follows:

	Onset	Cessation	Duration
"Long rains"	12-16 March	1-5 May	50 days
"Short rains"	18-22 October	22-26 December	60 days

This shows that the names "long rains" and "short rains" are somewhat misleading in the survey area, as the rainy period October-December is longer than the season March-May. Furthermore the rainfall quantity is higher and the probability of receiving a certain amount tends to be greater; therefore one can conclude that the rainy season October-December poses less risk to cropping activities.

3.4 Woody vegetation

The dominant tree/shrub vegetation in the area is comprised mainly of *Combretum molle*, *Acacia abyssinica*, *Balanites aegyptiaca* and *Terminalia brownii*. While these species are mainly found on the red clay soils, *Acacia drepanolobium* is common on the black clay soils.

3.5 Service infrastructure

Marketing of agricultural produce, mainly maize and beans, takes place through middlemen (shopkeepers), who in turn sell to the National Cereal and Produce Board as well to private traders from elsewhere. There is one market day each week in nearby Kitangi market. Although there is some form of price control, the farm gate price received by the farmer is often lower. The Kenya Farmers' Association sells agricultural inputs, such as seeds, chemicals, artificial fertilizers and livestock feed in its store in Machakos town (40 km). Very little is available locally, although the Machakos Integrated Development Programme is making an effort to improve this situation.

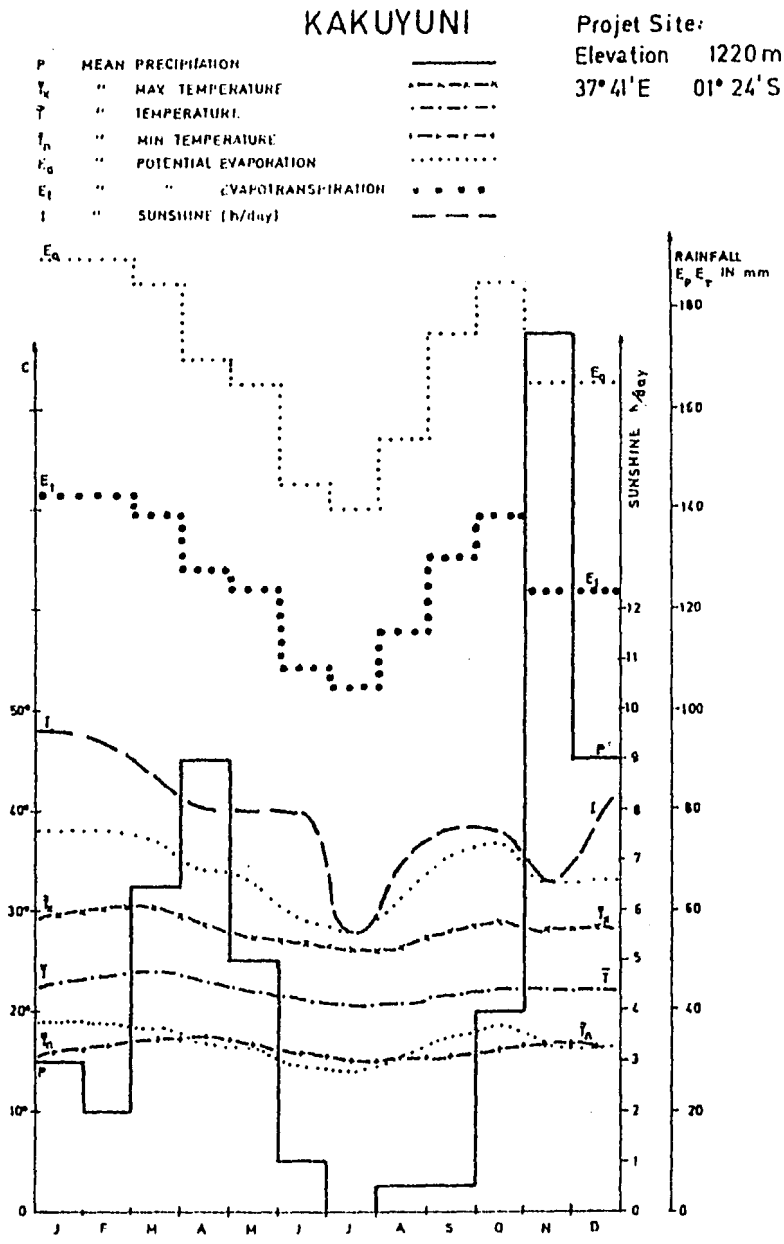

Figure 2. Climate diagram for the Kakuyuni area.

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The government provides agriculture and livestock extension service, mostly at the location level, where a farmer may go to seek advice. Credit for small subsistence farmers is hardly available.

3.6 Population and land use

The majority of the population in Machakos District are Akamba people who have gradually shifted their emphasis from cattle grazing to arable cropping over the past fifty years.

Because of the rather unfavourable climatic conditions in zone 5, people moved into these areas only fairly recently mainly because of a population increase in the higher potential zones. The Kakuyuni catchment area is no exception to this pattern since farmers started settling in only as late as the 1950's. Until now no land has been officially adjudicated to invididual farmers in the area, although adjudication has been completed in some other parts of Machakos District.

Population density in Kinyatta Location, of which the Kakuyuni catchment area is a part, is 65 persons/km^2 (1979 census). This confirms the fact that the catchment is representative of the more densily populated areas of agroclimatic zone 5, where the overall population density is 47/km^2.

According to a recent aerial survey (Ecosystems Ltd., 1981), land use in Kinyatta location is as follows: 9,975 hectares are classified as cropland, 965 hectares as fallow, 5,065 hectares as infrastructural overhead, while the remaining 29,604 hectares can be used for grazing. Most of the area which is suitable for grazing is unimproved bushland in which the farmers invest very little labour. The fact that so much of the area is still in this condition does suggest that, given the present method of agriculture, labour is a constraining factor.

The livestock population, according to the same source, was estimated at 12,326 heads of cattle and 8,207 shoats. Based on herd composition data from the area, a stocking rate of about 0.4 A.U. $hectare^{-1}$ of grazing land was computed. This appears to be well above the stocking rates recommended by Rossiter and Ndegwa (1974), i.e. 0.16 A.U.

The main crops grown by the farmers are maize, cowpeas, beans and pigeon peas. The most common trees/shrubs and their uses are shown in Table 2.

Table 2. Most common indigenous trees and shrubs and their uses as observed in the Kakuyuni catchment area.

Name			Uses						
Botanical	Family	Location	Fuelwood	Building Material	Craft Wood	Fodder	Food	Fencing	Medicinal and other purposes
Acacia abyssinica	Mimosaceae	G	X	X	X	X		X	
Acacia drepanolobium	Mimosaceae	B	X					X	
Acacia tortilis	Mimosaceae	G	X	X		X			
Balanites aegyptiaca	Balanitaceae	G, A&B	X	X	X	X	Fruits	X	
Cassia singueana	Caesalpiniaceae	G & A	X						Stomach-ache, leaves also used for banana ripening
Combretum molle	Combretaceae	G	X	X	X	X			
Commiphora africana	Burseraceae	G & A						X	Prevention of infection on open wounds
Croton megalocarpus	Euphorbiaceae	G & A	X	X					
Grewia tenbensis	Tiliaceae	G	X	X		X	X		
Harrisonia abyssinica	Simaroubaceae	G	X			X			Stomach-ache and diarrhoea
Hymenodictyon parvifolium	Rubiaceae	G	X						
Ipomea spathulata	Convolulaceae	G							
Kigelia aethiopica	Bignoniaceae	G & A					Brew		
Lannea schweinfurthii	Anacardiaceae	G	X	X					
Maytenus putterlickodes	Celastraceae	G	X			X		X	Rheumatism
Ormocarpum kirkii	Papilionaceae	G & A	X			X			Wounds
Pappea capensis	Sapindaceae	G	X	X		X			Treatment of bruises
Rhus tenuinervis	Anacardiaceae	G & A	X	X		X	X	X	Stomach-ache & diarrh. measles.
Securinega virosa	Euphorbiaceae	G	X			X			Tonsillitis
Terminalia brownii	Combretaceae	G & A	X	X	X	X			
Thespesia danis	Malvaceae	G	X	X			X		

G Grazing area
A Arable land
B Black Cotton soil

3.7 Distribution of farm resources

The distribution of the farm size in the Kakuyuni catchment area varied from 3 to 17 hectares, as shown in the following histogram.

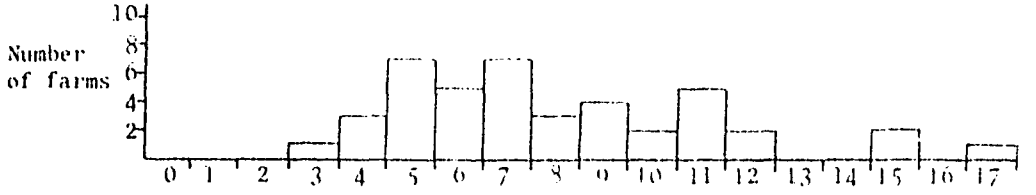

Figure 3. Farm size distribution in Kakuyuni catchment (hectares)

All farms were of a mixed enterprise composition, i.e. crops as well as livestock (cattle and shoats). The distribution of the livestock population over the farms is presented in the following histogram.

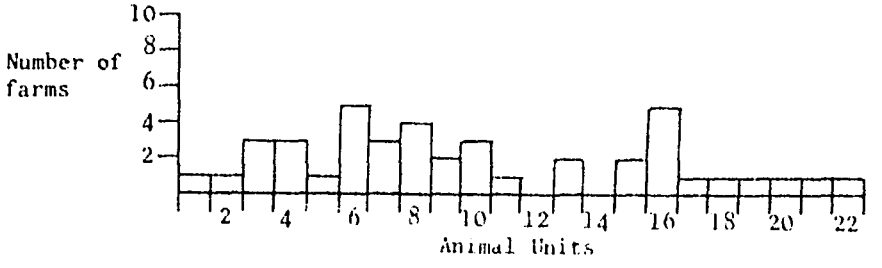

Figure 4. Livestock distribution on farms in Kakuyuni catchment.

A regression analysis of the farm size data indicate that the crop acreage increases with farm size. According to a survey in nearby Mwala Location, Machakos District, this is caused by the fact that most farmers want to reserve part of their land for grazing (Rukandema, 1981).

$Y = 0.15 + 53x$ ($r = 0.91$, $n = 43$) in which y = acreage of cropland (in hectares), x = farm size (in hectares), r = correlation coefficient, n = number of observations.

It is doubtful, however, that this straight line would continue once the crop acreage has reached a certain size, since it is exptected that labour and/or draught animal power would become constraining factors.

Although on average the larger farms were found to keep slightly more livestock units than the smaller farms, no clear relation could be found between farm grazing area and number of livestock units. This may be explained by the fact that most smaller farms rent additional grazing land during the latter part of the main dry season (August-October).

The grazing area of the farm is not only a source of food for the animals, but it is also the farmer's main source of fuelwood, poles and timber.

Most farmers rely entirely on family labour to produce their crops and to tend their livestock. The average farm family consists of two adults and a varying number of children who assist on a part-time basis.

The farm's capital resources are limited to land, livestock, buildings and ox-plough(s).

4. DIAGNOSIS OF FARMING SYSTEMS

4.1 Present resource utilization patterns and problems

4.1.1 Cropping activities

The cropland is cultivated on a permanent basis and is usually planted twice a year, following the bimodal rainfall pattern, with a mixture of maize, beans, cowpeas and pigeon peas.

Land preparation takes place at the onset of the rains and most farmers use oxen. Farmyard manure is applied to part of the cropland, usually prior to the start of the short rains (October-November). Due to lack of appropriate means of transport, most of the manure is applied on the cropland nearest the cattle coral (boma). The soil nutrient status and organic matter content of the remaining cropland is, therefore, rather low.

The most common planting practice involves a simultaneous ploughing/planting operation. One person follows behind the plough and puts the seeds in the furrow and each plough line covers the seeds of the previous furrow with soil. Intercropping, in-row as well as in alternating rows, is the rule.

Owing to the rather short duration of the rainy seasons, planting time is critical and ploughing has to be completed as early as possible. The larger farmers, who like to cultivate as much area as possible to raise cash, are usually faced with a labour and draught animal constraint. A few may be able to hire some additional labour, but most rely on family labour. Moreover, at field preparation/planting time, when fodder resources for the animals are at their lowest, work performance of the oxen is rather poor. The smaller farmers have similar problems with their oxen and some also seem to have labour problems because they hire themselves out to larger farmers to earn some extra cash for household expenses.

The labour constraint is further compounded by the fact that the first weeding has to take place one to two weeks after planting. In practice, planting and weeding often take place simulteneously.

Rukandema (1981), calculated monthly labour requirements for an average farm in Mwala, i.e. 7.47 hectares with 1.95 hectares cropped twice a year. The following labour profile is based on these data (Fig. 5).

Because of the labour constraints at planting time, weeding is often not done properly, resulting in moisture stress for the agricultural crops as well as an increase in the weed population. The latter is particularly evident on the larger farms, where couch grass (*Digitaria scalarium*) has infested parts of the cropland. Eventually farmers abandon such areas and open new cropland within the grazing land to compensate for the lost land. However, the couch grass is not suppresed during grazing and the land is therefore permanently lost for cropping if no measures are taken to remove it.

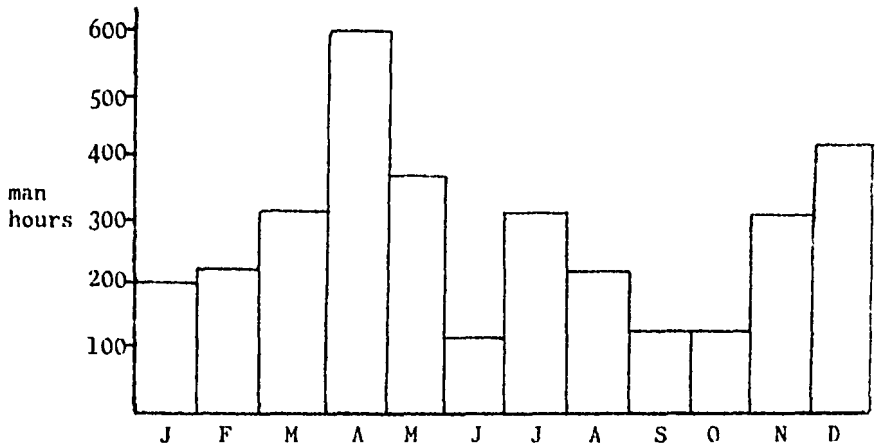

Figure 5. Labour profile of cropping activities on a typical farm in Mwala Location, Machakos District. Source: Rukandema (1981).

In spite of the widespread concern over insect and other pest problems, the overwhelming majority of farmers do not take any measures to protect their crops. Insect damage is therefore quite high for maize, pigeon peas and cowpeas. Some of the early sown maize is often eaten by squirrels.

Harvesting is a labour-intensive hand operation for all crops. Transport of produce from field to home is normally done by head/shoulder loads and sometimes with ox-cart or wheel-barrow. After harvest, most farmers allow their livestock to browse crop residues in the field, especially pigeon pea leaves. Some crop residues, mostly maize stover, are collected and used as supplementary feed in the boma, especially at the end of the dry season when the quality of the grazing is almost nil. The removal of such crop residues is considered beneficial from a field sanitation point of view; it also leads to a further reduction in the organic matter content of the soil. Wind erosion occurs during the months of August, September and October, when most fields are harvested and bare, at the same time strong winds are common.

Crop produce is stored in simple storage structures, ranging in quality from grass-thatched to more sophisticated tin roofed structures. After drying, maize is usually stored on the cob while the other crops are mostly threshed after drying and then put into gourds. Ashes are used frquently to combat insect problems during the storage period.

Due to limited land resources and some of the outlined production constraints, the smaller farmers are usually unable to provide sufficient food for the family.

All small farmers interviewed reported food shortages during the period September to February because of insufficient cropland acreages combined with usually poor harvests from the long rains crop (March, April). On average KShs. 400-500 month^{-1} was reportedly spent to purchase additional food for the family during that period (see food profile, Figure 6.).

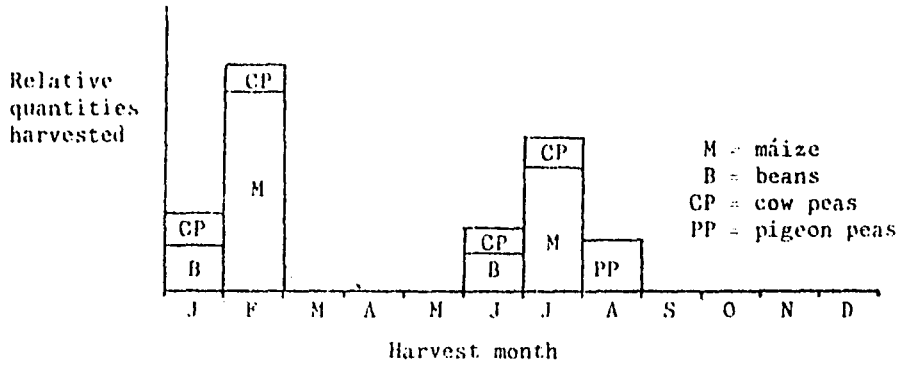

Figure 6. Food production profile, Kakuyuni

The larger farms are by and large self-sufficient in their food requirements and sell part of the surplus produce to raise cash. Food shortages do occur, however, in years with poor rainfall.

