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PROGRESS REPORT NO. 9

October-December, 1984

USAID/ICRAF COOPERATIVE AGREEMENT

No. DAN-5545-A-00-2075-00

PROJECT NO. 936-5545

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1. INTRODUCTORY NOTES (E. Zulberti)

This is the 9th report of the USAID/ICRAF Cooperative Agreement. Project No. 936-5545, for the period October-December, 1984.

According to the three year agreement which became effective as of 1 September 1982, ICRAF receives support from USAID for three projects of ICRAF's Programme of Work. These are:

- Agroforestry Training
- Diagnostic and Design Methodology Development
  and
- Agroforestry Systems Inventory

The respective project leaders prepared the attached progress reports for the three projects. The third ICRAF/USAID Agroforestry Course was held in October in Malaysia and the second ICRAF/USAID Course report was written and disseminated. Further conceptualization, documentation and dissemination of the D&D methodology through training and participation of ICRAF staff in international meetings added an important dimension to the development process of the D&D. The data evaluation phase of the Systems Inventory Project is ongoing; several methods for computer coding of data were tried and analyzed systems data is being coded and stored on the IBM PC microcomputers.

Following the individual project progress reports is the financial statement for the period.

2. AGROFORESTRY TRAINING (E. Zulberti)

The main activities of the October-December period focused on the implementation of the third ICRAF/USAID Agroforestry Course held in Serdang, Selangor, Malaysia from 1 to 19 October 1984. Hosted by the Universiti Pertanian Malaysia (UPM), the course was jointly organized by the Forestry Faculty at UPM and ICRAF.

2.1 *First ICRAF/USAID Agroforestry Course, Kenya 1-18 November 1983.*

Follow-up activities cortinue (see previous quarterly reports). Analysis of returned questionnaires will begin in early 1985.

2.2 *Second ICRAF/USAID Agroforestry course, Kenya 4-22 June 1984.*

A report on the course above was printed and distributed during this quarter. It is a narrative report of activities undertaken week by week together with a description of the training materials distributed to participants and summary of evaluation results and recommendations. Copy of the report is in Annex 1. Follow-up activities are going on.

2.3 *Third ICRAF/USAID Agroforestry Course, Malaysia 1-19 October 1984.*

The third course on Agroforestry Research for Development was successfully held in Malaysia. Co-organized by ICRAF and the Universiti Pertanian Malaysia the course was attended by nineteen participants from COSPRO Collaborating countries/ institutions in the ASEAN region and India. A total of twenty two participants were expected to attend but unfortunately, three positions requested by USAID to nominate candidates from the region were not filled. Multidisciplinary country teams from Malaysia, Indonesia, Thailand, Philippines and India met at the Center for Continuing Education and Extension (PPPL) within the UPM campus. The list of participants is presented in Annex 2. The course programme followed the model of the previous courses. Activities began on 1 October with the official cpening session by the UPM Vice-Chancellor - Prof. Dr. Nayan Ariffin - and the Dean of the Faculty of Forestry - Assoc. Prof. Mohd Zin Jusoh. E. Zulberti addressed the audience on behalf of the Director of ICRAF.

National institutions from Malaysia provided a strong input to the course programme. Presentations were given by the Universiti Pertanian Malaysia (UPM), the Malaysian Agricultural Research and Development Institute (MARDI), the Rubber Research Institute Malaysia (RRIM) and the Forestry Research Institute (FRI). From ICRAF a team of three people (F. Torres, D. Hoekstra and E. Zulberti) participated in the course on a full time basis while four staff members (P.K. Nair, J. Raintree, P. Huxley and B. Lundgren) joined in for short periods according to the programme requirements. Dr. Napoleon Vergara, from the East West Center in Hawaii joined the course for the first two weeks. He gave a presentation on "MPT in Agroforestry". A course report is under preparation.

2.4 *Fourth ICRAF/USAID Agroforestry Course, Peru*
3-21 June 1985.

Following the course announcement (see last quarterly report) nomination of candidates are beginning to come in. E. Zulberti is to undertake a coordination mission to Yurimaguas in February '85..

2.5 *Fifth ICRAF/USAID Agroforestry Course, Kenya*
4-22 November 1985.

This is to be the last course under the ICRAF/USAID Agreement. In-house programme planning and coordination activities are already underway. The course is to be announced during the next quarter.

2.6 <u>Major Activities Planned for the next quarter</u>
(January - March 1985)

- Printing and distribution of the third ICRAF/USAID Agroforestry Course Report.

- A mission to Peru is to be undertaken to coordinate programme and administrative aspects of the fourth ICRAF/USAID Agroforestry Course.

- Start analysis of information of follow-up questionnaire sent to participants of the first ICRAF"USAID training course.

- Send follow-up questionnaire to participants of the second ICRAF/USAID Agroforestry Course.

- Print and disseminate a leaflet announcing the fifth and last ICRAF/USAID Agroforestry Course in institutions in Africa.

3. DIAGNOSTIC AND DESIGN METHODOLOGY (J.B. Raintree)

The focus of work in the D&D project this quarter was on review, documentation and dissemination of the methodology.

3.1 External and Programme Committee Reviews

The objectives, progress to date and future plans of the D&D project were subjected to intensive scrutiny by the External Review Team in the context of its overall review of ICRAF's activities. The Systems Programme and the D&D Project in particular were also the focus of an extended review session by the Programme Committee. Both reviews were helpful in consolidation an up to date perspective on the Project and both expressed general satisfaction with the timely accomplishment of Project objectives. The widespread dissemination of the draft D&D manuals was noted with approval, along with the integration of D&D with other components of the overall Programme of Work (i.e. the use of D&D in COSPRO missions and as a central module in the ICRAF short courses).

Among the constructive suggestions for further work were:

1) to give increased attention in future to the adaptation of the "prototype" methodology to the different needs and circumstances of different users;

2) to monitor the use of the methodology by collaborating institutions and to give special emphasis to efforts to

assist users in implementing the D&D logic throughout the entire progression from planning, to research, to the extension follow through;

3) to actively pursue the integration of D&D methods with land evaluation methods for agroforestry in order to develop a comprehensive approach to the planning and implementation of agroforestry systems at the full range of potential scales of application (i.e. household, local community/ecosystem, national and regional/zonal levels).

3.2 Documentation and Dissemination

Several opportunities arose during the quarter for the further documentation and dissemination of the methodology.

New training materials were prepared for the Malaysia short course (see addendum, previous quarterly report). The course featured a field application of D&D procedures by the participants which, with its focus on problems of joint land use in a forestry reserve, throught a new dimension into D&D training applications (previously concentrated on application to farming systems).

Dr. Rocheleau attended the Farming Systems Research Symposium at Kansas State University, October 7-10, and presented a paper entitled: "Criteria for Re-Appraisal and Re-Design: Within-Household and Between-Household Aspects of Farming Systems Research and Extension in Three Kenyan Agroforestry Projects" . In addition to being a very well received contribution to focus of the Symposium on aspects of implementation and monitoring in farming systems projects, the paper also represents an advance in the documentation of the "variable scale" and "feedback monitoring" aspects of the methodology, which was the primary focus of Dr. Rocheleau's Methodology development work over the past two years. These additions to the D&D methodology will be incorporated into the revised manuals in 1985.

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Another paper on "Land Use Planning with Rural Farm Families: Particularly Agroforestry Research", was presented by Dr. Rocheleau to the Workshop on the Role of Anthropology and Rural Sociology in Farming Systems Research, held October 26-28 in Zambia. This paper highlights communal aspects of the variable scale methodology for agroforestry development.

Dr. Raintree was invited to attend (as an observer) the restricted CGIAR meeting on "Inter-Center Consultation on the Use of System Oriented Research in Eastern and Southern Africa," held in Nairobi, October 18-20, and attended by researchers from CIAT, CIMMYT, CIP, ICRISAT, IFPRI, IITA, ILCA, IRRI and ISNAR. The purpose of the meeting was to review commonalities and differences among the various FSR methodologies used by these Centers and to arrive at a basis for a coordinated approach to work with national institutions in the region. Dr. Raintree prepared a paper entitled "Brief Notes on ICRAF's Diagnostic and Design Methodology for Agroforestry" (see Annex 3) which was distributed to all participants for comparison with their own methodologies. One interesting conclusion which can be drawn from this workshop is that the only Center whose methodology entails a specific and detailed focus on technology design, comparable to D&D, is IRRI (represented at the meeting by Dennis Greenland and Jim Hooper). What all the others mean by "design" is their terminologies is experimental design (which comes as a separate item under the "planning" stage of the D&D procedures). It is interesting to note the probable reason for this is that both ICRAF and IRRI deal with complex cropping systems (agroforestry and intensive rice-based systems), which necessitate a more explicit treatment of design considerations (in the engineering sense).

Dr. Raintree was also invited to attend an informal meeting on rapid appraisal of irrigation systems, organized by Robert Chambers, at the new International Irrigation Management Institute (IIMI) in Digana (near Kandy) in Sri Lanka, December

8-9. A presentation of the major lessons from the D&D methodology development at ICRAF by Dr. Raintree provided a focus for discussions on methodological approaches to irrigation systems (attended by the initial IIMI staff of 2 scientists and the Director General. Tom Wickham, and by Robert Chambers and Mick Moore of IDS).

Following the Sri Lanka meeting, Dr. Raintree went on the to the Philippines for the VI World Rural Sociology Congress, December 15-21, on the theme "Inter-Disciplinary Approaches to Development," In addition to chairing a session on "The Role of National and International Research in Rural Development Programs," Dr. Raintree also presented a paper for the final summary session ("A Systems Approach to Agroforestry Diagnosis and Design: ICRAF's Experience with an Interdisciplinary Methodology," see Annex 4). Considerable interest was expressed in the D&D methodology as an example of a workable interdisciplinary approach and important contacts were made (e.g. with Michael Cernea, Sociology Advisor to the World Bank and Odd Grande of IFAD).

Dr. Young presented a paper entitled "Evaluation of Agroforestry Potential in Sloping Areas" (see Annex 5) to the International Workshop on Land Evaluation for Land Use Planning and Conservation in Sloping Areas in the Netherlands in December. This paper contains a concise comparison of D&D methods with those of standard land evaluation surveys and concludes, among other things, that the methods of land evaluation appropriate to agroforestry must go beyond existing methods for rainfed agriculture and forestry to include an increased emphasis on existing land use patterns, a diagnosis of problems, and increased scope for a research component in the followup to the planning exercise in order to develop the agroforestry technologies needed to complement those presently suitable for immediate implementation. Aspects of the emerging lines of integration with D&D are outlining in this paper.

Opportunities for further conceptualization, dissemination and feedback from colleagues, which often take the form of invited papers at international meetings such as described above, are an important dimension of the continuing D&D development process.

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

4.1 Data Collection

Although the data collection phase has formally ended, efforts were continued, mostly as continuation of previously initiated acitivities. Some significant voluntary contributions were received including detailed descriptions on AF Systems involving babassu palm (Orbignya spp.) in Brazil, AF systems in Auroville, Tamil Nadu, India, and organic farming and AF systems in Rwanda.

4.2 Data Evaluation

Abstraction of all data sheets continued in order to transfer the primary data to the secondary data format mentioned in the previous QR (July-September 1984). This work is in progress both at ICRAF and the University of Reading, U.K. It needs to be emphasized that this extraction and transformation of primary data (Co-ordinator returns and other reports) is an essential step in computerisation of the data.

4.3 Data Bases

The computer program for storing the system data was devised; transfer of data from the secondary data format to the computer has started. Examples of two such computerized data registers are appended as Annex 6 and 7.

4.4 Systems Description Series

Six system descriptions have already appeared in Agroforestry Systems vol. 2, nos. 2 and 3. Copies of nos. 1 and 2 of the Series are appended as Annex 8 and 9.

A paper entitled "Dynamics of fallow successions and introduction of robusta coffee in shifting cultivation areas in the lowlands of Papua New Guinea" by B.J. Allen was sent to the journal as No. 9 of the Systems Description Series. (Annex 10). Work on several other papers in the Series is in progress.

4.5 Other Outputs

- P.K. Nair delivered a lecture on global overview of AF Systems to the ICRAF/USAID training course in Malaysia, October 1984 and moderated the participants' presentations of country reports on existing AF systems.

- Various outputs from the AFSI project were distributed to the participants of the training course e.g. slide sets, system descriptions and other training materials.

- P.K. Nair, who is a member of the Commission on Ecology (COE) of the International Union for Conservation of Nature and Natural Resources (IUCN) participated in the COE meeting on November 3-5, 1984, on the occasion of IUCN General Assembly in Madrid and presented the theme paper "Agroforestry", which contained some results of AFSI project.

- The progress of the project was evaluated by ICRAF's Programme Committee in December, 1984.

4.6 Major Items of Work Planned for Next Quarter

- Continuation of data evaluation
- Computerization of Systems data
- Up-dating of data bases
- Formulation of programmes for publication of final output(s) of the project
- Publication of more system descriptions in AFS journal

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

14th January, 1985

Ref: ADM/3841/USAID

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

Dear Sir,

RE: ICRAF COOPERATIVE AGREEMENT NO. DAN-5545-A-00-2076-00

Enclosed please find the original and two copies of the project financial implementation report as at 31 December 1984 and the request for advance for expenditure in the first quarter of 1985.

Yours faithfully,
International Council for Research in Agroforestry

R.J. Trundell
Acting Treasurer

Encls:

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Standard Form 1034
Revised January 1980
Department of the Treasury
1 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: 10th January, 1985

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

REQUISITION NUMBER AND DATE: SEPTEMBER 14, 1982 and amend No. 1dd 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 of 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 January to 31st March, 1985 (see attached signed project implementation report)				US$52,822

(Use continuation sheet(s) if necessary) **(Payee must NOT use the space below)** TOTAL US$52,822

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

APPROVED FOR =$

EXCHANGE RATE =$1.00

DIFFERENCES

BY [2]

TITLE

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)[2] (Title)

ACCOUNTING CLASSIFICATION

PAID BY

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

CASH $ | DATE | PAYEE [3]

[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

GPO : 1981 O - 361-526 (7302)

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.

(2)

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

PROJECT FINANCIAL IMPELEMENTATION REPORT

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

APPROVED BUDGET LINE ITEM	AMOUNT 1	BUDGETED 2	DISBURSEMENTS (US$) 3	4	5	6
	US$	KSHS	Prior cumulative US$	This period US$	Cumulative Thro' US$	Estimate Next 90 days US$
1. Salaries	444,525	-	391,430	17,242	408,672	15,000
2. Consultants	104,000	-	95,313	-	95,313	3,000
3. Trav and Transportation	103,500	-	54,717	18,874	73,591	15,000
4. Equipment, materials & Supplies	107,240	-	90,072	1,978	92,050	10,000
5. Participant training	63,400	-	56,030	6,645	62,675	-
6. Overhead	162,335	-	136,607	8,948	145,555	8,600
7. Evaluation	15,000	-	12,568	-	12,568	-
TOTAL	1,000,000	-	836,737	53,687	890,424	51,600

Estimated disbursements thru (columns 5 & 6) March 31, 1985	US$ 942,024
Less cash advances received thru/disbursements to 31.12.84	US$ 889,202
Cash advance/requested	US$ 52,822

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 review by US Government representatives upon request

Signature:
Name: BJORN LUNDGREN
Title: DIRECTOR
Date: JANUARY 10, 1985

INTERNATIONAL COUNCIL FOR
RESEARCH IN AGROFORESTRY

PROJECT FINANCIAL IMPLEMENTATION REPORT

COOPERATIVE AGREEMENT NO: DAN-5545-A-00-2076-00
PROJECT NO. 936-5545

APPROVED BUDGET/LINE ITEM	AMOUNT	EXPENDITURE TO DEC 31 1984				
	US$	TOTAL EXPENDITURE	SUB PROJECT (1) DIAGNOSTIC & DESIGN METH.	SUB PROJECT (II) SYSTEMS INVENTORY	SUB PROJECT (III) TRAINING MATERIALS	SUB PROJECT (IV) TRAINING COURSES
1. Salaries	444.525	408,672	194,400	76,382	83,700	54,190
2. Consultants	104,000	95,313	-	95,313	-	-
3. Travel and transportation	103,500	73,591	-	47,247	-	26,344
4. Equipment, materials supplies	107,240	92,050	43,889	18,965	17,295	11,901
5. Participant training	63,400	62,675	-	-	-	62,675
6. Overhead	162,335	145,555	47,246	47,815	19,963	30,531
7. Evaluation	15,000	12,568	-	-	-	-
TOTAL	1,000,000	890,424	285,535	285,722	120,958	185,641

Total expenditure as at December 31	US$ 890,424
Total advances or disbursements received at that date	US$ 889,202
Deficit	(1,222)

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

Signature:

Name: BJORN LUNDGREN
Title: DIRECTOR

ICRAF

INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY
CONSEIL INTERNATIONAL POUR LA RECHERCHE EN AGROFORESTERIE
CONSEJO INTERNACIONAL PARA INVESTIGACION EN AGROSILVICULTURA

P.O. Box 30777 Nairobi Kenya Telephones 29867 332858/332304 Cable ICRAF

REPORT ON THE SECOND ICRAF/USAID AGROFORESTRY COURSE

4–22 JUNE 1984

NAIROBI

by

ESTER ZULBERTI

with

JAMES WAHOME

SEPTEMBER 1984

REPORT ON THE SECOND ICRAF/USAID AGROFORESTRY COURSE

4-22 JUNE 1984

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SEPTEMBER 1984

II

THE AGROFORESTRY COURSE IN PICTURES*

Registration Day

Participants filling pre-course forms

* This is a compilation of pictures taken and so arranged as to record the main activities of the Course. Unless otherwise stated, acknowledgement for photographs goes to Dr. Ester Zulberti.

The Conceptual and Technical Background of Agro-forestry

An introduction to Technology and Agroforestry by Dr. Peter Huxley

Dealing with the Environmental Base of Agroforestry with Dr. Anthony Young (standing) and Applied Meteorology for Agroforestry with Dr. Till Darnhofer (sitting, wearing glasses)

IV

Field Trips

Observation of agroforestry systems in the tea-producing areas of Kiambu District

At Mr. Mbogo's farm participants observed terrace risers stablilized with napiergrass; bananas planted in channel in fron of terrace risers; and bananas on terrace planted in holes.

At the ICRAF Field Station in Machakos

Being introduced to the Field Station by Dr. P.K. Nair

A demonstration tour of multipurpose tree species. Mr. Peter Wood explains to the participants some of the most relevant characteristics of Prosopis juliflora

This will shortly be our tree nursery, explains Mr. Peter von Carlowitz (third from the left, standing by the pole).

VII

ICRAF's Diagnostic and Design Methodology

Presentation of the India Case Study by Dr. Dianne Rocheleau. The exercise gave participants an understanding of what to expect with a D&D application.

Field Survey

Interviewing farmers around the Kakuyuni site.
(Photo E. Fernandez)

Carrying out more house-hold interviews, under the friendly shade of a tree.
(Photo E. Fernandez)

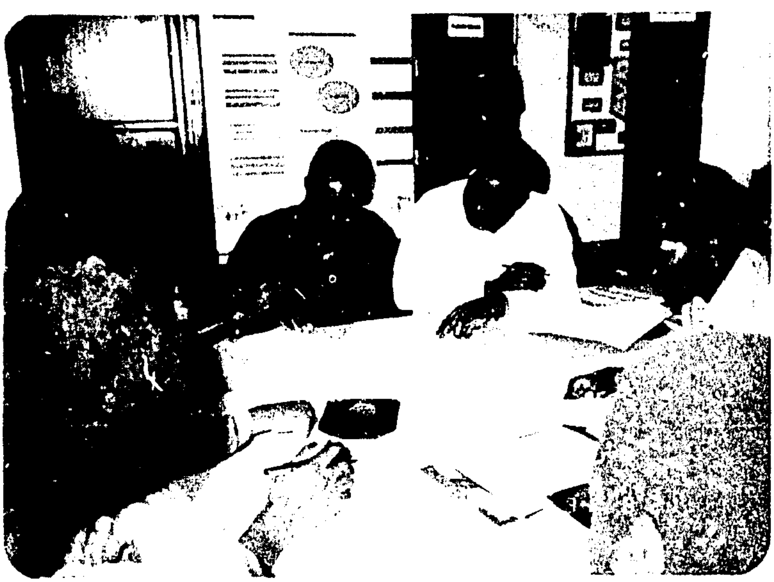
A tented camp was set up on the grounds of a school of the Undugu Agricultural Society in Katangi Market, where participants and ICRAF staff spent one night while undertaking the two-day field survey.

The setting was a good occasion for participants' interactions, (from left to right) Dr. Arap-Sang from Kenya seen chatting with S. Adegbanke from Nigeria & G. Agbahungba from Benin.

Lively discussions took place around the fire!

It was hard to believe, but the group ate three goats!

Back in Nairobi, each field team met to diagnose land use problems and design specifications for problem-solving interventions. Dr. J. Raintree (sitting by the blackboard) leads the analysis by this working group. (Photo E. Fernandez)



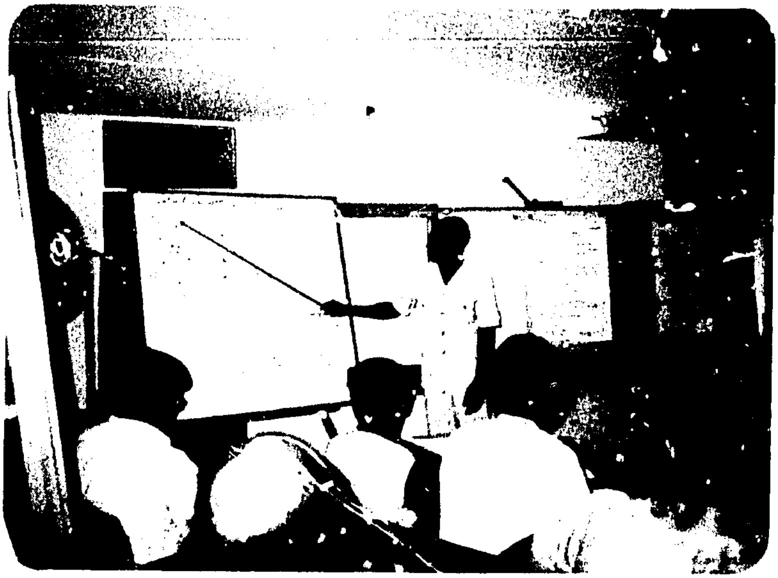
The group of participants worked out the diagnostic analysis and design recommendations for the farming system they surveyed.