4.1.2. Grazing land/livestock activities

Cattle are of small East African Zebu type which are used to provide draught power (bullocks only) and milk and are sold to meet big cash expenses. Sheep and goats are mainly kept for sale and home consumption; some farmers also consume goat milk.

Due to the poor vegetation cover in the grazing land and over-stocking on most farms, there usually is a feed shortage towards the end of the dry season. Some farmers, usually the smaller ones, rent additional grazing land at KShs. 500-700 for a period of 2 to 3 months. These expenses are met by selling animals. Because of overstocking, significant portions of the grazing area are badly eroded.

Over the past years, smaller farmers have seen a decline in their grazing land area because it was given over to food production, most likely because of an increased demand for food by growing families and little scope for off-farm employment.

The labour requirements for herding the cattle are quite high since cattle have to be prevented from entering the crop areas (inadequate or no fencing). During the dry season, drinking water for livestock becomes very scarce in the area and farmers have to herd their animals to the Athi River (approximately 7 km) every other day.

Tick-borne diseases, like East Coast Fever, anaplasmosis, heart water and Nairobi sheep disease, as well as pneumonia coccidoisis and anthrax, were reported for the Yatta Plateau (Neunhäuser *et al.*, 1983).

While labour is used for crop and livestock activities, it is also used to collect fuelwood, to keep bees, to engage in wood carving, to make charcoal, or to engage in off-farm employment. Most firewood is obtained from the grazing land but the annual increment from the existing vegetation is very low i.e. 1-2 m^3 hectare $^{-1}$ (KREMU 1981). Since part

of this annual increment is used for fencing purposes, the actual fuelwood off-take may even be lower.

Consumption of fuelwood is estimated at between 1 to 2 m^3 $capita^{-1}$ and although it is doubtful that consumption is a linear function of the family size, it is not difficult to see that most farms can only meet their requirements by consuming the standing volume and/or "borrowing" from friends and neighbours. The small farmers in particular, spend a considerable amount of time (labour) collecting fuelwood from neighbouring places. This shortage of fuelwood on the small farms may be further compounded because of the anticipated expansion of the crop areas. This may lead, in turn, to an increasing amount of labour being spent on this activity if no appropriate measures are taken.

4.1.3 Cash constraints

Because of the uneven inflow of cash, farmers usually experience serious cash shortages during the growing periods of the crops. At the same time the total amount of cash is usually insufficient to meet the farmer's basic needs, let alone improve his production resources (for example fencing).

While relatively little cash is spent on the purchase of agricultural inputs (aside from the rental of additional grazing land by the smaller farms), considerable amounts of cash are spent on additional food (especially on the smaller farms), clothing, children's school fees and maintenance and/or improvement of buildings. In this respect, it is worth mentioning that dwellings are often damaged by strong winds during August-September.

Owing to the rapidly dwindling tree resources on the farms in the area, farmers who engage in charcoal making or wood carving have to purchase trees, thus increasing the cash outflow.

4.1.4 Summary of present problems and constraints

The relationship between the identified problems in both the smaller and the larger farms are presented in causal diagrams (Figs. 7 and 8).

Both farming systems suffer from a very low level of productivity in crop as well as the livestock activities. The causes for these low production levels are basically the same for both farm types except, perhaps, that the shortage of labour contributes more to the low level of productivity on the larger farms than on the smaller farms, while the lack of land resources at the present moment is only affecting the production of the smaller farms.

4.2 Future farming systems and sustainability problems

The present conversion of grazing areas into cropland on the smaller farm is expected to erode even further the production base for livestock, firewood, timber and poles. Because of the apparent preference for crop activities, it is very likely that the grazing areas on the small farm will gradually disappear, forcing the farmers to abandon livestock altogether or reduce their number and adopt a new feeding strategy (cut and carry), since herding tends to become too labour-intensive per livestock unit when the herd size decreases.

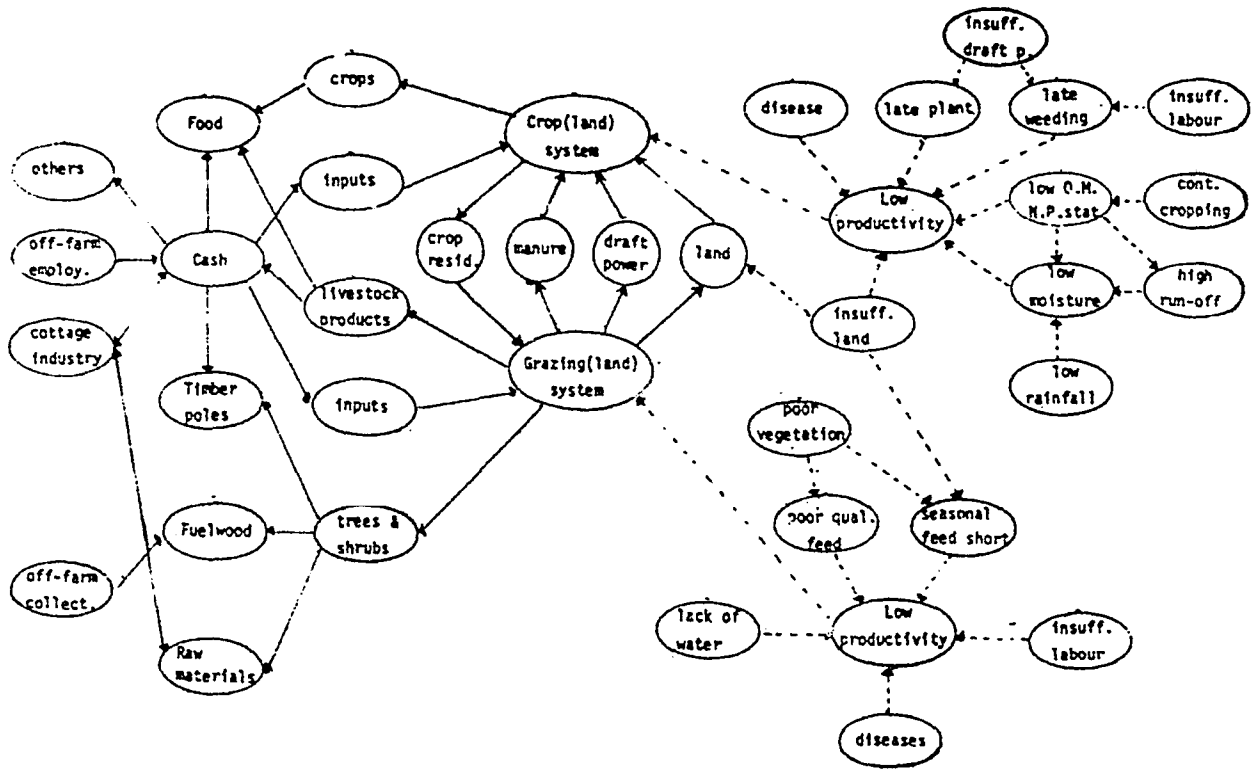

Figure 7. Combined input-output and causal factors diagram (small farms). Unbroken lines (———) indicate the flow of inputs and outputs within the farming system. Broken lines (- - -) indicate the chain of causal influences responsible for diagnosed problems.

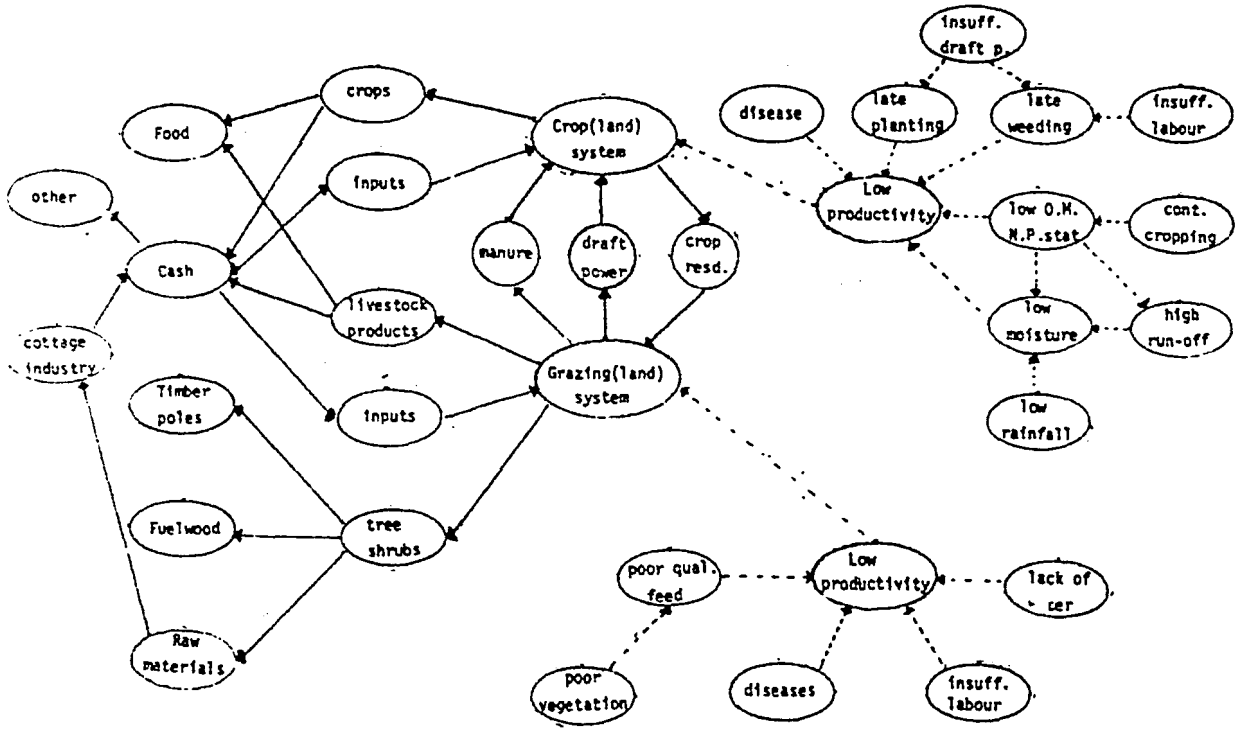

Figure 8. Combined input-output and causal factors diagram (large farms). Unbroken lines (———) indicate the flow of inputs and outputs within the farming system. Broken lines (- - -) indicate the chain of causal influences responsible for diagnosed problems.

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Such a reduction in livestock numbers may have various effects on the farming systems as can be seen in the causal diagram.

Effects on the crop production system:

loss of manure
loss of draught power

Effects on the food system:

loss of part of the food supply (livestock products)

Effects on the cash system:

loss of part of the cash income and/or loss of saving function

The scope for conversion of grazing land into crop land seems to be limited on the large farms due to a lack of labour and draught animal power. It seems, therefore, realistic to assume that the large farms in the medium term will still have grazing areas as well as be engaged in livestock activities.

These trends as well as the other identified factors affecting the sustainability and productivity of the production systems will have to be addressed when designing appropriate agroforestry research.

5. APPROPRIATE TECHNOLOGIES

5.1 Design specifications

The following set of specifications for design of appropriate technological interventions are derived from the diagnosis of farming system problems and potentials. The specifications are expressed in terms of *functional specifications* (i.e. the general type of improvement and the specific constraints to be addressed by the intervention) and relevant *farm resource restrictions* (i.e. the limits within which the design must be conceived in order to fit the system).

5.1.1 Functional design specifications

Improve productivity of the crop production system

i) Maintain or improve soil organic matter
ii) Improve soil nutrient status
iii) Reduce erosion and water run off
iv) Remove labour bottlenecks at field preparation and weeding time
v) Improve pest and disease management

Improve productivity of the livestock production system

i) Improve quantity and quality of fodder
ii) Improve seasonal distribution of fodder
iii) Improve drinking water availability
iv) Reduce labour requirements of feeding
v) Improve veterinary service

Improve cash balance of the farm

i) Decrease (future) cash outflow
- reduce need to buy food
- reduce need to buy building materials
- reduce need to buy raw materials for on-farm cottage industries
- reduce need to buy agricultural inputs

ii) Increase cash inflow
- improve productivity of crop and livestock production
- improve raw materials supply for on-farm cottage industries

iii) Improve seasonal distribution of cash

5.1.2 Farm resource restrictions

Large farms

i) Ample land resources
ii) Insufficient labour resources
iii) Low level of capital

Small farms

i) Insufficient land resources
- no grazing areas on some farms

ii) Insufficient labour resources
- part time engaged in off-farm activities

iii) Low level of capital

- no draught animal power on some farms

5.2 Non-agroforestry alternatives

Improving the service infrastructure as well as creating off-farm employment opportunities were not explicitly mentioned in the design specifications but there should not be any doubt that these areas need attention in order to raise the general standard of living of the farmers.

Some of the previously mentioned design specifications are also difficult to achieve by means of agroforestry, e.g. improve crop pest and disease management, reduce storage losses, improve drinking water availability for livestock, improve veterinary services.

The Kenyan institutions responsible for project implementation are, in fact, already pursuing some of these objectives with non-agroforestry technologies, e.g. improve storage facility structures, construct dams to collect and store water, etc.

All the other design specifications may be accomplished with agroforestry as well as non-agroforestry technology. In some cases these may be mutually exclusive while others may complement each other.

It is difficult, however, to say at this stage whether the agroforestry alternatives are superior to the non-agroforestry alternatives. The results of the non-agroforestry experiments/developments at present being conducted by the implementing institutions should therefore be carefully compared with the results of the agroforestry experiments. Some of the non-agroforestry experiments/demonstrations are: use of artificial fertilizers and crop rotation to improve/restore soil fertility, soil conservation works, etc.

5.3 Agroforestry Technologies

5.3.1 Hedgerows with or without an upper storey of fuelwood or fruit trees in the cropland ('alley cropping')

The main purpose of the hedgerows would be to improve the productivity of the crop production system which, in turn, would reduce the cash outflow

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from the smaller farms while the cash inflow of the larger farmers would be increased.

Lopping the hedges, 15 cm above ground, would take place twice a year, two to three weeks before land preparation and planting. The branches would be spread in the alleys in between the hedges and the woody components would be removed just before ploughing and to be used as fuelwood (in a similar way as the traditional pigeon pea stems). The remaining, already decomposing, leaves and small twigs would be ploughed into the soil.

Such a system aims at improving the soil nutrient status, maintaining soil organic matter, controlling erosion (by reduced runoff) and making better use of land, labour and draft animal resources.

An *ex ante* economic analysis of such a land use system was conducted (Hoekstra, 1983) on the following assumptions:

i) between-row spacing is 2 meters
ii) row width 1 meter
iii) production starts after about 18 months (after transplanting)
iv) total dry matter production m^{-1} $year^{-1}$ is 0.9 kg.
v) 60% of the dry matter is leafy mulch and 40% woody stems
vi) organic N in the leafy material in 3.75 percent
vii) a mixture of maize and beans is grown in the alleys (traditional cropping pattern)
viii) 1 kg of organic N results in 13.5 kg of additional maize, while the bean production remains the same (yield per unit area doubles)

The analysis indicated that the addition of nutrients to the maize and beans in the alley as well as the fuelwood output would result in a better use of the land, labour and draught animal resources as compared to the traditional maize bean mixture:

	Hedgerows	Traditional
N.P.V.* $hectare^{-1}$ $year^{-1}$	1,286	631
N.P.V.* $man\text{-}day^{-1}$	15.2	8.6
N.P.V.* draught $power\ unit^{-1}$	1,459	435

* at 12%

The potential addition of organic matter by the leafy mulch and the roots of both the maize/beans mixture and the hedgerow is estimated at 1,630 kg $hectare^{-1}$ $year^{-1}$, which is computed as follows:

> *above ground biomass production of 2 crops of maize and beans occupying 0.5 hectare is about 6,400 kg $year^{-1}$ (harvest index 0.4), while the above ground biomass of the remaining 0.5 hectare of hedgerows is 4,500 kg $year^{-1}$. The percentage of roots is estimated at 25% of the above ground biomass production while the conversion factor of root dry matter to organic matter is estimated at 0.4, i.e. added organic matter 1,090 kg $hectare^{-1}$ $year^{-1}$. The annual quantity of leafy mulch added to the soil is 2,700 kg and the conversion factor of leafy mulch to dry matter to organic matter is estimated at 0.2, i.e. added organic matter 540 kg $hectare^{-1}$ $year^{-1}$.*

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The loss in organic matter due to cropping depends on the organic matter content of the soil. Assuming a 1% soil organic matter content (common for soils in semi-arid regions under natural conditions) the loss is estimated at 1,500 kg hectare^{-1} year^{-1}, while, if the soil organic matter content has already when lowered, because of cultivation, to about 0.5%, the loss would be 750 kg hectare^{-1} year^{-1}.