Economic Appraisal of Selected Agroforestry Interventions

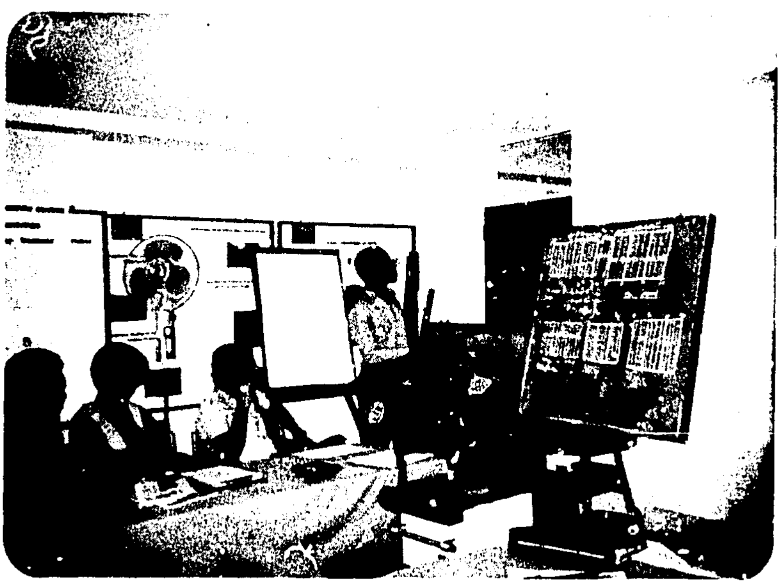
Ir. Dirk Hoekstra introduces the participants to MULBUD

Hands-on experience with the computer!

Plenary sessions



Participants' presentations of diagnosed problems and potential interventions for system improvement.



Participants' presentations and discussion of experimental approaches to generate agroforestry technology.

Participants Consultations with ICRAF staff

Ing. Manuel Villavicencio from PERU & Dr. P.K. Nair

Georges Agbahungba from BENIN & Ir. Dirk Hoekstra

The Library

A place frequented for consultation of books, journals, and other documents.

... as well as for social interaction with colleagues.

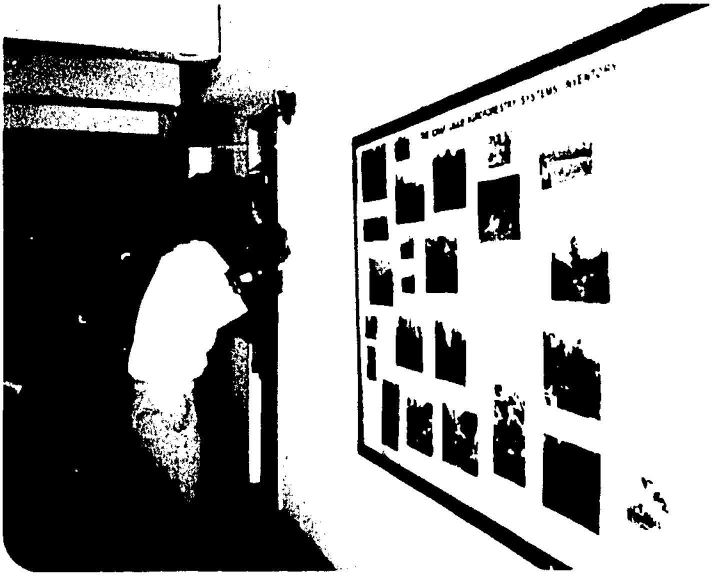
Last Day - Closing Session

Participants' final evaluation and recommendations
(Photo E. Fernandez)

Certificates of Attendance...
(Photo E. Fernandez)

Dr. John Raintree, Officer-in-Charge, during the closing session...Time to say Good-bye, Adios, Kwaherini, Au revoir...
(Photo E. Fernandez)

Farewell reception...



Just before I leave, I would like to take a picture of a live fence of Erythrina abyssinica in Ethiopia...said Imadeldin Abunaib from SUDAN, and so he did!

END

REPORT ON THE SECOND ICRAF/USAID AGROFORESTRY COURSE

4-22 JUNE 1984

by

ESTER ZULBERTI

with

JAMES WAHOME

SEPTEMBER 1984

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CONTENTS

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1. INTRODUCTION

1.1 BACKGROUND

The Second ICRAF/USAID Training Course on Agroforestry Research for Development was held in Nairobi, Kenya from 4 to 22 June 1984. It was carried out as part of a series of training courses launched by the International Council for Research in Agroforestry to disseminate available knowledge on Agroforestry practices and systems, and on methods for assessing land use problems and evaluating agroforestry potentials. Like the previous one*, it was made possible through a Cooperative Agreement between ICRAF and the United States Agency for International Development (USAID). It was organized by ICRAF.

ICRAF's multidisciplinary scientific and professional team participanted in the development of the training programme covering a wide range of conceptual, methodological and practical aspects of agroforestry. The co-ordinator of the course was Dr. Ester Zulberti, ICRAF's Training Officer.

1.2 PARTICIPATION

Twenty-four professionals from Africa and Latin America attended the course. The distribution of participants by countries was as follows: Benin (1), Botswana (1), Costa Rica (1), Ghana (1), Kenya (5), Liberia (1), Nigeria (2), Peru (2), Senegal (1), Sudan (2), Tanzania (1), Uganda (3) and Zimbabwe (2). A complete list of participants - including invited speakers and members of ICRAF staff - 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 for initiating and implementing agroforestry research, leading to the development

* The First ICRAF/USAID Agroforestry Course was held in Nairobi from 1 to 18 November 1983. For further information see Ester Zulberti: Report on the First ICRAF/USAID Agroforestry Course, January 1984.

of systems and technologies that are both suited to local conditions and adoptable by farmers.

To accomplish the above objective participants were exposed to:

- the concepts and practices of agroforestry as a land use system;
- ICRAF's methodology to diagnose agroforestry-related land use problems and potentials and the design of appropriate interventions to overcome the diagnosed constraints (the D&D Methodology);
- available agroforestry research information; and
- appropriate experimental approaches to generate agroforestry technology.

2. PROGRAMME

2.1 REGISTRATION DAY

Participants reported to ICRAF headquarters in Bruce House, Nairobi, on Monday 4 June for registration. There they had their first chance to get acquainted with some of the ICRAF senior and support staff; they received the package of training materials, general information about the course and settled administrative and financial matters with the Course Coordinator. All participants were accommodated at the Sixeighty Hotel, across the street from ICRAF. An evening reception was held at Dr. Zulberti's residence to welcome participants.

2.2 OPENING SESSION

It took place on the morning of Tuesday June 5. Dr. Peter Huxley, Officer-in-Charge, highlighted the Council's efforts in training research scientists and development planners from developing countries and declared the course officially open.

The Course Coordinator then provided the participants with a technical overview of the programme, outlining the objectives of the event and the steps that have been taken to reach these goals; she also introduced ICRAF's Role and Programme of Work. The rest of the morning was devoted to participants' self-introductions. A very positive relationship evolved as a result of this exercise where individual members highlighted their current professional activities and agroforestry interests.

2.3 STRUCTURE AND CONTENT

The focus of the course was on ICRAF's multidisciplinary methodological approach to land use systems and technology development, in particular, on how to undertake the interdisciplinary identification of priorities for research to develop and test sound agroforestry technologies to fill the identified gaps.

The programme was organized in three modules; the scope and sequence of content for each module is indicated in Table 1.

Three field trips were undertaken during the first week (module I) to complement classroom presentations. They provided the opportunity to observe a wide range of land use systems - from the fertile coffee - and tea - producing uplands of Kiambu District to the semi-arid regions of Machakos District. Dr. Lill Lundgren, Regional Soils conservation Adviser with the Swedish International Development Agency (SIDA), provided the participants with an introduction to soil conservation in Kenya, followed by field observations in the Kiambaa Division of Kiambu District. At the ICRAF Field Station participants visited the demonstration plots on multipurpose trees and were introduced to on-going activities related to microclimate monitoring and soil sampling and monitoring in agroforestry.

ICRAF's rapid appraisal Diagnostic and Design Methodology (module II was introduced at the beginning of the second week of the course. The sequence of activities as they occurred was as follows:

- Introduction to the D&D conceptual framework and methodological procedures by Dr. John Raintree;
- Example of a D&D application, specifically the India Case Study, by Dr. Dianne Rocheleau;

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Table 1.

SCOPE AND SEQUENCE OF CONTENT

MODULE	MAIN TOPIC	PROVIDED ANSWER TO	@DURATION
I	The Conceptual and Technical Background of Agroforestry	. What is Agroforestry? . What are some of the existing systems and practices? . What is the role of (trees, crops, animals, economics, the human factor, etc) in agroforestry?	4 days
II	The Diagnostic and Design Methodology	. What is the conceptual framework? . What are the steps and stages? . What examples are there of D&D applications and with what results? (Case studies). . How does it work in practice?	7 days
III	Appropriate Experimental Approaches to Generate Agroforestry Technology	. What do we know that can be of immediate use? . What appropriate experimental designs to generate agroforestry technology?	3 days

- Pre-diagnostic analysis of the Kakuyuni Case Study. Baseline information on the project site was presented by Dr. Anthony Young and Dr. Till Darnhofer and discussed among participants in preparation for the field survey;
- Organization of Field Survey teams in four small multidisciplinary groups to carry out interviews with farmers (see Annex 2).
- Field Survey was carried out during two consecutive days (Tuesday 12 and Wednesday 13 June) at the site of the Kakuyuni Agroforestry Project. A tented camp was set up in the grounds of an Agricultural School in Katangi where the participants and ICRAF staff spent one night. The "safari" type of arrangement fully justified the organizational efforts involved, as the group had a lively interaction with the ecological as well as the human environment in the area.
- Diagnostic and Design exercises were carried out in four simultaneous working groups (the same field survey teams) with the aim of evaluating diagnosed land use problems, design specifications for problem-solving interactions, analyzing technology options to address the identified design specifications, and evaluating design alternatives to select 'best bet' options.

Following the steps above, Ir. Dirk Hoekstra led the course participants into the "economic appraisal of selected agroforestry interventions". A full day (Tuesday 19 June) was spent in the economic analysis and practical MULBUD exercises.*

The next step in the development of the programme was to identify research needs to generate the required technology, wherever it was not readily available, and to discuss specific research planning and implementation of investigations (module III). During two full days (Wednesday 20 and Thursday 21 June) participants and ICRAF staff addressed themselves to such questions as:

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* MULBUD is an interactive package designed to assist in the economic appraisal of land use systems involving trees, either as 'sole' enterprises or in combination with other enterprises.

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- What do we need to know about planning field trials that have different spatial arrangement? (Dr. Peter Huxley and Mr. Peter Wood)
- How can we experiment on tree/crop mixtures? (Dr. Peter Huxley)
- What environmental/social factors do we need to measure and how? (with Drs. Dianne Rocheleau, Anthony Young and Till Darnhofer)

Working groups were assembled to develop experimental models for three selected agroforestry technologies based on problems identified during the Diagnostic stage. The topics for the design models were: a) species/provenance trials; b) hedgerow intercropping; and c) fodder. Conclusions of the groups were presented in a plenary session on Thursday 21 June. The pre-established focus of the course on ICRAF's D&D methodology did not allow for further involvement in technology generation issues, which justifiably merit a separate training course.

The course timetable and the detailed day-to-day account of the programme activities and responsible staff involved can be found in Annex 3 of this report.

2.4 PARTICIPANTS' CONSULTATIONS WITH ICRAF SCIENTIFIC STAFF

Time was assigned during the three-week period for participants to consult with ICRAF scientific staff on matters of their own professional interest. Meetings were arranged either on an individual basis (participant and ICRAF staff) or in a collective way (small group of participants and ICRAF staff). Consultations covered a wide range of issues - from discussions on site-specific agroforestry research problems and/or potentials to gathering of information/references on particular agroforestry aspects, e.g. tree species, provenances, etc.

2.5 SPECIAL ACTIVITIES

During the course period participants were guests of different ICRAF staff on several occasions. Fun-tours to wild animal reserves were also organized. Tourist attractions in and around Nairobi were visited over the weekends, especially by those participants visiting Africa and/or Kenya for the first time.

2.6 MONITORING

Monitoring procedures were applied throughout the development of the three-week course with the aim of detecting programme deficiencies, if any, and applying corrective measures in time. Formative evaluations were carried cut by the Course Coordinator at the end of the first, second and third modules as part of the programme of activities. Minor adjustments were introduced in the programme as a result of this action; on the whole, the structure and content remained as originally planned.

2.7 FOLLOW-UP

On the morning of Friday 22 June, ICRAF staff met with the group of participants to discuss possible follow-up actions. A double channel of communication between ICRAF and the participants was identified as highly desirable to: a) provide ICRAF with feed-back information on the extent to which the course knowledge/methods are put into use by participants upon return to their home country institutions; b) update participants on agroforestry research developments; and, c) identify possible cooperative activities between ICRAF and national institutions in developing countries. Agreement was reached on the following specific actions:

- ICRAF will include all participants' on the Council's mailing list;
- ICRAF will send a follow-up questionnaire (see Annex 4) to all participants 4-6 months after the end of the course;
- Participants will send to the Training Unit at ICRAF a copy of the reports presented to their respective institutions with detailed recommendations on possible agroforestry research alternatives and potentials at national/regional levels:

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

2.8 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 course. An evaluation form was enclosed in the training package handed out to participants. A copy of this form will be found in Annex 5 of this report.

Twenty-three evaluation forms were filled and returned. In general, participants expressed very positive comments about the course. Particularly appreciated was the informal and friendly atmosphere which made it easy for direct relationships to be quickly established among the participants and ICRAF staff involved.

The detailed evaluation information is presented in Annex 6. A summary of participants' main observations and recommendations is given below.

- the course objectives - as defined - were considered relevant to the participants' professional activities and they were fully achieved;
- pre-course information was, in general, adequate; some recommendations to complement the information package were made;
- the course was considered 'too short'; recommendations for lengthening the duration go from 4 to 6 weeks more;
- the training materials were adequate;
- the distribution of participants by discipline and sex should improve to reduce the bias towards foresters and male participants;
- more time was in general, requested for Experimental Designs

in Agroforestry, Economic Appraisal, and consultations with ICRAF staff.

2.9 CLOSING SESSION

The official closing address was given by Dr. John Raintree, Officer-in-Charge. Course participants were presented with certificates of attendance by ICRAF staff. A farewell reception was then held for participants and the 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 - under the ICRAF/USAID Cooperative Agreement - to develop such training materials. This is 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. A preliminary version of this package was developed and tested during the First ICRAF/USAID Agroforestry Course. Training materials were placed in a two-ring binder to be used as a portable system which could be easily revised and to which important information could be easily added.

Dividers were established to identify modules on "Technical and Conceptual Background of Agroforestry", "Diagnostic and Design Methodology", and "Experimental Approaches in Agroforestry". For each module the training materials included main notes or key articles, practical exercises (case studies, field trips, MULBUD) and a list of recommended readings or references. Additional information and hand-outs were provided during the daily activities.

A slide set on "Agroforestry Practices and Systems in Developing Countries" was made available from the on-going ICRAF global Agroforestry Systems Inventory project, also sponsored by the ICRAF/USAID Cooperative Agreement. The 20 - slide set, plus a two-page description of the main systems involved, had a nominal cost of USD 3.00.

As mentioned at the beginning of this Report ICRAF is in the process of developing the model of a training course on Agroforestry Research and Development, together with the training materials. Both are still undergoing testing/trial as they are expected to be in its final form for distribution by the end of the ICRAF/USAID Agreement in late 1985. Thus, the decision was reached not to enclose copy of the training material with the present report but rather to include a list of the main articles, documents, working papers etc. used which can be made available to the general public on request. (See Annex 7.)

ANNEX 1.

LIST OF PARTICIPANTS

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22. VILLAVICENCIO, Manuel
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PERU

23. WANDERA, Foustine
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24. YAHIA, Abdalla
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(Annex 1 cont.)

ICRAF STAFF AND INVITED SPEAKERS

1.	Dr. Bjorn Lundgren	Director
2.	Mr. Peter von Carlowitz	Forester
3.	Dr. Till Darnhofer	Bioclimatologist/Agrometeo-rologist
4.	Mr. Denis Depommier	Forester
5.	Ir. Dirk Hoekstra	Farm Economist
6.	Dr. Peter A. Huxley	Horticulturist/Agronomist
7.	Dr. P.K.R. Nair	Agronomist/Soil Scientist
8.	Mr. Richard C. Ntiru	Publications Officer
9.	Dr. John Raintree	Ecological Anthropologist
10.	Dr. Dianne Rocheleau	Geographer/Systems Ecologist
11.	Dr. Filemon Torres	Range Management/Livestock Production
12.	Mr. Peter Wood	Forester
13.	Prof. Anthony Young	Land Evaluation/Soil Scientist
14.	Dr. Ester Zulberti	Training Officer
15.	Dr. Lill Lundgren	Regional Soil Conservation Adviser/SIDA

ANNEX 2

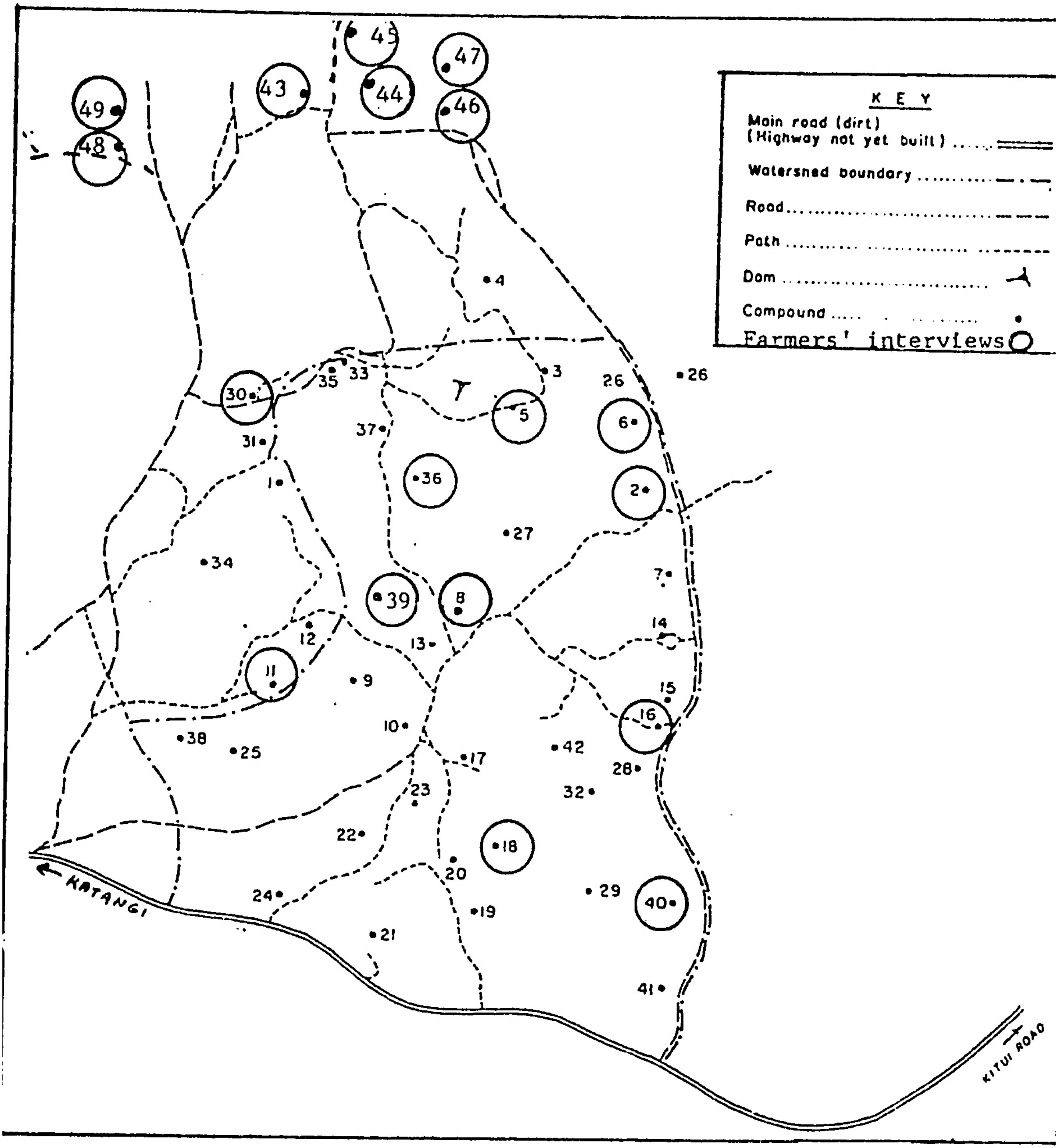
FIELD EXERCISE IN KAKUYUNI: group organization and farmers identification

GROUP NO.	GROUP LEADERS (Interpreters)	PARTICIPANTS	FARMERS TO INTERVIEW			
			TUESDAY 12		WEDNESDAY 13	
			FARMER'S NAME	HOUSEHOLD NO.*	FARMER'S NAME	HOUSEHOLD NO.*
1. LARGE FARMERS	Ester Zulberti Richard Mwendandu	ABUNAIB SAUNGWEME MHUNGU GARCIA VILLAVICENCIO NYAMAI	1. Mwangi Munyoki 2. Kaumbalu Katunda	40 16	3. Munyao Nzima 4. Kilei Mutisya	47 44
2. LARGE FARMERS	Dirk Hoekstra (Joseph Mutinga)	AGBAHUNGBA MORAPEDI OYATOGUN WANDERA CHAMSHAMA KIRIINYA	1. Mbomu Mutinda 2. Kimweli Mbithulia	49 48	3. Mukilya Kaula 4. Mbithi Ngeam	2 6
3. SMALL FARMERS	Dianne Rocheleau (Jackson Wambua)	OKORIO KADZICHE MOMO BA BIRIR KASOLO	1. Mbuya Iyuva 2. Koti Ngee	43 45	3. Maingi Mwilu 4. Kimonyi Ndolo	18 46
4. SMALL FARMERS	Peter von Carlowitz (Joyce Mutinda)	CHACHU MUNOZ ARAP-SANG ADEGBANKE YAHIA OMARA-OJUNGU	1. Matia Wambua 2. Mutiso Luvai	5 8	3. Muia Kithumbi 4. Ngului Nzeki	36 39

* See map

(Annex 2 cont.)