The computation of the annual loss is based on the following assumptions: top soil depth 0.2 m, specify gravity soil 1,500 kg/m^3 and a coefficient of decomposition under cultivation (k_c) of 0.05.

It may, therefore, be concluded that the hedgerow system will prevent a future decline in the organic matter status of the soil; however, it is unlikely that it would be able to raise it significantly in the short run.

The following tree/shrub species were identified for the hedgerows:

Leucaena leucocephala, Combretum sp., Erythrina sp., Cassia siamea

The addition of a top storey of fuelwood trees is meant to decrease present and future labour requirements to collect fuelwood or to prevent a future cash outflow. The trees would be coppiced on a regular basis. The following tree species were identified for this purpose:

Azadirachta indica, Jacaranda mimosifolia, Cassia siamea

The addition of a top storey of fruit trees aims at increasing the farm's cash inflow as well as to improve the seasonal distribution of cash.

The following tree species were identified for this purpose:

Carica papaya (pawpaw), Zizyphus mauritiana (Bertree)

5.3.2 Rehabilitation of useful tree species in the grazing land

The purpose of managing existing woody vegetation in the grazing land is to improve the quantity and quality of fodder and woodfuel (firewood and charcoal) produced on this part of the farm. Useful trees are present in most grazing areas but their productivity is limited by browsing pressure on the smaller trees and poor infiltration of rain water.

Improved management practices would include:

i) construction of individual microcatchments for each tree to be treated

ii) protection of small trees against browsing by livestock by appropriate fencing practices (e.g. cut thorn bushes around trees)

iii) thinning and/or prunning of tree shoots and branches and propping up to encourage vertical growth beyond browsing height (for eventual management by lopping or, in the case of pod-producing trees, simply letting the pods drop to the ground)

The local tree species identified for this treatment are:

Acacia tortilis, Balanites aegyptiaca, Commiphora africana, and *Terminalia brownii*

5.3.3 Fodder/browse trees in the grazing land

The purpose of these trees would be to improve the quantity, quality and the seasonal distribution of fodder on the farm. This, in turn, will increase the farmer's cash income.

This system is more appropriate for the larger than for the smaller farms, since the latter may only have very small grazing areas left (see 5.3.4 for small farm design).

Establishment of the trees will be a major problem because of the existing free grazing system. Trees will therefore require protection in the initial years. Making use of the existing thorny bush vegetation may be considered, i.e. heaping dead thorn bushes around the seedlings, or planting the seedlings within the area covered by thornbush.

Pod-producing trees with a fairly light canopy to allow grass or shrub growth underneath should be given priority.

The following species were identified:

Prosopis pallida, Acacia albida, Zizyphus sp., Balanites aegyptiaca

5.3.4 Cut and carry fodder systems in the grazing land or farm boundaries with or without an upper storey of fuelwood, timber, poles and/or craftwood trees

The purpose of such system is also to improve quantity and quality as well as seasonal distribution of fodder, especially on the smaller farms. Such a system will also contribute to lowering the labour inputs required per A.U. as compared to the existing practice of herding a small number of animals.

Tree species identified for this purpose are:

Prosopis pallida, Leucaena leucocephala, Acacia saligna, Stylosanthes scabra

The addition of an upper storey of fuelwood trees serves a similar purpose as in the hedgerow system explained earlier (see 5.3.1).

The addition of an upper storey of timber/pole trees and/or craftwood trees aims at reducing (future) cash expenditures for building materials and on-farm cottage industries.

The following species were identified for these purposes:

Craftwood: *Brachyleana hutchinsii, Dalbergia melanoxylon*
Timber/poles: *Terminalea brownii, Casuorina equisetifolia, Agave(sisal)*

5.3.5 Living fences around the grazing land with or without an upper storey of fuelwood trees

The purpose of this fence is to reduce the labour input requirements of the free grazing system on the larger farms as well as to reduce the need for cash expenditures on fencing materials.

Two species were identified for this purpose:

Parkinsonia aculeata, Commiphora africana

The addition of an upper storey of fuelwood trees serves a similar purpose as in the hedgerow systems (see 5.3.1).

5.3.6 Windbreak around the home compound

The purpose of this system is, in the first instance, to protect the buildings inside the home compound from damage by wind and so reduce the need for cash expenditure. The use of fruit trees for this purpose would help to increase the farm's cash inflow as well as the seasonal distribution of the inflow.

Mangifera indica is proposed for this purpose.

A hedgerow with some of the previously identified species may be added as an understorey.

5.3.7 Fruit trees in the home compound

These trees would provide the necessary shade and improve the cash inflow as well as its seasonal distribution.

Mangifera indica is proposed for this purpose.

6. RESEARCH PROGRAMME

6.1 On-farm versus on-station research

Five factors were considered to determine whether research on these candidate technologies should be carried out on farm and/or on station.

Readiness of proposed technology:

The principles of living fences and boundary planting are more or less known in the area, however tree planting in the grazing land to provide animal fodder, the hedgerow system in the cropland and the windbreak around the homestead are relatively unknown to the farmers, although some are known in other parts of Kenya. The proposed tree species and management practices are not well known nor tested in the area, perhaps with the exception of the mango trees proposed for the windbreak and the home compound.

Farmers/extension officers attitude towards on farm trials:

M.I.D.P. in its program in the Kakuyuni catchment started introducing some trees. Farmers appear to be very keen to plant trees, often even without knowing their useful purposes, with the possible exception of tree planting in the cropland itself.

Riskiness of the proposed technology:

The positive effects as well as the feasibility of establishing a hedgerow system in the cropland are still relatively uncertain, while at the same time the introduction of these hedgerows may result in a reduction of the arable land and therefore in the production of basic food crops. The risks imposed by the other candidate technologies are considerably lower since the opportunity cost of the land used (production forgone) is low. Care should be taken, however, with regard to the introduction of trees in the grazing areas which may have the potential of becoming a weed (*Prosopis, Leucaena?*).

Need for the candidate agroforestry technology to be exposed to different environmental conditions:

Because the recommendation domain for the proposed candidate agroforestry technologies is limited to part of agroclimatic zone 5, some of the differences in rainfall conditions have been eliminated, reducing the need to test the technologies at many different sites. However soil conditions in this zone differ considerably, requiring the testing of the technologies

on different sites. The soil types found in the project area offer this opportunity.

Need for the candidate technology to be exposed to real farming systems conditions:

Due to the absence of free grazing conditions on the Research Station, establishment trials (especially protective measures) in the grazing area and living fence trials have to be conducted on farm. Similarly, windbreak trials have to suit the specific farm conditions and are therefore best conducted on farm. Furthermore, farmer evaluation of all the technologies is essential.

A summary of the weighing of these 5 factors for the candidate agroforestry technologies in the study area is presented below.

Table 3. Weighting of on farm/on station research factors

Technology	Readiness	Attitude	Riskiness	Need for env. Exposure	Need for farm sys exp
3.1	L	L	H	M	H
3.2	L-M	H	M	M	H
3.3	L-M	H	L	M	H
3.4	M	H	L	M	H
3.5	M	H	L	L-M	H
3.6	M	H	L	L-M	M

L = Low M = Medium H = High

Based on a simultaneous weighing of these factors it is recommended to conduct simultaneous on farm/on station research for the following technologies 5.3.3. - 5.3.5 sequential on station/on farm research for 5.3.1 and on farm research only for 5.3.2, 5.3.6 and 5.3.7 (see also section 6.2)

6.2 Research required on candidate agroforestry technologies

6.2.1 Hedgerows in the cropland

Purpose: see 5.3.1

Variable factors

a) species
b) establishment methods
c) spacing in and between rows
d) cutting height and frequency
e) rate of application of mulch
f) time of application

Parameters to be monitored

a) labour inputs for establishment, maintenance and harvesting
b) survival rates and growth
c) yield of mulch
d) resistance to termites
e) rate of decomposition
f) nutrient content of mulch
g) soil nutrient status and moisture balance
h) erosion
i) weed development (including labour requirements)
k) crop yields

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The addition of an upper storey will add the following variable factors:

a) species
b) in-row spacing
c) harvesting frequency and method

As a result, the following additional parameters have to be measured:

a) labour inputs, establishment, maintenance and harvesting
b) yield (including fruiting season for fruit trees)
c) yield adjacent crops

Type of research

On-station

Species selection (elimination, survival/vigor, phenology) establishment methods and management prectices required in the first years of this land use system. Suitability of species will not only depend on growth performance in general but also on the suitability of the leafy components to improve soil nutrient status, water holding capacity and O.M. status of the soil. To analyse these aspects a series of independent mulching trials will be carried out, using different tree leaves. Such experiments will have to be complemented by soil and leaf analyfis. This on-station research will continue over the entire life of the project.

On-farm

Testing of some of the best species and establishment methods developed on station in the previous year of the project (researcher managed, inputs and evaluation jointly by farmers and researchers).

6.2.2 Rehabilitation of useful trees in the grazing land

Purpose: see 5.3.2

Variable factors

a) species
b) protection methods (block vs. individual trees)

Parameters to be monitored

a) existing vegetation (for block approach)
b) labour input for fencing, treatment of trees, construction of micro-catchments
c) growth (tree height and ground cover; latter only for block approach)
d) farmers' reaction

Type of research

On farm

Effects of microcatchments, growth form management and on woodfuel and fodder production (researcher managed, inputs and evaluation jointly by farmers and researchers).

6.2.3 Fodder/browse trees in the grazing land

Purpose: see 5.3.3

Variable factors

a) species
b) spacing
c) establishment methods

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Parameters to be monitored

a) labour inputs for establishment, maintenance (harvested by animals)
b) survival rates and growth (termite resistance)
c) fodder yield
d) seasonality fodder production
e) palatability of fodder
f) nutritive value of fodder
g) additional products (fuelwood and nectare production)
h) vegetation growth underneath the trees

Type of research

On-station

Species selection and establishment trials including nutrient analysis and palatability analysis. The screening trials and analysis will take place during the entire project life.

On-farm

Species selection trials and establishment trials simultaneous with on station research during the entire life of the project. Management trials of the 'best bet' species and establishment methods in the last two years of the project (researcher managed, inputs supplied jointly by farmer and researcher).

6.2.4 Cut and carry fodder systems

Purpose: see 5.3.4

Variable factors

a) species
b) establishment methods
c) spacing
d) harvest management

Parameters to be monitored

a) labour inputs for establishment, maintenance and harvesting
b) survival and growth (termite resistance)
c) yield of different products
d) quality fodder, timber, poles or craftwood
e) nectar production

Type of research

On-station, On-farm as in 6.2.3.

6.2.5 Living fences around the grazing land

Purpose: see 5.3.5

Variable factors

a) species
b) establishment methods
c) in-row spacing
d) trimming frequency

Parameters to be monitored

a) labour inputs establishment, maintenance
b) survival rates and growth (termite resistance)
c) additional products (including nectare production)

Type of research

On-station

Species selection and establishment trials

On-farm

Species selection and establishment trials simultaneously with the on-station research. Both research activities will last for the entire project life (researcher managed, inputs and evaluation jointly by farmers and researchers).

The addition of an upper storey may be treated in the same way as the hedgerows in the cropland.

6.2.6 Windbreak around the home compound

Purpose: see 5.3.6

Variable factors

a) variety/cultivars of mango
b) in row spacing
c) tree management

Parameters to be monitored

a) labour inputs for establishment, maintenance
b) survival rates and growth (termite resistance)
c) wind speeds
d) additional products (including nectare production)

Type of research

On-farm only

Selection of variety, in row spacing (researcher managed, inputs and evaluation jointly by farmers and researchers).

6.2.7 Fruit trees in the home compound

Purpose: see 5.3.7

Variable factors

a) variety/cultivar

Parameters to be monitored

a) labour inputs for establishment and maintenance
b) survival rate and growth (termite resistance)
c) additional products (including nectare production)

Type of research

On-farm only

Selection of variety (researcher managed, inputs and evaluation jointly by farmers and researchers).

6.3 Initial experimental designs

The following experimental layouts have been designed for on-station experimentation on the hedgerow/mulch farming system (6.2.1). Other experimental designs are being created as the project progresses.

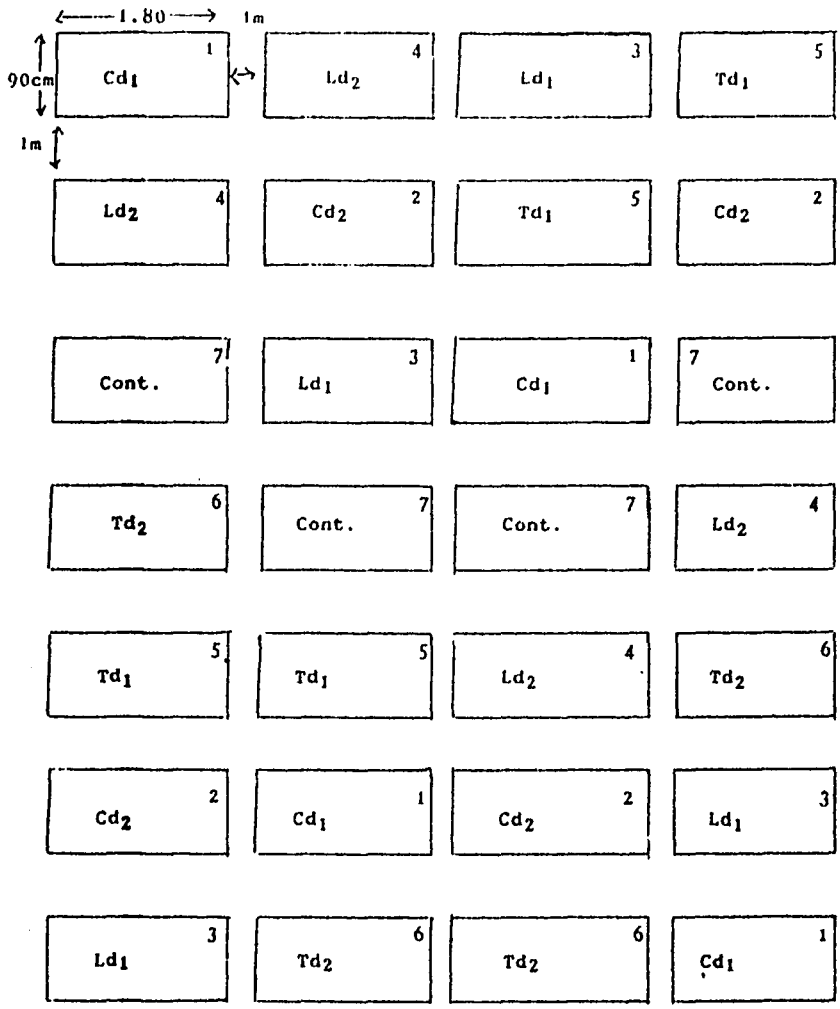

Figure 9. Plot design for maize/mulch-green manure trial.

Treatment Combinations

1. Cd_1 - Cassia siamea @ 1 kg/m^2
2. Cd_2 - Cassia Siamea @ 2 kg/m^2
3. Ld_1 - Leucaena leucocephala @ 1 kg/m^2
4. Ld_2 - Leucaena leucocephala @ 2 kg/m^2
5. Td_1 - Terminalia brownii @ 1 kg/m^2
6. Td_2 - Terminalia brownii @ 1 kg/m^2
7. Cont. - Control (maize only, no mulch applied!)

Total amount of mulch require Leucaena) Cassia) 19.44 kg of each Terminalia) (fresh weight)

Each plot will have 1 row of maize in the centre, in-row spacing = 30 cm (6 plants):

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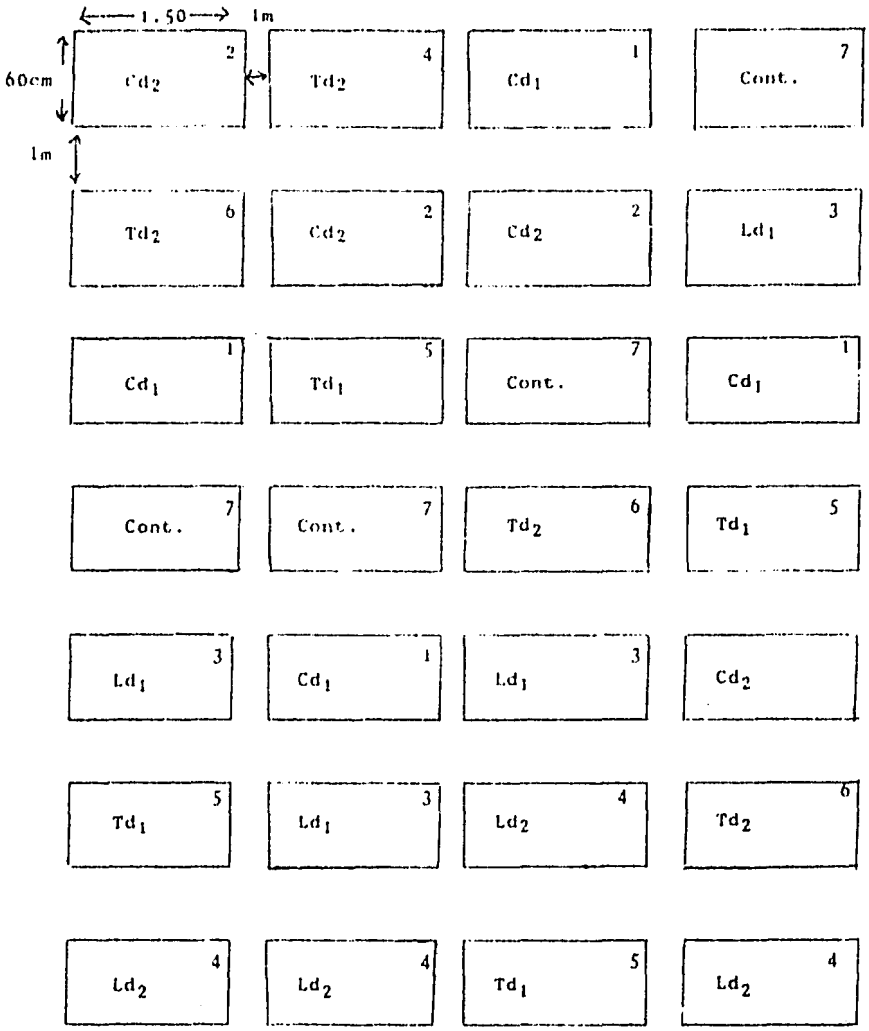

Figure 10. Plot design for beans/mulch-green manure trial.