KAKUYUNI WATERSHED WITH HOMES, ROADS, PATHS



ANNEX 3

TIMETABLE

		MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
FIRST WEEK	morning	(June 4) PARTICIPANTS ARRIVE	(June 5) .Opening session, introduction to the course and participants introductions	(June 6) Agroforestry field trip	(June 7) .Concepts in AF technology a)environment b)soils	(June 8) .Participants' consultations with ICRAF Staff	(June 9) A visit to ICRAF's Field Station in Machakos & Nairobi Game Park	(June 10) FREE
	afternoon	AND REGISTRATION	.ICRAF Programme .The concept of AF	.Overview of AF systems in LDC .Participants' consultations with ICRAF Staff	c)multipurpose trees d)animals e)tree/crops f)economics	.Field trip to Kiambaa Division		
	eve.	Reception	Independent work			Return to Nairobi		
SECOND WEEK	morning	(June 11) .First week review .Introduction to the D&D methodology	(June 12) Field Survey in the Kakuyuni	(June 13) Field Survey continued.	(June 14) .Diagnostic Analysis (in working groups)	(June 15) .WG's presentations and discussion of potential intervention points	(June 16) FREE	(June 17) FREE
	afternoon	.The India Case Study .Pre-diagnostic information on the Kakuyuni area	area.			.General "systems specifications" for candidate technologies.		
	eve.		Overnight	Return to Nairobi				
THIRD WEEK	morning	(June 18) .Identification of candidate technologies & service functions	(June 19) .Economic appraisal of selected agroforestry interventions	(June 20) .Planning research on species and provenances	(June 21) .Experimental designs for selected AF technologies	(June 22) .Last participants consultations with ICRAF Staff	(June 23) PARTICIPANTS LEAVE	(June 24)
	afternoon	.General technology specifications .Scientific & technical information sources	.MULBUD exercise	.Planning field trials .Environmental & Social factors in technology generation		.Course evaluation .Closing session & certificates FAREWELL		
	eve.	.Second week review						

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: MONDAY 4th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
	Registration Day	Ester Zulberti Amina Musa
19.30	Reception at Dr. Zulberti's residence	

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: TUESDAY 5th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.30-09.30	Opening session	Peter Huxley Officer-in-Charge
	Introduction to the course: objectives, structure and organization.	Ester Zulberti
09.30-10.15	Participants introductions and description of professional activities and agroforestry interests.	Participants
10.15-10.45	Coffee break	
10.45-11.45	Continued	
11.45-12.30	ICRAF's Role and Programme	Ester Zulberti
12.30-14.00	Lunch	
14.00-15.30	The Concept of Agroforestry	Filemon Torres
15.30-16.00	Coffee break	
16.00-16.15	Introduction to ICRAF Library	Stephen Okemo
	Independent work	Participants

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AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: WEDNESDAY 6th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.30-12.00	An agroforestry field trip to Kiambu District	Peter Huxley P. von Carlowitz Ester Zulberti
12.30-14.00	Lunch	
14.00-15.30	An overview of agroforestry systems in developing countries	P.K.R. Nair Erick Fernandez
15.30-16.00	Coffee break	
16.00-	Participants' consultations with ICRAF staff	

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AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: THURSDAY 7th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.30-09.00	Technology for agroforestry: an introduction	Peter Huxley
09.00-10.00	The environmental basis of agroforestry	Anthony Young
10.00-10.30	Coffee break	
10.30-11.30	Soil productivity aspects of agroforestry	P.K.R. Nair
11.30-12.30	Multipurpose trees: opportunities and limitations	P. von Carlowitz
12.30-14.00	Lunch	
14.00-14.45	Animal production in agroforestry systems	Filemon Torres
14.45-15.30	Tree/crop mixtures - The benefits (or otherwise) of mixed marriages	Peter Huxley
15.30-16.00	Economics and agroforestry	Dirk Hoekstra
	Independent work	Participants

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: FRIDAY 8th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.30-09.30	Introduction to a field trip on soil conservation	Lill Lundgren
09.30-10.15	Participants' consultations with ICRAF staff	
10.15-10.45	Coffee break	
10.45-11.30	Continued	
11.30-13.00	Lunch	
13.00-17.00	Field trip to Kiambaa Division	Lill Lundgren Peter Wood Ester Zulberti

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: SATURDAY 9th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.15	Departure from Nairobi	
	A visit to ICRAF's Field Station in Machakos District	
	- Introduction to the Field Station	P.K.R. Nair
	- Visit to the demonstration plots	P.K.R. Nair P. von Carlowitz Peter Wood
	- Microclimate monitoring	Till Darnhofer
	- Soil sampling and monitoring	Anthony Young
12.30-13.30	Lunch at the Field Station	
13.30-	A visit to Nairobi National Park and return to hotel	Ester Zulberti

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AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: MONDAY 11th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.30-09.00	Review of first week	Ester Zulberti
09.00-10.15	Introduction to ICRAF's Diagnostic and Design Methodology	John Raintree
10.15-10.45	Coffee break	
10.45-12.30	Independent work	Participants
12.30-14.00	Lunch	
14.00-15.30	An example of a Diagnostic and Design application: the India Case Study	Dianne Rocheleau
15.30-16.00	Coffee break	
16.00-17.00	Pre-diagnostic information	Anthony Young Till Darnhofer

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AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: TUESDAY 12th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.00-10.00	Travel to the Kakuyuni area	Group leaders & ICRAF staff
10.00 onwards	Diagnostic survey in four working groups	
	(Overnight at Kakuyuni)	

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AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: **WEDNESDAY 13th June, 1984**

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.00-12.00	Diagnostic survey continues in four working groups	(Same as previous day)
12.00-14.00	Lunch in Machakos town	
14.00-15.00	Return to Nairobi	

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AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: THURSDAY 14th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.30 onwards	Diagnostic analysis (in four working groups)	
10.00-10.30	Coffee break	
12.30-14.00	Lunch	
15.30-15.45	Coffee break	

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: FRIDAY 15th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.30-10.00	Group presentation and discussion of problems and potential intervention points for system improvement	Dirk Hoekstra
10.00-10.30	Coffee break	
	Continued	
12.30-14.00	Lunch	
	Continued	
15.00-15.30	Coffee break	
15.30-17.00	General "systems specifications" for candidate technologies	John Raintree

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: MONDAY 18th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.30-10.00	Identification of candidate technologies and service functions (within existing system)	John Raintree
10.00-10.30	Coffee break	
10.30-12.30	General technology specifications	Peter Huxley Peter Wood
12.30-14.00	Lunch	
14.00-15.30	Scientific and Technical Information Sources. Data Bases	Richard Ntiru Anthony Young P. von Carlowitz
15.30-16.00	Coffee break	
16.00-16.30	Continued	
16.30-17.00	Second week review	Ester Zulberti

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: TUESDAY 19th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.30-09.30	Economic appraisal of a selected intervention	Dirk Hoekstra
09.30-10.30	Practical MULBUD exercise	Lubaina Fidaali Margaret Mutua Simeon Kanani
10.30-11.00	Coffee break	
12.30-14.00	Lunch	
14.00-15.00	Practical exercise continues	
15.00-15.30	Coffee break	
15.30-16.45	Continued	

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: WEDNESDAY 20th June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.30-09.00	Recapitulate steps 10 and 11 (Prioritized specifications and detailed Technical/Scientific/ Economic/Social appraisal of technological choices that best fit the specifications)	Peter Huxley
09.00-10.00	Planning research on species and provenances	
10.00-10.30	Coffee break	
10.30-12.30	Planning field trials e.g. spacing arrangements, and experiments on tree/crop mixtures	
12.30-14.00	Lunch	
14.00 onwards	What environmental and social factors do we need to measure and how?	Till Darnhofer Anthony Young Dianne Rocheleau

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AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: THURSDAY 21st June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.30 onwards	Experimental design for a selected agroforestry technology in working groups A. Species/provenance trials B. Hedgerow/intercropping C. Looking for fodder	
10.00-10.30	Coffee break	
	Continued	
12.30-14.00	Lunch	
14.00-15.00	Working groups presentations of experimental designs on the above topics	Rapporteurs
15.30-15.45	Coffee break	
15.45-16.30	Wrap-up session	Peter Huxley

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Training Course

Nairobi, 4-22 June 1984

PROGRAMME OF ACTIVITIES

DATE: FRIDAY 22nd June, 1984

TIME	TOPIC/ACTIVITY	RESPONSIBLE
08.30-10.00	Final individual participants' consultations with ICRAF staff	
10.00-10.30	Coffee break	
10.30-11.30	Summary session and course evaluation	ICRAF Staff and participants
11.30-12.30	Closing session. Presentation of Certificates. Farewell to participants	John Raintree Officer-in-Charge
	E N D	

ANNEX 4

ICRAF/USAID AGROFORESTRY COURSES FOLLOW-UP
Nairobi, 4-22 June 1984

Participants' Feedback Information

1. Please indicate whether there have been any changes in your employing institution affecting your position and/or responsibilities since you attended the June course. Tick as appropriate.

☐ NO

☐ YES. Briefly describe your new responsibilities.

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During the three week training course, time was approximately distributed as follows:

Week I	*- The conceptual and technical background of agroforestry*
Week II First half of Week III	*- ICRAF's Diagnostic and Design Methodology*
Second half Week III	*- Agroforestry research information and relevant experimental approaches*

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2. Please indicate whether you have been able to use information presented during the course in Research Activities

☐ NO ☐ YES (Please, specify below)

Name the project or activity. How many people are involved?