Treatment Combinations

1. Ld_1 - Leucaena leucocephala @ 1 kg/m^2
2. Ld_2 - Leucaena leucocephala @ 2 kg/m^2
3. Cd_1 - Cassia siamea @ 1 kg/m^2
4. Cd_2 - Cassia siamea @ 2 kg/m^2
5. Td_1 - Terminalia @ 1 kg/m^2
6. Td_2 - Terminalia @ 2 kg/m^2
7. C - Control @

Total amount of mulch required/10.80 kg of each! (fresh weight)
Each plot will have 1 row of beans spaced 15 cm apart (10 plants)

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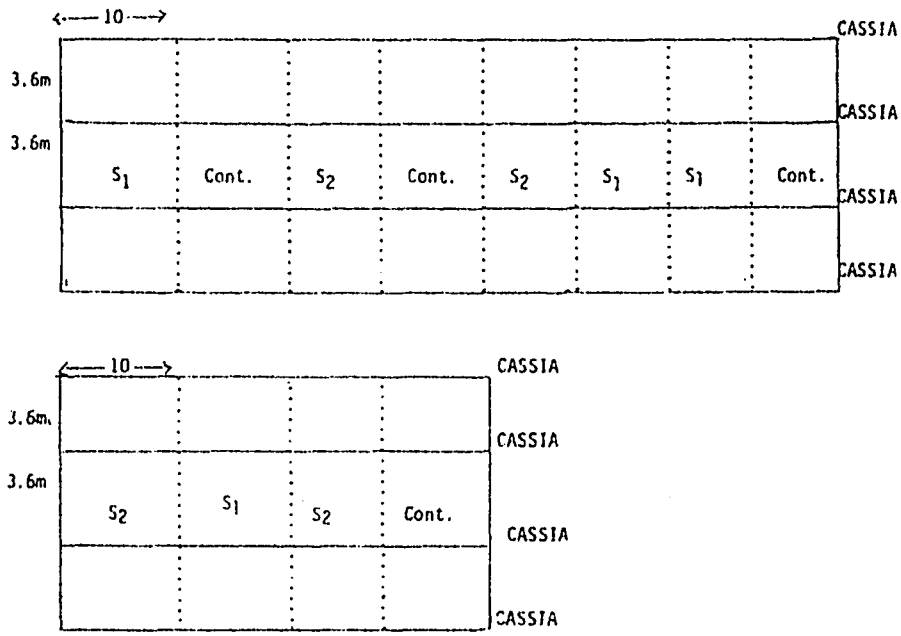

Figure 11. Plot design for hedgerow trial

TREATMENTS

S_1 - Cassia siamea in furrows at 0.25m spacing

S_2 - Cassia siamea in holes at 1m spacing

Cont. (Control) (Maize only)

Three rows of maize are planted between each 2 rows of Cassia (90cm between rows). In the control plots, each cassia row is replaced by a maize.

Note: These experimental plots are designed to provide information only on relative differences between treatments. Experiments with larger plots will be conducted in the second phase of experimentation to obtain yield data on the most promising treatments.

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The Chagga Homegardens: a multistoried agroforestry cropping system on Mt.Kilimanjaro (Northern Tanzania).

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Abstract: The homegardens are characterised by an intensive integration of numerous multipurpose trees and shrubs with food crops and animals, simultaneously on the same unit of land.

The Chagga are skilled farmers with an intimate knowledge of the crops and their ecological requirements. They have a good idea of functions/uses of the plant species on their farms. The large species diversity provides both subsistence and cash crops. It enables the farmer to keep his management options open and provides insurance against drought, pest and economic risks.

Key words: Tanzania, Chagga, agroforestry, homegarden, multipurpose trees, livestock integration, multistoried cropping, land tenure.

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1. Introduction

The Chagga are Bantu speakers descended from immigrants of various tribes who migrated into the once forested foothills of Mt.Kilimanjaro. Then began the process of transforming the native forest. Trees that provided fodder, fuel and fruits were retained while the less useful species were eliminated and replaced with new tree and crop species. This process is still continuing on Mt. Meru - a neighbouring mountain.

Mt.Kilimanjaro is one of the most densely populated areas in Tanzania. This is due largely to the ecological and economic success of the Chagga cropping system. The homegardens enable the farmer to obtain a sustained production with a minimum of external inputs and thus represent a good model of landuse for extrapolation to other areas with similar ecological and socio-economic characteristics.

Although the Chagga homegardens are often cited as an example of model landuse (1,7), the system has not been described in any detail. This paper identifies the major components, describes their interactions and management aspects and presents an evaluation of the system's ecological stability, productivity and sustainability.

2. General Description of the Area

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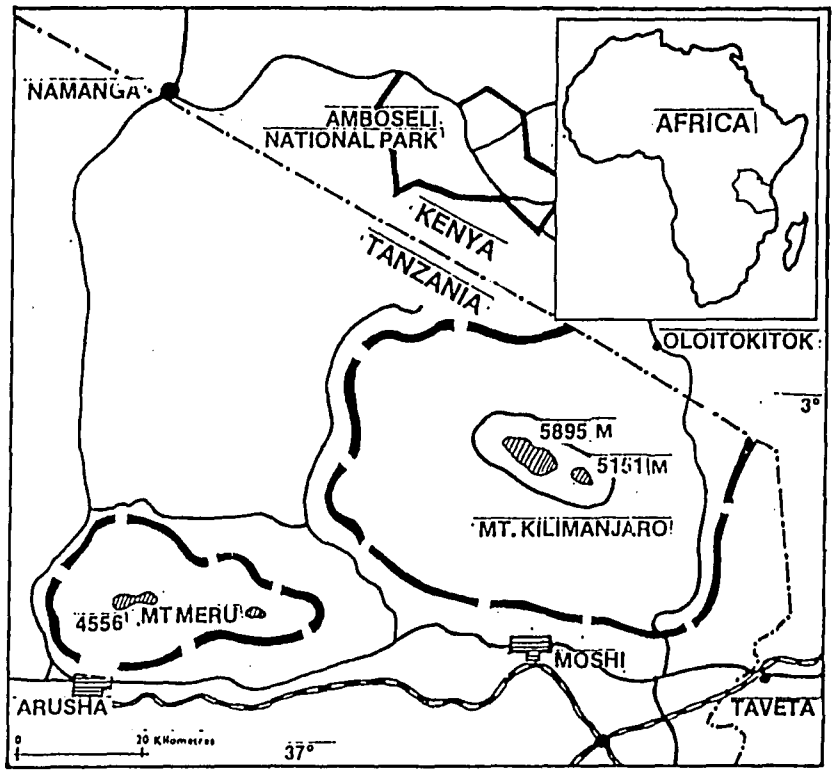

—.—.—.— International boundary

Fig 1. Location of Mt. Kilimanjaro in northern Tanzania

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2.1. Geographic location

The Chagga homegardens are found on Mt.Kilimanjaro in northern Tanzania (2.9-3.3°S,37.0-37.5° N) (Fig.1).The bulk of the mountain covers about 3100 Km^2 and the highest peak is 5895 m.a.s-l. The area above the 1900 m. contour is a designated forest reserve ~~re~~ and national park.

2.2. Biophysical environment

2.2.1. Climate: Mt.Kilimanjaro region has a bimodal rainfall pattern;'short rains' from October to December and 'long rains' from March to May.The average annual rainfall ranges from 1000 to 1700 mm with marked variation depending on elevation,exposure and aspect.Thus,Kilimanjaro gets more rainfall on its southeastern and eastern flanks (where the Chagga homegardens are) than on its northern and western sides which are sheltered from the wet southeast winds.

2.2.2. Soils: There are four major groups (FAO/UNESCO Soil Map of the World - Sheet VI-3):

1. Humic nitosols and associated Humic andosols
2. Chromic cambisols and associated Eutric cambisols
3. Orchric andosols and associated chromic cambisols and vitric andosols
4. Mollic andosols and associated Eutric nitosols

In general, these volcanic soils are fertile with a high base saturation and cation exchange capacity.A major limitation are the steep slopes which prevent mechanization and requires substa-

ntial erosion control work. Other limitations include stoniness or a shallow petrocalcic horizon.

2.2.3. Vegetation: Climax vegetation is montane rainforest. The forest varies in composition and structure along altitudinal and rainfall gradients. On the wetter southeastern slopes, there is a zone of *Ocotea usambarensis* and *Podocarpus usambarensis*. This occurs at an altitude of 1900 to 2400 m.a.s.l. and a rainfall of 1500 to 1800 mm. The drier end of *Ocotea* forest sometimes grades into a forest with much *Cassipourea malosana* associated with *Myrica salicifolia*. At lower altitudes what little remains of the forest is characterised by the following species: *Newtonia buchananii*, *Macaranga kilimandscharica* and *Parinari excelsa*. At around 1200 m.a.s.l. and 1300 mm rainfall, species include *Albizia* spp., *Bombax schumanianum*, *Chlorophora excelsa*, *Diospyros mespiliformis*, *Khaya nyasica*, *Newtonia paucijuga* and *Terminalia kilimandscharica*. In contrast, the drier northwestern slopes (1000 to 2800 m) have *Juniperus procera* as the dominant species in association with *Olea africana* and *Olea welwitschii* and sometimes in pure stands.

2.3. Landuse systems

2.3.1. Agriculture: The southeastern and eastern slopes are characterised by intensive smallholder production of both subsistence and cash crops. Individual homesteads are densely scattered and food crops are grown under the canopies of banana and coffee. In addition, there are state owned coffee estates and farms. The drier northern and western slopes are used mainly for extensive grazing by the Masai.

2.3.2. **Forestry:** Major plantation species are *Cupressus lusitanica* and *Pinus patula* of which there are about 3000 ha in the west and 3500 ha in northeastern Kilimanjaro. The Forestry Department carries out various silvicultural operations in natural forests to encourage natural regeneration or root suckers of *Ocotea usambarensis*, *Podocarpus gracilior*, *Podocarpus milanjianus* and *Juniperus procera*.

2.3.3. **Agroforestry:** The intensive cropping system of the Chagga involves integration of several multipurpose trees and shrubs with food and cash crops and livestock simultaneously on the same unit of land. Within this cropping system several agroforestry practices can be identified. These include the use of multipurpose trees/shrubs :

- to provide shade for coffee
- as live fences
- for fodder and mulch production
- for bee forage
- with anti-pest properties.

A typical homegarden scene is depicted in Fig.2.

3. Structure of the system

The Chagga homegardens ('vihamba') cover about 1200 km^2 (120,000 ha) on the south and east slopes of Mt. Kilimanjaro. Recent estimates indicate that the the south slopes have a population density of 500 km^{-2} and an annual population growth rate of at least 3%. Marketing facilities are fair with Moshi town (Fig.1) being the nearest major market and a good road linking Moshi with Arusha, Tanga and Dar es salaam.

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The homegardens are located mainly between 900-1900 metres above sea level. In addition, each family has another plot ('kishamba') 10 to 16 km away in the drier plains below the southern and eastern slopes. The kishamba has only very few trees and is used mainly for growing annual crops.

3.1. Components of the homegarden

3.1.1. Crops:

3.1.1.1. Food crops: Banana (*Musa* spp.), beans (*Phaseolus vulgaris*), cabbage (*Brassica oleracea*, cow pea (*Vigna unguiculata*), chili (*Capsicum* spp.), egg plant (*Solanum melongena*), maize (*Zea mays*), onion (*Allium cepa*), potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), taro (*Colocassia* spp. and *Xanthosoma* spp.), tomato (*Lycopersicon esculentum*), yam (*Dioscorea* spp.).

3.1.1.2. Cash crops: coffee (*Coffea arabica*), cardamom (*Elettaria cardamomum*). Surplus bananas and other food crops are also sold. Women are responsible for marketing the surplus bananas, vegetables and milk and they keep the proceeds. Men get the money from coffee, poultry and egg sales.

There are at least 15 different types of banana grown on the homegardens. These include cultivars for food, brewing and fodder. In addition to the fruit, the leaves and pseudostems are also used for fodder while the stem sheaths and dried leaves are used as mulch for coffee bushes.

Although a little maize is grown in some homegardens, the bulk of

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the crop is grown intercropped with beans on the lowland kishamba.Finger millet (Eleusine coracana),an important crop used for brewing and making a porridge,is also grown in the lowlands

3.1.2. Trees and shrubs:Chagga farmers deliberately retain and manage numerous species of trees and shrubs on homegardens.Table 1 provides an indication of the species diversity and their uses.The men are responsible for lopping the fuel and fodder trees while the women harvest the fodder grasses and herbs.

3.1.3. Animals:Cattle are kept for milk,while goats and pigs are kept for meat for sale and/or for home consumption.Recently,some farmers have started keeping improved cattle.The more popular breeds are Fresian,Jersey,Ayrshire and crosses involving these and local breeds.Each farmer has an average of 3 cows,2 goats and 6 chickens (6).In some cases a pig is also kept.Livestock are stall-fed with fodder from trees/shrubs,banana plants and grasses grown on the homestead.Supplementary fodder is harvested from the kishamba in the plains or bought at 20 Tshs * a headload (30-50 kg.).

3.1.4. Arrangement/Interaction of components

The spatial arrangement of components is irregular and appears very haphazard with the trees/shrubs and food crops intimately mixed.Vertically,however,several relatively distinct zones can be distinguished.A schematic presentation of the canopy structure is presented in Fig.3. In terms of canopy depth,the lowest zone (0 - 1m) consists of food crops like taro,beans,and fodder herbs and

* 1 US$ = 12.45 Tanzanian shillings (January 1984).

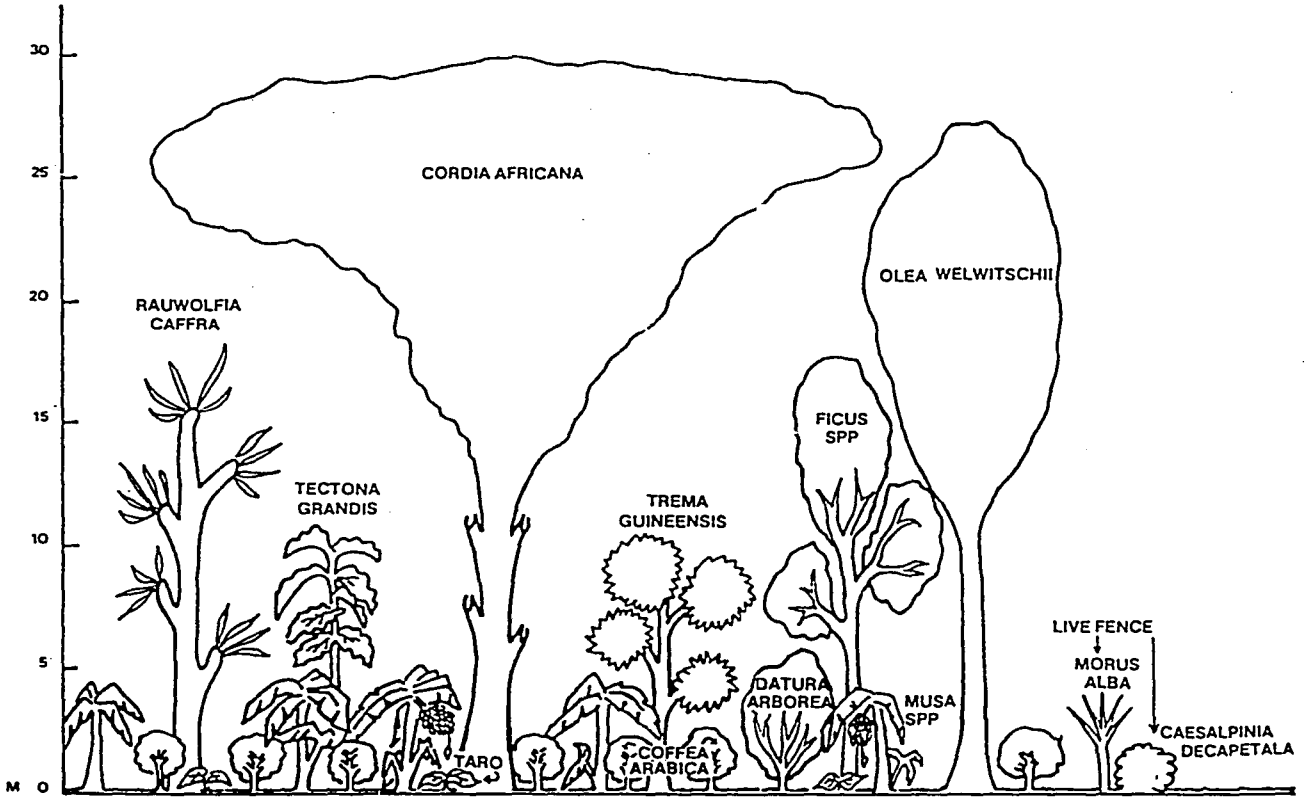

FIGURE 3. TYPICAL VERTICAL ZONATION IN A CHAGGA HOMEGARDEN

grasses. Included in this zone is the regeneration of the overstorey trees/shrubs. The next zone (1 - 2.5m) comprises mainly coffee with a few young trees/shrubs and medicinal plants. Next is the banana canopy (2.5-5m) with some fruit and fodder trees. Above the 'banana' layer, vertical zonation is less distinct with a diffuse zone (5 - 20m) of the preferred fuel and fodder species and another zone (15-30m+) of the valuable timber trees and other fodder and fuelwood species. There is considerable overlap of the stories with continuous recruitment to the various zones.

The intimate arrangement of components results in the interactions between components occurring both in time and space. The nature of interactions varies and can be

- direct, e.g. fodder trees/shrubs and livestock
  tree/shrubs and bees
  cattle manure and crops, tree/shrubs.

- cyclic, e.g. crop residues and cattle

- competitive, e.g. bananas and coffee
  tree/shrubs and crops

No data is available to indicate the magnitude of the direct or cyclic interactions. Trials conducted at the Coffee Reasearch Station, Lyamungu and over a part of the main coffee area on Mt. Kilimanjaro showed that bananas interplanted in either young or mature, lightly shaded or unshaded *Coffea arabica* significantly reduced coffee yields (8). Other trials elsewhere showed that provided farmyard manure was applied to the banana clumps, the yield of bananas planted at 960 stools per ha was not greatly affected

by the presence or absence of interplanted coffee.Reduction of the density of bananas interplanted in coffee from 960 to 480 stools per ha resulted in a lower total banana production,which was partially offset by the higher rate of fruiting and larger bunches from the wider spaced plants (2).This is significant since it is bananas and not coffee that is the primary crop in the Chagga cropping system.

3.1.5. Management aspects

The Chagga have an intimate knowledge of the various crops and plants and their ecological requirements.Management techniques applied today have been continuously refined and tested over the ages and handed down from one generation to the next.Thus,when the farmers think the time is right,they carry out various operations such as opening up the canopy to ensure better fruiting of the coffee,spacing out the banana stools and manuring the different crops.They maintain plant species (e.g.*Datura arborea*,*Rauwolfia caffra*) that repell or eradicate various pests and know the best fodder trees/shrubs and when and how to lop them.

Each homegarden has a network of irrigation/drainage furrows distributed over its area and linked to other homegardens in the vicinity.The farmer is thus able to tap and utilise run off from the forest reserve and other homegardens on the slopes above.

The number of banana clumps and coffee bushes on a homegarden varies not only with altitude and aspect but also with the management capabilities and preferences of the owner.In general,the range of banana clumps per homegarden varies from 200 to 800 (330 to 1200 ha^{-1}) and coffee 300 to 1000 (500 to 1400 ha^{-1}).There are in addition,an average of 39 other trees/shrubs retained and

managed on the homegarden. Shade tolerant crops e.g. taro, yams and beans are intercropped between the coffee and bananas while the more light demanding species are grown in a section of the homegarden over which the canopy has been thinned to minimise shade.

Coffee extension services provide advice on prunning and spraying against coffee berry disease and leaf rust. Most of the coffee trees have a single stem, while each banana clump is maintained with 3 to 5 pseudostems of different ages so as to facilitate a continuous banana harvest.

Most Chagga farmers either plant or encourage any natural regeneration of valuable timber species (see table 1). These young trees in the understorey experience considerable shade and this encourages straight stems with few branches. When appropriate, the overhead canopy is thinned to allow the tree to grow into the upper stories. Fig. 4 shows teak trees growing up through the banana canopy. The trees are allowed to grow to a size approaching 0.6 to 1 m^3 i.e. a rotation of 60 to 80 years. A large tree (about 1 m^3) of Olea welwitschii can fetch a price of 10,000 Tshs. If such a tree is to be felled during the lifetime of the present owner, then he in turn plants one so that the next owner will also inherit a valuable tree.

It is important to note that although the great majority of homegardens are intensively cultivated and well managed, one also encounters some that are neglected, overgrown and sometimes abandoned.

4. System functioning

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4.1 Resource input and utilisation

4.1.1 Quantity and pattern

4.1.1.1 Land: The average size of a homegarden is 0.68 ha with a range of 0.2 to 1.2 ha. Traditionally, the land was divided only between the sons but nowadays daughters can also inherit the homegarden or part of it. Land tenure is based on a strongly held traditional belief that there is a close 'spiritual' link between one's ancestors and the soil (1). Thus, once a member of the immediate family is burried in the homegarden, tenure is assured for the current owner and his descendants and such a homegarden may even be abandoned for several years without the danger of someone else assuming ownership. This is in contrast to the lowland kishamba (allocated by the state and whose size is proportional to family size) where tenure is on an annual and usufructuary basis. If this land is not used for one or two years it may be claimed by another person.

4.1.1.2 Labour: An average household size of 9.9 people provides a workforce of four family members. In the homegardens, planting, tending and harvesting of bananas, taro and yams occurs throughout the year. Coffee harvesting usually starts in August and continues till January. The peak labour period is between January and March (3). This is because coffee harvesting coincides with land preparation and planting of crops both in the homegardens and on the lowland kishamba. In contrast, April to June is a low labour period and preceeds the harvesting of maize, beans and finger millet from the lowlands. In the homegardens all operations are performed by human labour, whereas in the lowland, ploughing may be done by tractor.

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4.1.1.3 Capital: Each farmer has an average of 560 Tshs worth of farm implements (axes, hoes and pangas). Only a few farmers own a tractor. These are leased to others for ploughing the lowland kishamba.

4.1.2 Inputs: Seeds are mostly obtained from prevous crops although it is possible to buy seed from the Tanzania Farmers' Association. Dung from the stall-fed livestock and other household wastes are spread around the banana clumps and coffee bushes. Chemical fertilisers are generally not used. The Kilimanjaro Uremi Cooperation (KUC), a cooperative concerned with the production and marketing of coffee, supplies pesticides free of charge for use against coffee berry disease and leaf rust. In addition, the Chagga use a variety of plant species with anti-pest properties (see table 1). Credit facilities are offered by the KUC and the Tanzania Rural Development Bank (TRDB). The TRDB also offers soft loans for dairy cattle and pig production.

4.1.3. Production:

An average homegarden of 0.68 ha produces about 125 kg of beans (184 kg ha^{-1}), 280 kg of parchment coffee (412 kg ha^{-1}) and 275 bunches of bananas (404 ha^{-1}) annually. In August 1983, Coffee fetched 16.85 Tshs kg^{-1} while the average price of a bunch of bananas was 30 Tshs. The maize harvest from the lowland plot averages 360 kg per year. Almost all the coffee produced is sold, although the poorer quality beans obtained towards the end of the harvest are retained for home consumption. No production data is availale for taro, yams cardamom and onions. Local sources indicate that crop failure involving coffee and/or maize and beans occurs

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once every 3 or 4 years.However,total failure involving in addition,bananas,other fruits,root crops and livestock has never occured.Each farmer keeps between 3 - 5 traditional bee-hives.It is conservatively estimated that each hive produces at least 5 kg of honey per year.Milk production by traditional breeds under stall feeding conditions is low (1-4 litres per day),whereas improved cattle produce between 8 - 16 litres per day.Pigs are fattened up and sold within a period of 6 - 12 months.

It is difficult to estimate the quantity of fodder produced in the homegarden,but most of the Chagga farmers are almost self sufficient in fodder production for their livestock.As outlined in 3.1.3. supplementary fodder is bought if needed.

Fuelwood production in homegardens is estimated to be between 1 - 2 m^3yr^{-1} (1.5-3 m^3 $ha^{-1}yr^{-1}$).If we assume a minimum consumption of 1 m^3 per adult per year,then each family requires between 4 - 6 m^3yr^{-1}.Thus a homegarden supplies 1/4 to 1/3 of the fuelwood requirements.The rest is obtained from the forest reserve or from the kishamba where Acacia spp. and Combretum spp. are retained.

5. System Dynamics

5.1. Rate of growth

There is no more land (outside the forest reserve) on Mt.Kilimanjaro that is suitable for the Chagga homegardens.Thus expansion in terms of increased area occupied by the cropping system is no longer possible on Mt.Kilimanjaro.Instead ,existing homegardens are reaching the limit of intensive use at the present level of management.They are also becoming increasingly fragmented due to sub-division.This land scarcity has led to the migration of some

Chagga to Mt.Meru (70 km southwest of Mt.Kilimanjaro),an area that has ecological conditions similar to those on Mt.Kilimanjaro.Local sources indicate that there has been some inter-marriage between the Chagga and Meru(the indigenous tribe on Mt. Meru) and this has probably been an important factor in enabling the Meru (who were formerly pastoralists).to successfully adopt the complex Chagga homegarden system within a period of about 50 years.

5.2. Sustainability

Although the Chagga cropping system has been stable over at least a century,it is only recently that the system as a whole has come under pressure due to rapid population growth,diminishing land resources and change in dietary habits (maize replacing bananas as the staple food).Migration of youngsters to urban areas leads not only to labour shortages,but also disrupts the traditional transmission, from one generation to the next,of the knowledge and experience required for successful management and perpetuation of the complex multicropping system.In recent years,coffee prices declined markedly on international markets and this combined with the labour intensive nature of the crop, resulted in some Chagga farmers threatening to remove the coffee bushes from their homegardens.Despite these pressures,however,the system still appears to be working well with the majority of farmers. Nevertheless,if the system is to remain sustainable,then its productivity wil have to be increased to cater for the rapidly increasing population.

6. Evaluation

6.1. Merits

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1.The continuous ground cover and high degree of nutrient cycling are the major factors that permit the Chagga homegardens to remain sustainable on the erosion-prone slopes of Mt.Kilimanjaro.

2.Coffee produced by the Chagga contributes significantly towards Tanzania's foreign exchange earnings.Over 52% of Tanzania's export coffee comes from Kilimanjaro and in 1982 this represented an earning of US$ 65 million.

3.The various crop species and varieties in the homegarden represent years of natural selection for survival and farmer selection for better production and quality.These species have a good resistance to prevalent pests,compete well with weeds and have a generally high level of genetic variability.The Chagga homegardens thus represent a valuable gene pool for use in any breeding programmes to improve crop varieties for multistory cropping systems.

In addition,the advantages attributed to intimate multispecies,multistory associations are many.They include soil conservation,nutrient cycling and nutrient efficiency microclimate enhancement(4) and other benefits such as labour efficiency,risk minimisation and continuous production.

6.2. Weaknesses/Constraints

1.Although the Chagga homegardens are a stable landuse system,their productivity is relatively low.In order to meet the demand for food of a rapidly growing population,the productivity

of the homegardens must be increased. The problem lies in the need to increase productivity while retaining the stability of the present system.

2. With the present trend of young people migrating to urban areas, it is mostly the older people left to manage the homegardens. Extension workers may thus find it more difficult to introduce innovations.

3. Present extension workers focus on individual crops/components. The absence of an integrated approach and subsequent lack of awareness of the possible interactions of the various components and their repurcussions can result in problems for the farmer and loss of faith in the extension service.

6.3 Potential:

On Mt. Kilimanjaro, the homegarden s potential as a productive and sustainable system can be enhanced by

1. Replacing the less productive trees/shrubs with fast growing nitrogen fixing species e.g. *Leucaena leucocephala*, *Calliandra calothyrsus*, *Gliricidia sepium* and *Lespedeza bicolor*. These would provide increased fuel, fodder and green manure on the homegarden and would reduce the time spent in travelling long distances to gather supplementary fuel and fodder.

2. Improving animal husbandary so as to achieve, for example, a lactation period of around 300 days per year.

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3. Improved apiculture e.g. the use of top bar hives,better bee strains,improved harvesting and honey extraction methods.

4. Introducing new crop species and breeding for higher yielding crop varieties using the gene pool developed by natural and farmer selection not only in Tanzania,but also from homegardens in other parts of the world.

5. Using fertilisers.Credit facilities could be provided by the Tanzania Rural Development Bank.Purchasing,storage and distribution of the fertiliser could be carried out by the Tanzania Farmers' Association or the Kilimanjaro Uremi Cooperation.

6.4 Extrapolability

Despite the need for intimate knowledge of the components and a high level of management capability,the Chagga homegardens can be extrapolated to upland areas (e.g. Kenyan highlands,S.W. Ethiopia,S.W.Rwanda) where ecological conditions are similar and farmers practice less intensive multiple cropping.Preferences for local species/varieties can be catered for by appropriate substitution or introduction.A demand for maize cultivation in such homegardens could be accomodated by growing the maize between rows of trees.Shade effects could be minimised by an east-west orientation of the rows.Ground cover can be maintained by intercropping the maize with beans or cow peas.

6.4. Reasearch neeeds

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Information is required on the following possibilities that could be used to improve the overall productivity of the homegardens.

1.Optimal spatial and temporal arrangements of the various components.

2.Optimal crop associations.This includes component crops/varieties differing in morphology,maturity period,shade tolerance,rooting depth and photoperiod sensitivity.

3.Since chemical pest control is no real alternative in small holder cropping systems,information is required on crop/species combinations with a greater potential to reduce pests,diseases and weeds.The effectiveness of the plant species with anti-pest properties that are already used by the Chagga could be investigated as a first step.

4.Better soil management techniques e.g.green manure,mulches and the most appropriate time of application.

5.Appropriate fertiliser prescriptions for the intimate multispecies associations present in the Chagga homegardens.

Acknowledgement

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TABLE 1. Woody species commonly found in the Chagga homegardens and their functions and uses.

Species	Functions/Uses
Albizia schimperiana	fuelwood, building material.
Bridelia micrantha	building poles, fodder, roots used medicinally.
Caesalpinia decapetala	live fence.
Calpurnia aurea	coffee shade, poles, tool handles, leaf decoction as anti-helminthic for cattle.
Carica papaya	fruit, mosquitto repellent.
Cassia didmyobotrya	medicinal uses, poisonous to cattle.
Cedrella mexicana	fuelwood, timber.
Chlorophora excelsa	valuable timber.
Citrus spp.	fruit.
Commiphora spp.	fodder, anti-insect properties, live support for yams, fencing material.
Cordia africana	coffee shade, fuelwood, building material, beehive construction.
Croton macrostachys	coffee shade, fuelwood, fodder, anti-insect properties.
Datura arborea	bee forage, anti *Armilaria mellea*, anti-nematodes.
Diospyros mespiliformis	valuable timber.

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Dracena usambarensis	live fence,boundary marker.
Dracena afromontana	live fence,boundary marker.
Ehretia spp.	poles,tool handles,anti-biotic properties.
Eriobotrya japonica	fruit,building material, hedge tree.
Ficus spp.	fodder,charcoal.
Gardenia spp.	utensils,anti-insect properties.
Grevillea robusta	coffee shade,fuelwood, building material.
Iboza multiflora	live fence,leaves fed to cattle as anti-helminthic,roots have anti-Bilharzia properties.
Markhamia platycalyx	termite proof building poles, fuelwood.
Morus alba	fodder,fuelwood,reinforce live fence of*Caesalpinia decapetala*.
Newtonia buchananii	fuelwood
Olea welwitschii	valuable timber,fodder.
Persea spp.	fruit.
Psidium guajava	fruit,fuelwood.
Rauwolfia caffra	fuelwood,bark for brewing, anti-pest properties,used as store for maize cobs which are hung in its branches.
Rauwolfia inebrians	coffee shade,fuelwood.

Table 1 (cont.)