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3. Please indicate whether you have been able to use information presented during the course in extension activities

☐ NO ☐ YES (Please, specify below)

Briefly describe the activity.
Indicate how many farmers you are reaching.

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4. Please indicate whether you have been able to use information presented during the course in <u>Teaching Activities</u>

☐ NO ☐ YES (Please, specify below)

Give title of courses/seminars.
Indicate approximate duration and number of students attending the activity(ies).

5. Have you used course information in any other activity?

☐ NO ☐ YES (Please, specify below)

At the time of the course you received a rather voluminous training package.

6. Have you been able to go over or read in depth the written information provided upon return to your country?

☐ NO ☐ YES ☐ PARTIALLY

7. What information did you find most useful?

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8. What information would you like to add to your training package?

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9. Have you been able to disseminate the course information among your colleagues/students? Please specify.

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10. Do you have any specific plan to use the agroforestry course information in the future? Please, briefly specify.

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11. Have you had contacts with any of the ICRAF scientific staff during the past five months?

☐ NO ☐ YES (Please, specify below)

In relation to what subject/area?

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12. Your general afterthoughts and recommendations about the course and training materials.

A N N E X 5

ICRAF/USAID AGROFORESTRY COURSE
Nairobi, 4-22 June 1984

(Post -Course)

EVALUATION SHEET

The purpose of the present evaluation sheet is to seek participants' opinions about the general structure, organization and co-ordination 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.

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SECTION 2. Please give us your views on the structure of the course. Were the following adequate?

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

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(Post-Course/2)

SECTION 3. The main objectives of the course are shown below. Indicate how appropriate you believe they were and to what degree they were achieved. Before completing this section note these definitions:

Appropriateness: the relevance to your work and usefulness of the course

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

1 = not appropriate/effective 5 = very appropriate/effective

OBJECTIVES	APPROPRIATENESS					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 organization and programme of work.										
3.3 To develop/enhance an understanding of the concepts of AF as a land use system, and of its potentials and constraints.										
3.4 To become updated on available AF research information and appropriate experimental approaches.										

3.5 Suggested improvements

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(Post-Course/3)

SECTION 4. We would like your views on the physical resources and administrative support for the course. Were they adequate?

1 = not adequate   5 = very adequate

Physical Resources and administrative support	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 exercises					
4.11 Other (please specify)					

4.12 Suggested improvements

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(Post-Course/4)

SECTION 5. Indicate your opinion about the organization of training sessions and general co-ordination of the course.

1 = not adequate 5 = very adequate

Aspect to evaluate	1	2	3	4	5
5.1 Training materials, written information given to participants					
5.2 Quality of presentations (clarify 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

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SECTION 6. What is your opinion about the course participants?

1 = not satisfactory 5 = very satisfactory

Aspect to evaluate	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)					

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(Post-Course/5)

6.6 Suggested improvements to Section 6.

SECTION 7. Your general comments about the course.

ANNEX 6

SUMMARY OF PARTICIPANTS EVALUATION & RECOMMENDATIONS

PRE-COURSE ARRANGEMENTS

Invitations to submit candidates' nominations were mailed to institutions in Africa and Latin America five months before the begining of the course. Twenty-two participants (out of twenty-three) indicated that they received the pre-course information between February and May 1984 - 2 in February, 8 in March, 8 in April and 4 in May. Table 1 summarizes participants' responses on "pre-course arrangements", followed by their recommendations on how to improve this aspect in future courses.

Table 1. Summary of participants' responses on pre-course arrangements

Aspect evaluated	YES (%)	NO (%)
Did participants receive the pre course information before the start of the course?	96	04
Was the pre-course information considered adequate?	81	19

* In percentage of total number of responses

Suggested improvements were:

- If possible, send to the future participants more information about the D&D methodology;
- Request participants to bring information on planned or on-going agroforestry activities in their countries;
- Advise institutions to distribute the information to other selected organizations.

OBJECTIVES

Participants were requested to express their views on the appropriateness and effectiveness of the course objectives using, for that purpose, a measuring scale form 1 to 5, where 1 - less appropriate/effective and 5 = very appropriate/effective. The terms were defined as follows:

Appropriatness - the relevance and usefulness of the course objectives to the participants' work

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

Final information is summarized in Table 2. All the four objectives were assigned 4 or higher than 4 average values.

Table 2. Summary of information on the appropriateness and effectiveness of the course objectives*

Objectives	Appropriateness	Effectiveness
(MAIN)		
1. To become familiarized with the concepts and procedures of ICRAF's methodology to diagnose agroforestry-related land use problems/constraints and design appropriate agroforestry systems	4.6	4.4
(COMPLEMENTARY)		
2. To become acquainted with ICRAF's institutional organization and programme of work	4.4	4.2
3. To develop/enhance an understanding of the concepts of AF as a land use system, its potentials and constraints	4.8	4.6
4. To become updated on available AF research information and appropriate experimental approaches	4.6	4.0

* Expressed in average values of the total number of responses.

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STRUCTURE OF THE COURSE

Participants' views were requested on the adequacy and duration/ length of the course, the daily working sessions, the field exercises and the independent/study sessions. These aspects were evaluated in terms of *too long*, *adequate* and *too short*. A higher percentage of the total number of participants thought that the "course" and the "independent work/study sessions" were too short while the daily working sessions were adequate. As for the "field exercises", about half of the participants thought they were adequate and the other half indicated they were too short. Table 3 summarizes the information on this section of the questionnaire.

Table 3 Summary of participants' views on the course structure *

Aspects evaluated	TOO LONG (%)	ADEQUATE (%)	TOO SHORT (%)
The total length of the course	0	39	61
Daily working sessions	22	69	9
Field exercises	5	50	45
Independent study/work	4	31	65

* In percentage of the total number of responses

Suggested improvements were:

- Extend the length of the course - from four to six weeks - to allow for more in-depth study/information mainly on the following: experimental designs; economic evaluation and computer exercises; and independent consultations with ICRAF staff;
- Some ICRAF staff could not be around throughout the course period, due to other engagements; some efforts should be made to invite experts with similar backgrounds to replace them during training periods;
- Fridays could be used for consultations with ICRAF staff; in this respect ICRAF needs to recruit more staff in animal husbandry/range management.

- Stress (in content and time allocated) the experimental design in AF systems;
- The course should aim to provide more hard data/information about tested technologies.

PHYSICAL RESOURCES AND ADMINISTRATIVE SUPPORT

These aspects were evaluated using a 1 to 5 scale, where 1 = not adequate and 5 = very adequate. Table 4 summarizes the information provided by participants. In general, the physical resources and administrative support were considered adequate as indicated by the values higher than 4.0. Information is given in Table 4 below.

Table 4. Summary of information on physical resources and administrative support *

Aspects evaluated	$\bar{X}$
Transport arrangements during field exercises	4.9
Meal arrangements in the field	4.8
Hotel accommodation	4.7
Travel arrangements to and from Nairobi	4.7
Secretarial services	4.7
Meeting rooms for small working groups	4.4
Computer services	4.3
Conference room	4.2
Library services	4.0
Per diem payments	3.8

* Expressed in average values of the total number of responses

Suggested improvements were:

- Increase the per diem rate as Nairobi is quite expensive;
- Pay the same per diem rate to all participants, regardless of whether they are resident in Kenya or not;
- Arrange to display books produced by ICRAF staff and have them for sale;
- Arrange for participants to be able to borrow books from the Library during the course period;

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GENERAL ORGANIZATION AND CO-ORDINATION

Participants views were requested regarding the adequacy of training materials, the quality of presentations, the use of visual equipment and training aids, and the availability of ICRAF staff for consultations. Again, a scale from 1 to 5 was used, where 1 = not adequate and 5 = very adequate. As shown in Table 5 below most aspects were considered more than adequate (values higher than 4). Once more, the time factor was considered the main constraint to consulting with ICRAF staff.

Table 5. Summary of information on general course organization and co-ordination

Aspect evaluated	$\bar{X}$
Adequacy of training materials and hand-outs	4.6
Availability of visual equipment and training aids	4.6
Quality of presentations (clarity of speaker, use of visual aids, time).	4.2
Availability of ICRAF staff for consultations	3.9

* Expressed in average values of the total number of responses

Suggested improvements:

- More time to be spent in consultations with ICRAF staff;
- Dr. Raintree needs to use a microphone, he has good material but his vocal projection is low; Dr. Rocheleau needs to slow down her presentations;
- Installation of a switch close to the speakers to control the lights;
- Hand out written information before the end of the day to allow for preparation for the next day;
- Avoid having too many speakers on the same day, otherwise participants lose interest;

- Use video tapes to demonstrate field experiments and practices, where constraints make actual trips to the sites impracticable.

PARTICIPANTS

Participants were requested to express their views about the size of the group, the various disciplines represented and the interaction among themselves as well as with the ICRAF staff. A five-numeral scale was used, from 1 = not satisfactory to 5 = very satisfactory. Table 6 summarizes the information on this section. In general, all aspects were considered more than satisfactory (values higher than 4).

Table 6. Summary of information about the course participants *

Aspect evaluated	$\bar{X}$
Size of the group	4.4
Interaction among participants	4.3
Interaction of participants with ICRAF staff	4.2
Various disciplines represented	4.2

* Expressed in average values of the total number of responses

Suggested improvements were:

- More time should be allowed for interaction of participants with ICRAF staff;
- Improve the distribution of disciplines represented; there was a strong bias towards foresters. As a result there was a strong hard-science impact at the expense of socio-economic concerns.
- More women participants should be encouraged as they have a strong input in rural development programmes.

GENERAL COMMENTS

The participants were prolific in their comments and recommendations for the organization of similar events in the future. This is what they said (with minor editorial changes);

- My overall view of the course is good. There are a few things that I would like to suggest for improvement:
  a) give more emphasis to Experimental Design;
  b) ICRAF staff is a multidisciplinary group but during discussions they do not always act in an interdisciplinary fashion;
  c) there is a strong interest in meeting the ICRAF staff on an individual basis but when we wanted to meet for a longer period we had to sacrifice part of the lectures;
  d) I expected more interaction with ICRAF staff at the Kakuyuni site.

- In my personal view, the course was very well organized, informative and successful. ICRAF and USAID are highly commended. I am particularly grateful for this opportunity provided by the two organizations to enable the participants to attend the course. the multidisciplinary approach to agroforestry is highly appreciated. It has been a job very well done. The course has exposed me to ICRAF and agroforestry, and has provided a forum for sharing my experiences with ICRAF staff and colleagues all over the world. On behalf of my country, and my institution, The Kainji Lake Research Institute at New Bussa, I am very grateful for this opportunity.

- The training course was very fruitful and rewarding. I was very impressed by the manner in which it was conducted. It was properly planned and implemented on schedule. I acquired tremendous knowledge about agroforestry during the three weeks. I would, however, like to suggest that in the future more emphasis be put on field/practical training and information. I extend my profound thanks and appreciation to the Director and the able ICRAF staff.