Ricinus communis	seed oil used medicinally,seeds in bait as rodent poison.
Syzigium africanum	fuelwood,fruit.
Tectonia grandis	valuable timber.
Trema guineensis	fodder,anti-insect properties, used medicinally.
Trichilia emetica	fuelwood,root decoction as anti-helminthic.
Uvaria spp.	fuelwood.
Vangueria tomentosa	fruit,roots as snake bite remedy and anti-helminthic.

Other useful plant species maintained in homegardens

Aloe volkensis	antibiotic properties,grave marking.
Cynodon dactylon	fodder grass.
Pennisetum purpureum	fodder grass.
Senecio kilimandscharica	medicinal use especially against kidney ailments.
Setaria sphacelata	fodder grass.
Vetiveria zizanoides	grass planted along contours for soil erosion control,roof thatch.

Over 100 crop and other plant species that appear in the Chagga homegardens have been listed in a seperate publication (5).

FOREST VILLAGES: AN AGROFORESTRY APPROACH TO REHABILITATING FOREST LAND DEGRADED BY SHIFTING CULTIVATION IN THAILAND

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ABSTRACT

The Forest Village scheme was introduced by the Forest Industries Organisation (FIO) of Thailand in 1967 as an attempt to stop further spread of the fast increasing shifting cultivation and deforestation in the country. The underlying principle of the scheme is to relate reforestation with social welfare of the people involved. It is essentially a modification of the traditional taungya method of plantation establishment.

The salient aspect of the scheme is to induce the shifting cultivators to settle down in villages where each family is given tenure over a plot of land to construct a house and develop a homegarden around it. The farmers are required to help establish and maintain forest plantations, in which they are permitted to raise agricultural crops during the first three years of its establishment. The farmers are also given free medical and educational facilities, and technical advice on crop and livestock husbandry. They can also earn cash rewards for successful plantation establishment.

Although the scheme has not achieved its full target in terms of area covered and number of families settled, it is proving to be a successful method of luring people away from destructive shifting cultivation. The approach is applicable to other countries and regions with similar land-use problems and socio-cultural background.

The paper also examines the constraints to the effective working of the scheme, provides some simple suggestions for improving its functioning and identifies some of the issues that can easily be tackled by research.

Key words: Thailand, Forest Villages, Shifting Cultivation, Agroforestry, Home garden, Reforestation.

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(Photo: P.K.R. Nair)

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(Photo: P.K.R. Nair)

Figure 3B: The second year of establishment of teak and eucalyptus in the Forest Village with rice as the agricultural crop. The decline in soil productivity is already evident from the relatively low vigour of the rice crop in comparison to that of the first year rice crop shown in Fig. 3A.

(Photo: P.K.R. Nair)

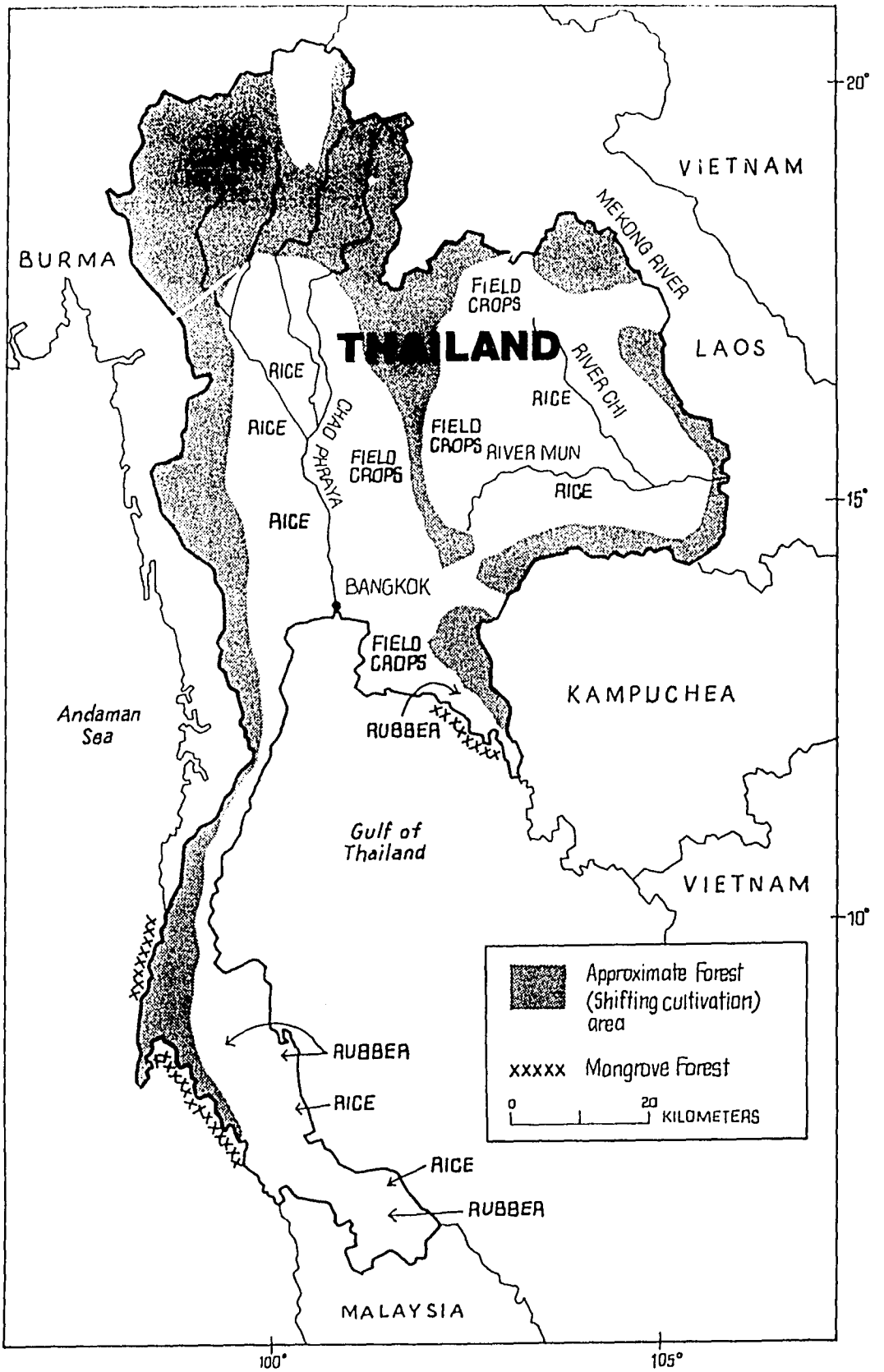

FIG: 1 : A ROUGH LAND-USE MAP OF THAILAND
(BOONKIRD, FERNANDES AND NAIR)

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1. INTRODUCTION

The number of people engaged in shifting cultivation in Thailand is estimated to have risen from 300,000 to well over 700,000 in the past 15 years (8). This phenomenal increase has been caused mainly by migration both from the neighbouring Laos and Burma as well as within the country from the lowland agricultural lands into the forests. Consequently, the forests in the country are under severe pressure. Moreover, the length of the fallow periods in shifting cultivation cycles is drastically shortened, and as a result, the land is rendered unsuitable to sustain repeated croppings and hence abandoned. Subsequent regeneration of forest species is very slow and poor in such abandoned sites. Shifting cultivation is thus causing large-scale forest destruction and land degradation in Thailand. It has been estimated that the country had around 0.8 million ha of land under shifting cultivation in 1980, and that increasing encroachment into the forest was causing forest destruction in over 400,000 ha each year (4).

With a view to arresting deforestation and reclaiming the degraded forest areas, the Government introduced and encouraged the taungya plantation system (5). The results were, however, not satisfactory, primarily because the scheme had no provisions for the social welfare of the people involved (2).

In 1967, the Forest Industry Organization (FIO) launched the Forest Village system in the northern highlands, in an effort to rehabilitate the degraded forest land. It is essentially a modification of the taungya system, and its main objectives are:

- to attract shifting cultivators and landless people to establish

themselves in forest villages which offer improved facilities and greater stability than nomadic life;

- to encourage village people to establish taungya plantation in order to reforest areas degraded by shifting cultivation. This could also result in opportunities for long term forest employment (3).

The scheme, though originally designed for the hilly areas of Northern Thailand where shifting cultivation has been most common, now extends all over Thailand. In 1981 there were 26 forest villages spread over the country, and they undertook plantation establishment in a total of 4,000 ha annually.

Encouraged by the success of the FIO Forest Village system, the Royal Family of Thailand and the Royal Forest Department (RFD) have also recently set up forest villages similar to those developed by the FIO. The underlying approach in all of them is to promote rural development and sound land use by relating forestry work with social welfare for the people involved.

This paper examines the details of working of the FIO Forest Village system. Since the scheme encompasses the whole of the country, it is relevant to give a general account of the biophysical and land use aspects of the country in order to understand the system in the proper perspective.

2. GENERAL DESCRIPTION OF THE AREA

Figure 1 shows salient aspects of the geographic location and land use systems of Thailand.

FIG.

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2.1. Geographic location

The Kingdom of Thailand is located on the Malay peninsula (5.45 - 20.30° N and 97.30 - 105.45° E). It has an area of around 514,000 km^2 and has four main geographic regions.

- The Northern region (16.96 million ha) comprises a range of fold mountains which extend along the western border through the peninsula to Malaysia. These mountains have an average elevation of 1600 m and are interspersed with fertile valleys through which flow the four tributaries of Thailand's major river - the Chao Phraya.
- The Northeastern region, which includes the Khorat plateau, covers around 16.86 million ha. The elevation of the plateau is around 200 m while the mountains to the west average between 800 - 1300 m. This region is characterised by saline soils and is quite dry and windy in the summer.
- The Central plain has a total area of 10.39 million ha and is the rice bowl of Thailand. In the north, three tributaries flow together into the Chao Phraya river and in the south is the fertile Chao Phraya Delta.
- The Southern region (7.07 million ha) is the peninsula which in the west is composed of mountains with an average elevation of 1000 - 1500 m. Most of the rivers and streams here flow eastwards into the Gulf of Thailand.

2.2. Biophysical environment

2.2.1. Climate

Thailand receives 90 percent of its annual rainfall from the southwest monsoon which lasts from May to September. During the period from

October to April, the southeastern Asiatic cyclonic storms bring irregular amounts of additional rain to the southern regions while most of the north and northeastern areas have a long dry season.

Annual rainfall is highest in the southern and western parts of the peninsula and in the southeastern region and ranges from 2000 - 4000 mm+. The central plain which lies in the rain shadow of the western mountains receives between 1000 - 1400 mm, while the northeast gets between 1000 2000 mm.

Temperatures are relatively steady throughout the year, averaging between 24° C and 30° C (75° F and 86° F). In the north, frost may occur at higher elevations in December, while in the south climate is moderated by the maritime influence. The cold dry winter air produces frequent morning fogs especially in the north.

2.2.2. Soils

(See UNESCO/FAO Soils Map of the World - sheet IX). The predominant soils are Acrisols with a Lithic phase i.e. the presence of continuous coherent or hard rock within 50 cm of the surface. In general, the soils are podsolized and have low base saturation and cation exchange capacity. Soils in the northeast are saline.

2.2.3. Vegetation

Thailand has a wide variety of vegetation types reflecting the wide range of ecological and climatic conditions. The major vegetation types include:

- Evergreen and semi-evergreen forests
- Dry and moist deciduous forests
- Dry dipterocarp forests

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. Fresh water swamp forests

. Mangrove forests

. Savanna forests

. Bamboo forests

. Beach forests

. Coniferous forests

. Scrub formations

2.3. Land Use Systems

2.3.1. Agriculture

The alluvial soils of the inter montane basins of northern Thailand are very suitable for the cultivation of rice, tobacco, fruit trees and vegetables. In addition, maize, peanuts, beans, garlic and onions are also produced. On the upper slopes, tea is grown both by large estates and also by smallholders. The former produce tea for drinking, while the latter ferment the tea leaves to produce a product for chewing ("miang") (6). In addition, the Hmong Hill tribe cultivate opium (at elevations between 1000 - 1500 m) as a cash crop and maize as a subsistence crop. There is a UN-supported crop-substitution project to encourage these farmers to give up opium cultivation in favour of agricultural crops such as coffee, maize, beans, etc. and flowers such as tulips (8).

The fertile Chao Phraya Delta region of the central plain is intensively cultivated. The main crop is rice although sugarcane is also produced. The alluvial deposits of the streams on the southeastern part of the central plain are also used for rice cultivation while the higher well-drained areas are used for rubber plantations, fruit orchards, sugar cane, cassava and pineapples. In 1979, Thailand's rice production

was estimated at 15.6 million tonnes. Only 10 percent of the total rice area receives controlled irrigation. The alluvial deposits of the rivers Mun and Chi in the northeastern region, although not very fertile, are extensively used for rice. The production per unit area is low and increasing soil salinity is a problem. Streams flowing off the peninsula into the Gulf of Thailand often have built up deltas which are utilised for wet rice cultivation.

2.3.2. Forestry

At the end of 1980, it was estimated that the natural forest area of Thailand amounted to 16.17 million ha or about 31 percent of the country's total area (4). This contrasts dramatically with a forest area of 57 percent in 1961 (1).

There are numerous types of forest types (see 2.2.3.). The main timber species from Thailand's natural forests are:

- *Tectona grandis*
- *Dipterocarpus alatus*
- *Shorea* spp.
- *Pterocarpus* spp.
- *Toona ciliata*
- *Instia palembanica*
- *Parashorea stellata*
- *Dalbergia cochinchinensis*

FAO estimated that in 1980, the annual value of all non-timber forest products from Thailand such as Dipterocarp oil, gum damar, bamboo pulp, edible bamboo shoots, canes, resin, honey, camphor, etc. was about US $ 30 million (4).

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In addition to natural forests, there were around 0.43 million ha of successfully established hard and softwood plantations in 1983. The main hardwood species used include *Tectona grandis*, *Pterocarpus macrocarpus* and *Dipterocarpus* spp. Other species that have been successfully established are *Acacia catechu*, *Casuarina junghuhniana*, *Casuarina equisetifolia* and *Eucalyptus* spp. Softwood species used are *Pinus kesiya* and *Pinus merkusii*. Rubber is one of the main tree crops with 1.35 million ha planted in 1979.

2.3.3. Agroforestry

Various agroforestry systems/practices can be identified in Thailand:

- swidden/shifting cultivation for growing rice as the main crop with a variety of other food and cash crops (6, 7) -- in some areas, the woody vegetation of the long fallow period is deliberately managed for a variety of products, e.g. fruit, honey, fodder, resin, etc. (6)
- home gardens dominated by a wide variety of fruit trees;
- sericulture, where various species of silkworm moths are reared on the foliage of mulberry trees;
- aquaculture in mangrove forests;
- intercropping of coconut with cacao *(Theobroma cacao)*;
- grazing of cattle in coconut plantations;
- forest villages.

3. ORGANIZATION AND STRUCTURE OF THE FOREST VILLAGE SYSTEM

3.1. Organization

The FIO selects the degraded land where a forest village is to be set up for reforesting the land. The benefits and features of the

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scheme are publicised widely within the locality through extensive media coverage and other extension methods. The services of the religious and other leaders are also solicited to disseminate such information and to allay any suspicion among the villagers. Families who come forward and agree to give up shifting cultivation in favour of settled land use are provided with a piece of land within the selected village unit for building a dwelling and setting up a homestead garden around it (see section 4.1. for details). Moreover, they are also permitted to grow crops between the young trees in the forest plantation that they will have to help in establishing according to the plan that would already have been prepared by the FIO.

The FIO has also set up "Development teams" having multidisciplinary expertise for each forest village. These teams provide agricultural, educational and medical services (see section 4.2.) to the people covered by the scheme. The objective is to encourage farmers to develop permanent bases in the forest village.

3. Components

3.2.1. Crops

Both subsistence and cash crops are grown. In the forest plantations, the major crops grown are dryland rice, maize *(Zea mays)*, sesame *(Sesamum indicum)*, sweet potatoes *(Ipomoea batatas)*, cassava *(Manihot esculenta)*, and water melons *(Citrulus lanatus)*. Tobacco *(Nicotiana tabacum)* and kenaf *(Hibiscus cannabinus)* are also grown in some areas.

The main crops in the home gardens are maize, cassava, pumpkins *(Cucurbita* spp.) and chilli pepper *(Capsicum frutescens)*. A large number of common agricultural crops are also grown. These include legumes such as beans *(Phaseolus* spp.), lablab bean *(Dolichos lablab)*,

soya bean *(Glycine max)* and winged bean *(Psophocarpus tetragonolobus)*; tuber crops such as sweet potato *(Ipomoea batatas)*, taro *(Colocasia antiquorum)*, and yams *(Dioscorea* spp.); cucurbitaceous crops such as cucumber *(Cucumis sativus)*, loofah *(Lufa acutangula)* and snake gourd *(Trichosanthes cucumeria)*; other vegetables such as egg plant *(Solanum melongena)*, and tomato *(Lycopersicon esculentum)*; minor millets such as Italian millet *(Setaria italica)* and finger millet *(Eleusine coracana)*; and spices and medicinal plants such as coriander *(Foeniculum vulgare)*, garlic *(Allium sativus)*, lemon grass *(Cymopogon citratus)*, mint *(Mentha arvensis)* and onion *(Allium cepa)*.