- Personally, I have gained a lot from this course, though it was very short. I have gained much knowledge, but I fear that I will be coming to you at the time of the implementation of the principles I have learnt. I have every hope that the gaps will be filled by mail returns. As I am leaving, I have more or less designed an experiment for my institution. You will soon receive a copy for comments and suggestions. I wish that in future you increase field visits and independent work.

- Congratulations! than you very much. The training course was very good. I think ICRAF should, in future, offer specific courses according to the interest of candidates.

- The course was very interesting and full of important experiences and research recommendations in agroforestry. The facilities, training materials, and written information were excellent. All participants had the opportunity to discuss with the ICRAF staff relevant aspects of both AF in relation to the course and in relation to specific projects on-going in our home countries. I think extending the duration by 1-2 weeks is difficult to achieve, but 2-3 days could be squeezed during the first week for further discussions about the D&D methodology. I am very grateful to all ICRAF staff for having given us all up-to-date information. Also, for their kindness and friendship.

- The course was certainly very useful in my case for teaching purposes, research, and practical introduction to farmers and government people. Unfortunately, but understandably, I feel that the time was rather short, especially for farm interaction and computer techniques. I expect that communications with ICRAF should continue from now on, especially in bringing to our attention emerging issues and literature neews.

- The duration of the course should be extended to 6 weeks instead of 3, to give both the speakers (lecturers) and participants enough time to critically analyze and understand the information being presented. In the Diagnostic Survey, more attention should be paid to the method of selecting the farmers to be interviewed so as to give an insight into the representativeness of the farms in the area. This did not come out clearly and one wonders whether the data and/or the designs carried out were representative of the area. If possible, the trials at Kakuyuni should be replicated in various parts of the semi-arid areas since: Kakuyuni is a recently settled area even without land tenure; has different farming system from areas like Kitui, Lower Embu, etc.; farms size are much larger than in the other areas of Machakos; there are areas like Lower Embu where the use of oxen is limited due to rockiness and farmers are confined to hand-tool technologies. All these variations require technology testing for adaptability to different farming systems and life styles. Otherwise, the course was very helpful in understanding the concepts of agroforestry in general, and in particular, the last week that dealt very well with experimental designs in agroforestry, was of great help to researchers trying to incorporate forestry into crop production and solving shortage of animal feeds on small-scale farms in semi-arid areas.

- The course was very helpful in clarifying the goals of ICRAF, agroforestry systems, agroforestry experimental designs and and diagnostic design. I hope such training courses will be continued to make the researchers who are interested in agroforestry are aware of what is important in designing agroforestry systems.

- The course was generally well organized and properly coordinated. In fact, we all should appreciate this good work. I, in particular, congratulate Ester Zulberti for he. tireless effort in ensuring that everything was correctly done. Regarding the academic aspect, I feel ICRAF has fairly - if not very - qualified staff with vast experience and practical orientation. This academic wealth has been adequately shared out in their presentations and discussions with the participants. This tendency should, if possible, be intensified in future courses. I must say that I am leaving for my place of work with broadened AF information. Lastly, there should be an increase in the female fox because if their number is little, they tend to be dominated in discussions by the male fox.

- The course was in general, satisfactory to participants of different disciplines. But there are some very important areas that were not given enough time, e.g. the computer exercise.

- The course has been so fruitful to the extent of generating the concept of agroforestry to be the general management of land use system into the mind of participants. I would like to suggest here that I feel the venue of this type of valuable training course should not be concentrated in one particular area. Maybe the organizers should plan the next one in another country in Africa?

- Very useful. I wish it could be extended to French-speaking countries, too.

- The course was excellently organized. I felt very comfortable from the start of the course to the end. This was possible because of the relentless efforts of Dr. Ester Zulberti to make the course a success. However, I should also mention that all the disciplines were well represented and I am positive to say that I shall be in a position to impart some knowledge on AF in my organization back home. Since economic analysis of AF is a very important part, I feel that it should not be left out until the final week but be introduced on the onset of the programme so that participants get acquainted with it right from the begining.

- The course was useful and enjoyable. But it can be more useful if enough time is given for oral discussions; sometimes the exchange of views among participants is more interesting than the lectures. Why doesn't ICRAF conduct research, since it is a Council for research and has well qualified staff? Why not include more scientists from developing countries? A case study should be presented by at least one of the participants. Last but not least, my best wishes to all ICRAF staff who made this course possible.

- I have attended other training courses before (two) and I consider this one as having been the best organized in all aspects. Congratulations to the course co-ordinator and all ICRAF staff.

- The course was properly and efficiently organized. The only suggestions are: ICRAF should be more available for consultations with course participants; and allocate more time in the course programme for "Experimental Designs in AF".

- The course is excellent. Staff dedication most commendable although they pushed in too much in such a short time. It is proposed that: the time be increased to 5 weeks, siting be changed to a remote hotel; a longer time, say 3 days be given to experimental design, planning and use of computer; the familiarization with the computer should result in preparation of project plans; a wider scope of computer programmes should be worked out by ICRAF staff; course materials should have an appended section on relevant exercises; the objective of the course should be changed from "familiarization" to having a "deeper understanding" of the subjects in question

- I must sincerely say that the course has been very successful and has added more and new knowledge to my work. I have learnt new concepts and practices related to land use and, no doubt, these will give me new avenues in planning for both research and extension work in agroforestry. I would suggest that more field exercises in different ecological zones - arid, semi-arid, and high rainfall - be added. More time for computer exercises and the use of computers should be given. It is my feeling that the three-week period for the course was too short as there is still a lot to be learnt about agroforestry. Suggested 6 weeks duration of the course would give brighter views and research in-sight of agroforestry for development.

- I am quite convinced that the course arrangement, design and approach have adequately covered and achieved the purpose.

- To me the course was useful as it has made clear the concept of agroforestry, which has many features in common with rural development, on which the project I am working is based. For sure this new understanding will help me and my colleagues to reconsider the project and our priorities taking into consideration livestock, crops and trees as an integral part of the farming system for improved production. One should express gratitude to ICRAF staff for their co-operation, help, commitment and devotion to ICRAF objectives.

- The course is fairly good. It has reached a high scientific level, well appreciated by the participants. Discussions among participants and ICRAF staff - mainly group work presentations - have led us to feel at a fruitful scientific workshop on Agroforestry. I personally appreciate the kindness of all the ICRAF staff. The feeling started from the airport, and has continued throughout the training course period. I am very grateful to them.

- The course, in its present form, is very stimulating. The period chosen to start the course is particularly appropriate, in view of the world-wide environmental degradation, which is particularly serious in the Third World. If the participant had been working in some form of agroforestry institution, he/she is mostly likely to have many of his doubts cleared by the end of the course. If the course was to stimulate interest in the potential benefits to be realized from the agroforestry system of land use, then this objective has been achieved admirably. The only bottle-neck is that the participants did not have enough time to assimilate the course materials. The theories introduced during the training were not sufficiently backed by field practicals. Such a situation may affect the application of theories into field realities. It is gratifying to know that ICRAF staff are ever-ready to assist, as much as is practicable. There is, however, an excellent probability that most participants will make an attempt to practise this new land use method they have been introduced to. Such individuals will learn how to practise agroforestry by ACTUALLY PRACTISING AGROFORESTRY, THE SEED OF AGROFORESTRY HAS BEEN SOWN. THIS ALONE, IN THE UNLIKELY EVENT OF NOTHING ELSE, IS AN EXCELLENT ACHIEVEMENT!!!

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A N N E X 7

THE TRAINING PACKAGE

On Registration Day participants received a binder containing a set of training materials (approximately 200 pages). A general description of the content of the training package by sections and a list of documents by title and author are presented below. Some of these materials can be made available on request.

DESCRIPTION OF CONTENT BY SECTIONS

Preface - By Dr. Bjorn Lundgren

Introduction - By Dr. Ester Zulberti

Provides an overview of the couse objectives and programme of activities, as well as a description of the organization and content of the training package.

Section 1 - ICRAF Role and Programme

The ICRAF information brochure, "An account of the Activities of the International Council for Research in Agroforestry", provides information on ICRAF's mandate and objectives as well as on the eight programmes.

Section 2 - The Conceptual and Technical Backgrounds to Agroforestry

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's global Agroforestry Systems Inventory Project; introduces the newly established concept of 'agroforestry research' focussing on woody perennial species and land use; outlines ICRAF's approach to agroforestry technology; and includes hand-outs for the field trips. Suggested readings on various aspects of Technology for Agroforestry are included e.g. on environmental, economic, animal husbandry, and others. Documents enclosed are:

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(Section 2 continued)

2.1 Main Notes

- Torres, F., Agroforestry concepts and practices. In Hoekstra, D. and Kuguru, F. (eds). Agroforestry Systems for Small-scale Farmers. Proceedings of a Workshop, Nairobi, 5-10 September 1982. Nairobi: ICRAF. 1983.

- Lundgren, B.O. and Raintree, J.B. Sustained agroforestry. Reprinted from "Agricultural Research for Development: Potentials and challenges in Asia". Report of a Conference held 24-29 October 1982, Jakarta, Indonesia. The Hague: ISNAR. pp. 37-49.

2.2 Practical Exercises/Field Trips

- Huxley, P. and Owino, F. Agroforestry Field Trip to Kiambu District, April 1981.

- Lundgren, L. Excursion to Kaimbu District/Kiambaa and Lari Divisions. June 1984.

2.3 Supplementary Material/Readings

- Nair, P.K.R. and Fernandez, E. An Output from ICRAF's Agroforestry Systems Inventory Project. 1984.

- Huxley, P. Outlining the Objectives, Outputs and Immediate Inter-programme Links. June 1984.

- Young, A. an Environmental Data BAse for Agroforestry. Working Paper 5. Nairobi: ICRAF, 1983.

- Nair, P.K.R. Soil Productivity Aspects of Agroforestry. Science and Practice of Agroforestry 1. Nairobi: ICRAF. 1984.

- Torres, F. Role of Woody Perennails in Animal Agroforestry. Reprinted from "Agroforestry Systems" 1: 131-163. 1983.

- Huxley, P. Intercropping with trees/optimising Tree-Crop Combinations. In A Manual of Methodology for the Exploration and Assessment of Multipurpose Trees. Huxley (ed).

- Hoekstra, D. The Use of Economics in Agroforestry. Working Paper 2. Nairobi: ICRAF. 1983.

- Darnhofer, T. Plant-Water Requirement and Water Availability Assessments/Temperatures and Plant Development. Taken from Resources of Agroforestry Diangosis and Design.

Section 3 - ICRAF's Diagnostic and Design Methodology

Documents included in this section cover the conceptual framework of the methodology; an outline and description of the step-by-step procedures; preliminary information on the India

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(Section 3 continued)

Case Study; and pre-diagnostic information on the Kakuyuni watershed. Practical field tools, including a diagnostic survey guideline and maps are also found in this section. A manual and a practical exercise to undertake the economic appraisal of selected agroforestry interventions completes the section. Documents by title and author are as follows:

3.1 Main Notes

- ICRAF. Guidelines for Agroforestry Diagnosis and Design. Nairobi: ICRAF. 1983. Working Paper No.6.