3.2.2. Trees

Teak *(Tectona grandis)*, which is native to Thailand, is the major FIO plantation species. In 1983, there were about 30,000 ha of FIO teak plantations. Other major plantation species include *Eucalyptus camaldulensis* (6,500 ha in 1983) and *Melia azedarach* (2,045 ha in 1983).

In addition to growing crops between the trees in the forest plantation the forest villagers also grow fruit trees e.g. *Parkia speciosa, P. javanica* and *Anacardium occidentale*. In some areas rubber trees *(Hevea brasiliensis)* are also grown between plantation trees and the proceeds from the latex sales are divided on a 70:30 basis between the forest villagers and the FIO. The 30 percent share retained by the FIO covers the cost of fertiliser and tools advanced to the forest villagers.

Other plant species maintained by the forest villagers in their home gardens (and their functions/uses) are listed in Table 1.

TABLE 1

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3.2.3. Animals

Forest villagers keep a variety of domestic animals in the home gardens for food, ritual/religious sacrifices and prestige. Common animals include cows, pigs, chickens and ducks.

3.2.4. Management aspects

Degraded forest is cleared and burned and trees planted in holes (20 x 20 x 20 cm). Teak was originally grown at a spacing of 4 x 4 m on a 60 year rotation. Recently, however, a spacing of 2 x 8 m and 40 year rotation has been adopted.

Where soils are poor and dry, *Eucalyptus camaldulensis* (four-month-old seedlings) and *Melia azedarach* (1 year-old-plants) are planted at 2 x 8 m spacing. Eucalyptus plantations are grown on 10-15 year rotation for fuel or 20 year rotation for timber.

After planting the trees, the forest villager plants his crops in the interrows. Cropping occurs for the first three years and the villager then moves on to another area. It is the responsibility of the villager to weed and tend the trees while tending the agricultural crops.

Some villages have a herding cooperative for their cattle. The owners of cattle take turns to herd the village cattle within the plantations where grazing is permitted.

4. SYSTEM FUNCTIONING

4.1. Resource input and utilisation

Each family in the forest village is allocated 1.6 ha annually for clearing and planting with plantation trees and food/cash crops. In

addition, 0.16 ha is allocated for house building and home garden. Fig. 2 depicts a typical forest village scene with houses of the farmers in the midst of the individual home gardens. Cropping in the forest plantation occurs for upto 3 years and hence a villager can have upto 4.8 ha per year on which to grow his crops. Since the intended number of families per forest village is 100, upto 160 ha of land may be cleared and planted with trees and crops each year. In 1981, however, there was an average of nearly 59 families per forest village with each family cultivating 2.61 ha per year, i.e., a total of 153.63 ha annually per forest village.

FIG. 2

In 1981 the average size of forest village families was 5.56 members. In addition to their annual responsibilities for establishing the forest plantation (on a minimum of 1.6 ha) and growing of crops in the plantation and home gardens, it was estimated that each forest village needed labour equal to 200 man days per year. This would be required for various plantation operations e.g. weeding, pruning, thinning, fire prevention, road and trail maintenance, etc. If a nursery was attached to the village an additional 50 man days per year would be required. Thus, depending on the number of families in the village, at least two members per family are guaranteed work on a continuous basis within the forest plantation. They are paid according to the prevailing minimum agricultural wage. Such labour is recruited exclusively from within the forest village.

4.2. Other facilities

In addition to providing land (4.1.), the FIO provides numerous other inputs and facilities. These include:

- provision of drinking water and electricity free of charge to

each house in the forest village;

- FIO medical team dispensing free medicines and advice to villagers on health, family planning, sanitation, etc.;
- forest village primary school in accordance with the Ministry of Education regulations, text books and uniforms being provided free of cost.
- Monetary incentives for successful establishment of forest plantation trees.

  . payment of a bonus of about US $ 60 for clearing, planting and two weedings of each hectare of allocated land;

  . a reward of about US $ 27 per ha if tree survival is 100 percent after harvesting of agricultural crops and third weeding. (This reward may be graded and related to percentage survival over 75 percent);

  . a bonus of US $ 75 for successfully tending 4.8 ha of forest plantation over 3 years payable at the end of the third year; if tending continues, the villager receives US $ 25 per ha per year for each successful 1.6 ha.

- Transport is provided for

  . taking workers to plantation site;

  . moving construction materials of forest villagers' houses;

  . taking forest villagers' agricultural produce to market.

- Advice on the market performance of various agricultural crops.

Table 2 provides a comparison of cost per hectare to FIO for establishing forest plantation with and without forest villages.

TABLE 2

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4.3. Production

Data on the production and income from maize, cassava and kenaf grown in forest plantations in 1981 are given in Table 3.

TABLE 3

The soils especially in the dry northeastern region are generally poor. This tends to exaggerate the competitive interaction between the trees and crops. Thus, often, yields of dryland rice intercropped between the plantation trees tend to be the best in the first year. Yields decline markedly in successive years. Photographs of a teak + eucalyptus + rice plot during the first and second years of cropping, given as Fig. 3A and 3B respectively, illustrate this point.

FIG. 3A
FIG. 3B

Production of upland rice is typically of the order of 0.5 - 1.5 tonnes per hectare per year. Generally, the rice produced is used for home consumption although occasionally some of it may be sold to raise cash. This is also the case with pigs and chickens.

In 1981, the forest villagers earned an average of US $ 266 per family from the sale of agricultural crops grown in forest plantation and in their home gardens.

Added income from rewards, bonuses and daily wages from forest plantation operations gave a total income of US $ 693 per family per year (Table 4) or US $ 10.38 per person per month.

TABLE 4

Estimates of timber production from the plantations based on local experience are 75 m^3 per ha in a 40 year rotation of teak and 75 m^3 from a 15 year rotation of Eucalyptus.

5. SYSTEM EVALUATION

5.1. Rate of growth

The original target was to start with 2000 forest villages covering

32,000 ha (at the rate of 1.6 ha per family per year, and 100 families in each village), increasing progressively to 4,500 villages undertaking plantation establishment in 73,000 ha annually by the year 2000. However, by 1981, there were only 26 such villages, which undertook planting in a total of about 4,000 ha per year. Thus, the scheme has not been able to accomplish the target at expected levels.

5.2. Merits

1. The forest village system is proving to be a successful but slow method of ensuring the long-term improvement of national and export wood sources.
2. The rehabilitation of the country's forest resource is being achieved by people who would normally be engaged in the present destructive practice of shifting cultivation.
3. Opportunities are provided for landless people to form settled communities. Long term employment, raising food and cash crops, and better health and education facilities result in a higher standard of living for the forest villagers. This is especially important in the strategic border areas that are prone to the destabilising insurgency activities.

5.3. Weaknesses/constraints

1. Enforcing the policy of forest reserves becomes difficult and expensive where forest land is still plentiful. Shifting cultivators are still able to operate illegally and it is difficult to induce them to settle in a forest village.
2. The initial years in a forest village can be hard and frictions can arise with other families in the village(5). This is often compounded by a cash flow problem since payments of rewards, bonuses,

etc. are not made till the end of the first year of participation.

3. Some forest villagers find the pay and other financial incentives low resulting in their deserting the forest village and seeking employment elsewhere.
4. Setting up large numbers of forest villages with free electricity, water, schools, medical facilities and other financial incentives requires a significant amount of capital expenditure.
5. Often funds are not available because of misunderstandings about the inclusion of social welfare expenditures in reforestation projects.
6. Some selfish politicians and unscrupulous businessmen undermine the concept of forest villages in order to ensure the availability of cheap labour force at their disposal.
7. Some reforestation sites are on steep slopes and the forest villagers find it difficult to cultivate and harvest their crops. Also, some soils are very poor and this results in minimal yields of agricultural crops.
8. There is a scarcity of capable managers (conversant with forestry, agriculture, administration and sociology) to take charge of forest villages.

4. Potential

The concept and philosophy of forest villages represent a sound approach to tackling the problems of shifting cultivation vis-a-vis land degradation. The benefits accrued from the scheme can, however, be enhanced by removing the observed bottlenecks and constraints as far as possible and improving the efficiency of working through appropriate technological interventions and social improvements. For example, providing forest villagers with improved varieties of seeds, appropriate types of fertilizers and sound advice on their proper use, credit facilities,

social facilities such as realistic rates of pay, bonuses and rewards, and so on, increasing the area of home gardens from the present rate of 0.16 ha per family to a more acceptable size, etc.

Todate the forest village system has proved to be a sustainable system although the growth of the system has been slow due to the various problems mentioned earlier. Suggested improvements in the system should assure the system's sustainability i.e. attracting shifting cultivators to settle down and help rehabilitate the degraded forest lands. This provides long term employment and better living standards and thus the shifting cultivators are prompted to stay within the ambit of the system. The system should be thought of as a multi-product enterprise rather than a system that provides supplementary income through forest land tenancy.

The forest village system has been tried successfully in various countries e.g. Kenya, Gabon, Uganda, India, Nigeria and Cambodia. Although it is more expensive than traditional taungya system it is particularly suitable for countries with a large natural forest resource and high numbers of shifting cultivators and other landless people. The system envisages the sustainable use of forest land for food production by landless people who would otherwise be engaged in forest destruction. Thus, it encompasses the concept of sound agroforestry approach to providing a viable alternative to resource-depleting and environmentally degrading shifting cultivation (9, 10). With appropriate technological back up and infrastructural improvement, the system can prove itself to be quite acceptable and adoptable under other situations with comparable land use problems and socio-cultural constraints.

5.5. Research needs

The foregoing analysis of the functioning of the system reveals that the major constraints to its effective functioning are both biological (technological) and socio-cultural. Whereas some of the socio-cultural problems are so intimately tied up with the general situation in the country and hence cannot easily be overcome, there are certain biological constraints that can be tackled effectively through research efforts. In fact it is a serious drawback of the scheme that research input has not been built into its operational framework so that the management techniques are based on the knowledge that was available at the time of project formulation. Moreover, no effective system exists for mitigating some of the simple problems through research-supported "mid-term corrections". Some of the issues that can be tackled through simple research are:

- the role of fast-growing nitrogen fixing multipurpose woody species in association with plantation trees;
- use of manures and fertilizers, at least to a limited scale, for ameliorating soil fertility decline that occurs after the first year of cropping;
- adjustment of planting patterns and management schedules of the plantation (forestry) species in relation to agricultural crops so as to facilitate profitable cultivation of agricultural species for as long a time as possible;
- use of appropriate varieties of crop species adapted to specific situations such as low light availability, soil reactions (acidity, salinity), soil conditions (poor drainage, low fertility), and so on;
- monitoring the visual interaction effects between the tree and the herbaceous components in order to devise appropriate ways to overcome some of the negative interaction effects to the extent possible even during the life of the project.

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Table 1: Plant species other than the common agricultural species found in forest villagers' homegardens and their functions/uses

Species	Functions/Uses
Areca catechu	masticatory nut
Artocarpus spp.	fruit, vegetable
Bambusa spp.	construction, mats, furniture
Calamus spp.	furniture, baskets, mats
Citrus spp.	fruit
Cocos nucifera	food, oil, thatching, fuel
Dendrocalamus spp.	construction, mats, furniture
Desmodium pulchellum	insent repellent
Imperata cylindrica	roofing grass
Magnifera indica	fruit, shade
Moghania strobilifera	insect repellent
Morus spp.	sericulture, fuel
Musa spp.	fruit, mulch
Psidium guajava	fruit
Saccharum spp.	food
Thyrsostachys spp.	construction, furniture, mats

Table 2: Cost (US $ per hectare) of establishing FIO forest plantation in Thailand with and without the Forest Village scheme[1]

	Without Forest Village		With Forest Village	
	Teak	Non-teak	Teak	Non-teak
First Year				
Labour	205.60	235.05	71.20	82.07
Administrative cost	287.28	287.28	287.28	287.28
Fixed cost (house, macninery, etc.)	74.00	74.00	74.00	74.00
[2]Stump or seedling and re-planting charges[3]	19.57	32.61	17.93	29.89
Forest village expense	-	-	168.29	168.29
Total	586.45	628.94	618.70	641.53
Second Year				
Labour and/or Reward	74.46	95.92	74.46	95.92
Stump/seedling	3.26	8.15	1.63	4.08
Total	77.72	104.07	76.09	100.00
Third Year				
Labour and/or Reward	56.79	68.86	56.79	68.86
Stump/seedling	1.63	4.08	0.82	2.04
Total	58.42	72.94	57.61	70.90
Fourth and Fifth Years				
Maintenance & protection per year	52.45	52.45	52.45	52.45
Total for 2 years	104.90	104.90	104.90	104.90

[1] Daily wage rate per labourer = ฿ 38; 1 US $ = ฿ 23

[2] Cost per teak stump = US $ 0.03; cost per non-teak seedling = US $ 0.04

[3] Replanting at the rate of 20% in "Without Forest Village" and 10% in "With Forest Village".

	Without Forest Village		With Forest Village	
	Teak	Non-teak	Teak	Non-teak
Sixth to Tenth Years				
[4] Maintenance & protection per year	20.65	20.65	20.65	20.65
Total for 5 years	103.25	103.25	103.25	103.25
GRAND TOTAL FOR TEN YEARS	930.74	1,014.10	960.55	1,020.58

[4] Thinning cost is not included as the output from thinning will cover the expenses involved.

Table 3: Area and total value of produce of the three agricultural crops grown in the forest village scheme in Thailand in 1981

Crop	Area of cultivation in plantation (ha)	Income (US $)
Maize	1,661	163,568
Cassava	1,782	75,874
Kenaf	380	49,348

Table 4: Income from the FIO forest village scheme in different regions of Thailand*

Region	No. of villages	Mean No. of families per village	Mean Area (ha) cultivated per village	Mean Area (ha) cultivated per family	MEAN INCOME (US $) FOR 1981					
					PER VILLAGE					Income per family
					From agricultural crops	Reward	Bonus	Daily	Total	
North	16	60.94	109.03	1.79	15,493	5,618	1,767	24,865	47,743	783.44
Northeast	6	64.67	315.05	4.87	20,888	2,948	1,696	19,634	45,166	698.41
South	-	41.75	98.87	2.15	8,246	4,526	652	21,489	34,913	321.54
Weighted means	-	58.85	153.63	2.56	15,623	4,909	1,697	23,139	41,868	692.76

* In 1981 there were a total of 1530 families cultivating a total of 3994 ha in different regions of Thailand.

PLANT SPECIES IN THE KILIMANJARO AGROFORESTRY SYSTEM

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ABSTRACT

An inventory of plant species was conducted on farms, farm boundaries and homesteads in the Kilimanjaro agroforestry system. The survey covered 30 farms in 6 villages in Hai District on the slopes of Mount Kilimanjaro, Tanzania. Over 100 plant species spread over 40 families were identified and their uses obtained through interviews with farmers.

The species identified include 53 tree species, 29 food crop species, 21 non-woody plants of economic value and 8 weed species. The food crops, trees and other economically useful plants are carefully chosen by the local farmers and intimately intercropped on the same unit of land. In most cases, the plants had two or more uses of which food, fuelwood, medicine, poles, timber and fodder were the most important.

Key words: Agroforestry, Multipurpose plants, Multiple cropping, Kilimanjaro, Chagga home gardens.

1. INTRODUCTION

In most of the tropics, selected tree species always form a component of the multiple cropping systems in farms and in rangelands. These multi-cropping systems, popularly called agroforestry systems, have been the subject of recent discussion among agronomists, foresters and animal husbandry specialists (3, 5, 9, 11), and a few such agroforestry systems have been described in detail (8, 16).

A recent study on the Chagga homegardens in northern Tanzania brought out the salient operational aspects and functional characteristics of that traditional agroforestry system (4). As a follow-up, an inventory of plant species was undertaken in 30 farms and their surroundings in the Chagga area on the slopes of Mount Kilimanjaro, and this paper summarizes its results.

2. THE STUDY AREA

Mount Kilimanjaro is in Tanzania at 2.9 - 3.3^{o} S latitude and 37 - 37.5^{o} E longitude. Its peak is the highest mountain in Africa, rising to 5895 m.a.s.l. The study was conducted on the southern slope of the mountain in Hai Mashariki Division. The area surveyed rises from 800 to 2500 m.a.s.l.

The slopes of Mount Kilimanjaro have a mild climate with mean annual temperatures of 22° C at 800 to 1000 m.a.s.l. and 18° C at 2000 m.a.s.l. The annual total rainfall ranges from 800 mm at lower altitudes to over 2000 mm at 2500 m.a.s.l. The rainfall is bi-modal falling between October and June with a dry spell in January and February. Soil types in the area have already been listed (4). The population density on the slopes

of Mount Kilimanjaro is 190 people/km^2 with an annual growth rate of 3.7% (15). Land is highly fragmented giving an average family farm size of 0.6 ha. This has led to a highly intensive mixed farming system with multiple cropping as its mainstay (10).

3. METHOD OF STUDY

An inventory of plant species was conducted on farms, farm boundaries and around homesteads in 30 subjectively selected farms. Five farms were selected from each of the following villages, Mwasi Kusini, Mwasi Kaskazini, Kushimundu, Mruwia, Kyaseni and Materuni in the study area, as shown in Fig. 1.

Plant species were identified by us. Herbarium samples are kept at the National Forestry Herbarium, Tanzania Forestry Research Institute, Lushoto. Data on the local names and uses of the plant species were obtained through interviews with farmers.

4. RESULTS AND DISCUSSION

Plant species identified and their economic importance are presented in Table 1. A total of 111 plant species spread over 42 families were identified. They include 53 tree species, 29 food crop species, 21 economically useful non-woody plant species and 8 weed species. Except for the weeds, the other plant species are carefully interplanted on the same unit of land to form a very dense multistorey ecosystem as described in the system description (4). Most of the plant species are maintained in the farm for two or more uses. For the trees, the main uses were fuelwood (90% of the tree species), medicines for humans and livestock (30% of the tree species), poles (25% of the tree species),

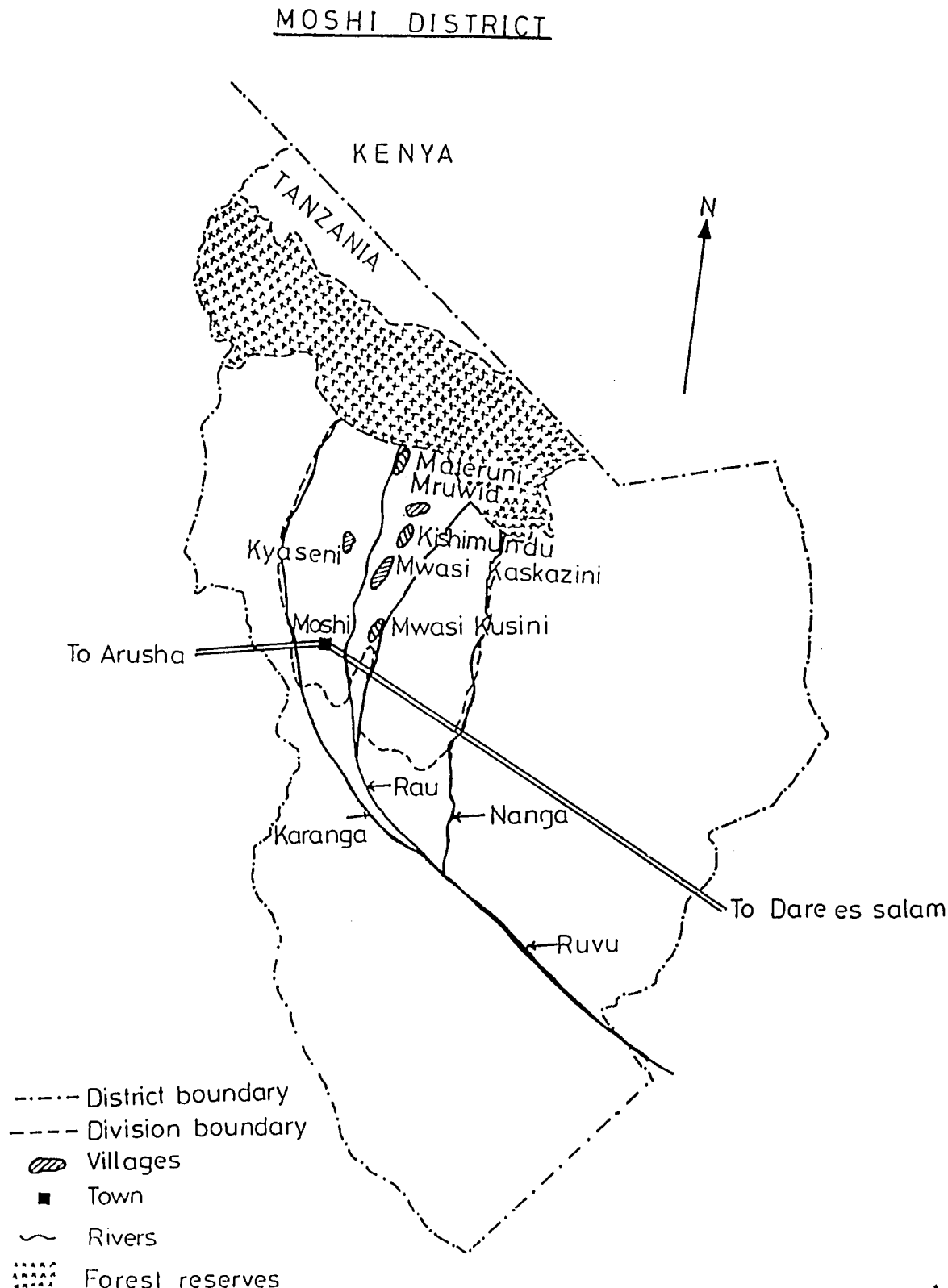

Fig. 1 : Location of villages sampled for this study.

shade (24% of the tree species), timber production (23% of all the tree species), fodder production (10% of all the tree species), other uses (19% of all tree species). Nearly all the non-woody plant species and climbers are grown for fodder or medicinal purposes.

The use of nearly all the trees to provide fuelwood is a reflection of the importance of this resource for the day-to-day life of rural communities in the tropics (2).

Nearly 30 food crop species are used in the multicropping system on the same unit of land. In one of the surveyed farms (2 ha in size), more than 15 food crop species were planted. This phenomenon is very different from the conventional two-crop intercropping that is often reported in the literature (for example, 1, 7, 12, 14), and provides the farmer with the insurance for basic necessities that is so crucial under poor economies and the vagaries of climate.

This inventory brings out for the first time the totality of plant species used in the multicropping as practised at the farm level in the region. Most of these species are under-exploited and their role and importance in the rural communities little understood by outsiders. Undoubtedly, one of the opportunities in agroforestry lies in exploiting the vast potential of such species, large numbers and forms of which can be found to exist in the various localized agroforestry systems around the world (6, 13).

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Table 1. Plant species in the Kilimanjaro agroforestry system, Northern Tanzania

Family name	Botanical name	Common name	Vernacular name	Uses	Remarks
ALANGIACEAE	*Alangium chinense*		Mringonu	Fuelwood, fodder and shade	fast-growing tree to
AMARANTHACEAE	*Achyranthes aspera*		Kisoka	Fodder, medicinal	shade tolerant shrub
	Amaranthus dubius		Shaana	vegetable	
ANACARDIACEAE	*Anacardium occidentale*	cashew	Mkorosho	edible fruit and seed, fuelwood	tree to 12 m
	Mangifera indica	mango	Mwembe	edible fruit, fuelwood	tree to 20 m
	Sorinaeia madagascariensis		Mngwera	shade, fuelwood & edible fruits	tree 10-15 m
ANNONACEAE	*Annona muricata*		Mstafeli	edible fruits, fuelwood	tree 5-8 m
	Uvaria sp.		Mrisirisi	timber and fuelwood	woody climbers, shrub or small tree
APOCINACEAE	*Rauwolfia caffra*		Msesewe	timber, fuelwood, catalyst for brewing, medicinal	tree 12-20 m
	Tabernaemontana usambarensis		Mracha	fuelwood, medicinal	
ARACEAE	*Colocasia esculenta*	taro	Maduma	edible roots	
ARALIACEAE	*Cussonia holstii*		Mnengere	fodder	tree to 8 m high
BALSAMINACEAE	*Impatiens kilimanjari*		Sunguala	weed, ornamental	
BIGNONIACEAE	*Jacaranda acutifolia*		not available	shade, fuelwood, ornamental	tree to 12 m
	Kigelia africana	sausage tree	Imomo	fuelwood, years and sponges from fruits	tree 6-15 m
	Markhamia platycalyx		Mtarawanda	timber, fuelwood, poles	tree to 22 m
BORAGINACEAE	*Cordia abyssinica*		Mringaringa	timber, shade, fuelwood, fodder	tree to 20 m
	Ehretia cymosa		Mnemvu	poles, medicinal	
BROMELIACEAE	*Ananas comosus*	pineapple	Mnanasi	edible fruits	

Table 1 (Cont'd)

Family name	Botanical name	Common name	Vernacular name	Uses	Remarks
BURSERACEAE	*Commiphora zimmermannii*		Mfifina	fodder	tree 10-20 m
CARICACEAE	*Carica papaya*	pawpaw	Mpaipai	edible fruits	
COMMELINACEAE	*Commelina latifolia*		Torontoro	fodder	rambling herb
COMPOSITAE	*Ageratum conyzoides*		Mafuna	fodder	shrubs
	Conyza sumatrensis		Inanzie	weed	
	Galinsoga parviflora		Shimakamaka	vegetable	
	Helichrysum spp.			weed	herbs/shrubs
	Senecio spp.		Ifuifui	medicinal	
	Vernonia subuligera		Iduhuduhu	medicinal, weed	shrub or small tree to 6 m
CONVOLVULACEAE	*Ipomoea batatas*	sweet potato	Shisowia	edible roots, vegetable	
CRUCIFERAE	*Brassica oleracea*	cabbage	Kabichi	vegetable	
CUCURBITACEAE	*Telfairia pedata*		Makungu	fat from seed	climber with stems to 30 m long
DIOSCOREACEAE	*Dioscorea alata*	yam	Ngao, Shia	edible tubers	
	D. bulbifera	yam	Nduu	edible tubers	
EBENACEAE	*Diospyros mespiliformis*		Msindesinde	timber, fuelwood	tree to 20 m
	Euclea divinorum		Mkinyanyi	fuelwood, red dye from bark	shrub or small tree
ERINACEAE	*Agauria salicifolia*		Not available	fuelwood	tree 12-15 m
EUPHORBIACEAE	*Bridelia micrantha*		Mmarie	fuelwood, poles, withies, fodder	tree to 15 m
	Croton macrostachyus		Mfurufuru	shade, fuelwood & goat fodder	tree to 15 m
	Jatropha curcas		Mchimbakaburu	boundary and grave marking	tree to 6 m
	Manihot esculenta	cassava	Muhogo	edible root, vegetable	shrub to 4.5 m
	Margaritaria discoidea		Mshamana	fuelwood, poles, fodder	
	Ricinus communis	castor oil tree	Mbarikà	purgative oil, medicinal	short lived shrub to
	Synadenium volkensii		Mracha	for making graves and boundaries, poisonous sap	tree with fresh bran

Table 1 (Cont'd)

Family name	Botanical name	Common name	Vernacular name	Uses	Remarks
	Tragia brevipes	Stinging nettle	Kimangima Shiwawo Kilachia		
GRAMINEAE	*Eleusine coracana*	finger millet	Mbege	grains are used in the prepararion of local brew (mbege) and making porridge	
	E. indica, E. africana	fowl-foot grass	Kikwale	pasture grass	
	Panicum monticola		Mlaa	pasture grass	
	Saccharum officinarum	sugar cane	Miwa, Mauwa	edible stem	
	Tripsacum laxum	Guatemala grass		fodder	
	Vetiveria zizanioides	vetiver	Khuskhus grass (manzao)	thatching, anti-erosion	
	Zea mays	maize	mahindi, meemba	staple food	
LABIATAE	*Geniosporum rotundifolium*		Isuwambewa	weed	
	Hoslundia opposita		Tarambe	hedges, fodder	
	Iboza riparia		Mombo, Ombo	medicine for stomach ache & fever	
	Ocimum suave		Ikachi	medicine for stomach ache	
LAURACEAE	*Persea americana*	avocado	Mparachichi	edible fruits, shade, fuelwood	
LEGUMINOSAE (CAESALPINIOIDEAE)	*Caesalpinia decapetala*	mauritius thorn	King'utuo	boundary marking, hedges	thorny shub
	Cassia didymobotrya		Iwinu	purgative, antihelminthic leaves	shrub to 6 m
	C. floribunda		Ototo	weed	
LEGUMINOSAE (MIMOSOIDEAE)	*Albizia schimperiana*		Mruka	fuelwood, shade	tree 20-30 m
	A. petersiana		Muula	poles, fuelwood, shade	tree to 12 m
	Newtonia buchananii		Mkufi	timber, shade, fuelwood	

Table 1 (Cont'd)

Family name	Botanical name	Common name	Vernacular name	Uses	Remarks
LEGUMINOSAE (PAPILIONOIDEAE)	*Calpurnia aurea*		Mletangawo	poles, fuelwood, antihelminthic, insecticide	
	Erythrina abyssinica		Mriri	shade, fuelwood	
	Phaseolus vulgaris	beans	Maharagwe	food	
	Pisum sativum	peas	Njegere	vegetable	
	Tephrosia aequilata		Urutupa	fuelwood, poisonus seed	
	Vigna unguiculata	cowpea	Kunde, Soko	food	
LILIACEAE (ALLIOIDEAE)	*Allium cepa*	onion	Vitunguu	spice	
LILIACEAE (ASPHODELOIDEAE)	*Aloe volkensii*		Sale la njofu, Iratune	grave marking, sap medicine for wounds	
LILIACEAE (DRACAENOIDEAE)	*Dracaena afromontana*		Masale	fence, boundary marking and grave marks	
MALVACEAE	*Sida acuta*		Mlenda	fodder	
MELIACEAE	*Trichilia emetica*		Mbomu	timber, fuelwood, poles, shade	
	Turraea robusta		Mokyanyama	fuelwood	
MELIANTHACEAE	*Bersama abyssinica*		Mchakuru	timber, shade and fuelwood	
MENISPERMACEAE	*Stephania abyssinica*		not available	weed, climber	

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Table 1 (Cont'd)

Family name	Botanical name	Common name	Vernacular name	Uses	Remarks
MORACEAE	*Artocarpus neterophyllus*	Jack fruit	Mfenesi	edible fruits, fuelwood	tree 10-
	Chlorophora excelsa			timber	tree to
	Ficus exasperata	fig	Msasa	shade, fuelwood	tree to
	F. natalensis		Mfumu	shade, ritual tree	tree 15-
	F. vallis-choudae		Mkuu	shade, fuelwood	tree 16-
	Morus alba	mulberry	Ipala, Wero, Iwero	boundary marking, hedges, edible fruits	tree to
MUSACEAE	*Musa nana*)	banana/	Kiguruwe	edible fruits, fodder	
	M. paradisiaca)	plantain	Mshare	fodder	
MYRTACEAE	*Eucalyptus camaldulensis*		Mkaratusi	fuelwood, poles, crushed leaves relieve colds	
	E. citriodora		Mkaratusi	fuelwood, poles, crushed leaves relieve colds	
	E. grandis		Mkaratusi	fuelwood, poles, crushed leaves relieve colds	
	E. robusta		Mkaratusi	fuelwood, poles, crushed leaves relieve colds	
	E. saligna		Mkaratusi	fuelwood, poles, crushed leaves relieve colds	
	Myrica salicifolia		Mkaratusi	fuelwood, medicinal	
	Psidium guajava	guava	Mpera	edible fruits, fuelwood	tree to
			Mwisi, Mmasi	fuelwood, edible fruits	tree to
OLEACEAE	*Olea capensis*		Loliondo, Mchio	timber, fuelwood, poles, withies	tree 20-
PASSIFLORACEAE	*Passiflora edulis*	Jack fruit	Isapiku	edible fruits	climber
PROTEACEAE	*Grevillea robusta*	Australian silky oak	Mkawilia	timber, shade, fuelwood	tree to 30 m

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Table 1 (Cont'd)

Family name	Botanical name	Common name	Vernacular name	Uses	Remarks
ROSACEAE	*Eriobotrya japonica*	loquat	Sambia?	edible	
			Mstafeli	edible fruits, fuelwood	tree [illegible]
	Rubus steudneri		Mawero	hedge, edible fruits	shrubs
RUBIACEAE	*Coffea arabica*	coffee	Mkahawa	coffee, fuelwood	
	Pentas lanceolata		not available	weed, ornamental	
	Vangueria madagascariensis		Ndawiro, Ndoro	fuelwood, edible fruits	tree [illegible]
RUTACEAE	*Citrus limon*	lemon	Mlimau, Ndimu	edible fruits, fuelwood	
	C. sinensis	sweet orange	Mchungwa, Ichungwa	edible fruits, fuelwood	
SOLANACEAE	*Capsicum annuum*	red pepper	Mpilipili	spices	
	C. frutescens	bird chillies	Ngogwe	edible fruits	
	Datura arborea		not available	boundary marking	tree [illegible]
	Lycopersicon esculentum	tomato	Mnyanya	edible fruits	
	Nicotiana tabacum	tobacco	Mbatu	snuff and tobacco	
	Solanum incanum		Nduo	medicine for stomach ache and anti-snake bites	shrub [illegible]
	S. nigrum		Nafu	vegetable	
ULMACEAE	*Trema orientalis*		Mrisio	fodder, fuelwood	fast-growing tree [illegible]
VERBENACEAE	*Lantana camara*		Singarere	hedge, grave marking, weed	shrub [illegible]

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