3.2 Practical Exercises/Field Work

- Case Study Review in India (Preliminary and Information)
- Pre-Diagnostic Information on the Kakuyuni Watershed.
- Diagnostic Survey Guidelines.
- Map of the Kakuyuni Watershed with homes, Roads and Paths.
- Hoekstra, D. Analysing Alley Cropping for Semi-Arid Conditions: The Kenya Case Study. ICRAF Training Materials/ The MULBUD Series No.2. May 1984.

3.3 Supplementary Material/Readings

- List of Centres Participating in AGRIS
- Etherington, D. and Matthews, P.J. MULBUD User's Manual. Australian National University. 1982.

Section 4 - Relevant Experimental Approaches to Agroforestry Research Needs

It provides background information on research planning considerations with emphasis on relevant agroforestry experimental designs and plant management. Notes, hand-outs and supplementary materials included in this section are as follows:

- Wood, P. Notes on Species and Provenances: A Guide to Field Practice.
- Darnhofer, T. Meteorological Elements and their observations. Nairobi: ICRAF. Working Paper No. 14
- Rocheleau, D. Update of ICRAF Methodology/Procedural Sequence for the Multi-Institutional Collaborative Projects.

- Assessment of Experimental Sites*
- The Scope and Design of Field Trials*
- Systematic Designs for Field Experimentations with Multipurpose Trees.*
- Considerations when Experimenting with Changes in Plant Spacings.*

Section 5 - Course Information

The last section of the binder contained general information about the course objectives, timetable and daily programme of activities, and the names and addresses of the participants. The Evaluation Form was also included. The organization and content of this section is as follows:

- Course Objectives
- Particiapants' Names and Addresses
- ICRAF Staff and Invited Speakers
- Timetable
- Programme of Activities (by day)
- Evaluation Form

* From Huxely, P. (ed). A Manual for the Exploration and Assessment of Multipurpose Trees. In preparation.

UPM/ICRAF AGROFORESTRY COURSE, Serdang, Selangor, Malaysia, 1-19 October 1984

INFORMATION ABOUT PARTICIPANTS

Name/Address	Degree	Main Subject	Name/Address Employer	Present Position
1. Chairil Anwar Siregar Forest Research and Development Centre Jl. Gunung Batu P.O. Box 66, Bogor Indonesia	IR	Agronomy	Forest Research and Development Centre Jl. Gunung Batu, P.O.Box 66 Bogor, Indonesia	Researcher on Agroforestry
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BRIEF NOTES ON ICRAF'S
DIAGNOSTIC AND DESIGN METHODOLOGY FOR AGROFORESTRY

Prepared for the Inter-Center Consultation on the Use
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1. INTRODUCTION

Although ICRAF is not a member of the CGIAR system it does collaborate with a number of CG centers in the area of Farming Systems Research relevant to agroforestry. In order to meet the need in agroforestry for a practical approach to the identification of research priorities in a field like agroforestry, which lacks an established tradition of research, ICRAF is in the process of developing a "Diagnostic and Design" methodology. Now, after more than twenty trial applications in a wide range of sites around the world, draft manuals of the methodology have been produced for wider dissemination and testing.

This methodology development activity takes place within the Agroforestry Systems Programme at ICRAF and is part of the Council's overall thrust in systems methodologies for agroforestry. Other projects in the Systems Programme deal with the adaptation and development of methodologies for economic analysis in agroforestry &land evaluation for agroforestry. Other current projects in the Programme include an Inventory of Agroforestry Systems and Practices and a project on Land Tenure and Agroforestry. The Agroforestry Technology Programme at ICRAF deals with the collation and synthesis of information on component technologies and with methodologies for technology generating research.

The "D&D" methodology is currently being used mainly to formulate agroforestry R&D projects in collaboration with national and international partners through the activities of ICRAF'S Collaborative and Special Projects Programme and as a major part of three week Agroforestry for Development courses offered by ICRAF'S Training and Education Programme. D&D activities provide a context in which ICRAF's other methodologies are brought into play.

The D&D methodology is basically an FSR type of approach, adapted to the special needs and potentials of agroforestry. As an observer at this meeting ICRAF is interested to learn of commonalities and differences in the Farming Systems methodologies being used by the CG centers, with a view toward improved coordination of collaborative activities. One possible future activity of the D&D Project is to develop a methodology module for use by national research institutes already using FSR methodologies, with the aim of aiding researchers to identify agroforestry potentials and research possibilities within the FSR context.

Although ICRAF's client institutions include forestry departments interested in integrating farmers, agricultural crops and livestock into forest management schemes, the main body of current work in agroforestry focuses on the integration of trees into farming systems to play a variety of production and service roles, leading to improvements in the productivity and sustainability of farming systems through integrated land management.

2. OBJECTIVES

The aim of the D&D Project is to develop an efficient procedural framework and practical tools for the diagnosis of agroforestry-related problems and potentials in land use systems and design of agroforestry systems and technologies to solve or mitigate the identified problems and develop the latent potentials of the system. The focus on land use systems provides a broad context for diagnostic activities appropriate to the wide scope of potential agroforestry designs.

In accordance with its role as a research council and with an opperating budget that does not currently allow scope for direct management of technology generating projects, the main use of the D&D methodology is to assist national and international partners to develop projects which they themselves implement, with backstopping from ICRAF. It is possible, however, that in future ICRAF will become more directly involved in project management.

One of the main differences between D&D and other FSR approaches is the emphasis on a more elaborate technology/land use system design objective. The second D in D&D stands for "design" in this concrete engineering sense.

As in the other methodologies being discussed at this meeting the emphasis on D&D is on providing a basis for technology generating research, although the potential is also present for direct application in development-oriented projects (with a research component) as well as for policy applications.

3. PROGRAMME STRATEGY

In its methodology development activities ICRAF follows a three phase strategy: 1) develop in-house capability, 2) expansion of in-house capacity (i.e. to handle an adequate volume of methodlogy applications), 3) transformation of the developed capability into a methodology which can be independently implemented by clients, through documentation (manuals, case studies, etc.) and training activities. The D&D methodology is now in phase 3. A revised version of the draft manuals will be published in late 1985. An eventual synthesis with technques of land evaluation for agroforestry now being developed will provide a means for larger scale land use planning in which D&D will provide system specific "ground truth" information.

4. STRATEGY FOR COLLABORATION WITH NARS

NARS are here taken to include forestry research institutions, watershed management authorities, etc., in accordance with the broad scope of agroforestry uses.

The main outreach arm of ICRAF is the Collaborative and Special Projects Programme (COSPRO), whose aim is to strengthen national capacity for agroforestry research and development. COSPRO has participated in seven project formulation exercises to date, in which joint multidisciplinary teams of ICRAF and national scientists have applied the D&D methodology to arrive at plans for technology generating projects. These applications have resulted in the training of some 50 national and regional scientists in the use of D&D for project formulation purposes. COSPRO also seeks to assist in the institutionalization of agroforestry research capacity through catalyzing the formation of national and regional research networks.

The Training and Education Programme of ICRAF also seeks to build national capacity. To date some 62 scientists have been trained in ICRAF's approach to agroforestry. The three courses held so far have included a 1½ week module on D&D built around a central case study exercise in which the trainees participate. ICRAF'S Information and Documentation Programme is another channel for dissemination of the buildup of agroforestry knowledge (databases, etc.) and methodologies.

In all of these outreach programmes ICRAF has collaborated with CG centers. One of the most interesting forms of collaboration is in the formulation and backstopping of national research projects.

5. SCOPE OF D&D

To identify agroforestry-related needs and potentials of land use systems we have to cast our diagnostic net pretty wide. While D&D concentrated initially on the basic land management and decision-making unit (usually the family farm, household herd, etc.), it was soon realized that many AF-related problems and potentials require a larger-than-farm scale approach to diagnose problems whose origins cannot be assigned exclusively to individual management units and/or which require larger scale, often cooperative approaches to the design of solutions (watershed management problems and the overexploitation of communal fuel and fodder resources are typical examples). In principle this same situation may arise in non-agroforestry oriented diagnoses as well, although they are not often addressed by most FSR methodologies (even those purporting to be "whole system" approaches, let alone those which explicitly restrict the focus to the "enterprise" level).

The point is that it is more difficult, if not impossible, to ignore larger than-farm scale factors in agroforestry diagnosis and technology design. Likewise with smaller scale factors. In Africa, where women often have quite distinct production opportunities and responsibilities from men (including often primary responsibility for fuelwood and fodder collection as well as the main burden of food production), it was found necessary to focus D&D activities onthe intra-household scale of analysis. Tenure problems vis-a-vis both land and trees cut across all levels of analysis and have a major impact on agroforestry potentials within existing land use systems. Accordingly, the D&D methodology attempts to address 3 levels as a routine practice: 1) watershed/community level, 2) management unit level (usually the household but it could also be a forest management unit), 3) intra-household level.

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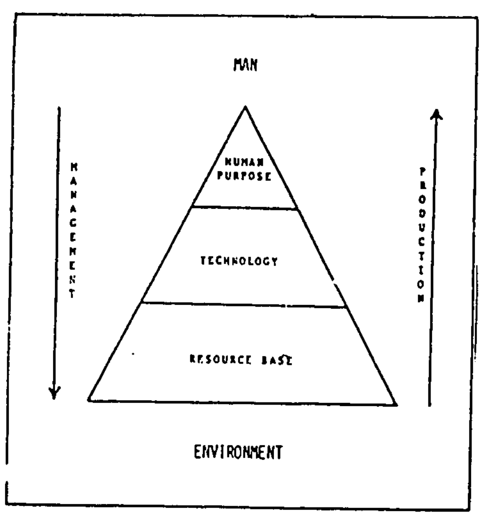
In taking the "land use system" as the focus for D&D activities we have been led toward a hybrid concept of "the system" for D&D purposes. As suggested by the following figure, a land use system is conceived as that part of the total human ecosystem of an area which is comprised of all those interactions by which by which Man exploits his perceived Resource Base by means of available Technology to satisfy Human Purposes. Accordingly, the diagnosis of the systems starts from an analysis of the production objectives of the land users. Those production subsystems in which the land user experiences difficulties in meeting his/her production objectives are then subjected to a "trouble-shooting" analysis to expose the constraints and causal factors implicated in the etiology of these problems. Although the D&D methodology attempts to provide a logical and efficient sequence of queries, heavy reliance is placed on the competance of the multidisciplinary D&D team, using the quidelines and checklists, to trace the lines of causality through as many levels in the sociobiophysical system as necessary to define the syndromes behind problems whose main "symptoms" are ~~are~~ experienced as particular types of failure in meeting the objectives around which the system is organized.

Again, this approach to the analysis of systems which are organized by human purpose needn't apply only to agroforestry oriented FSR, but in agroforestry, where the relevant production objectives can be quite wide ranging, a more generalized approach of this type is virtually unavoidable.



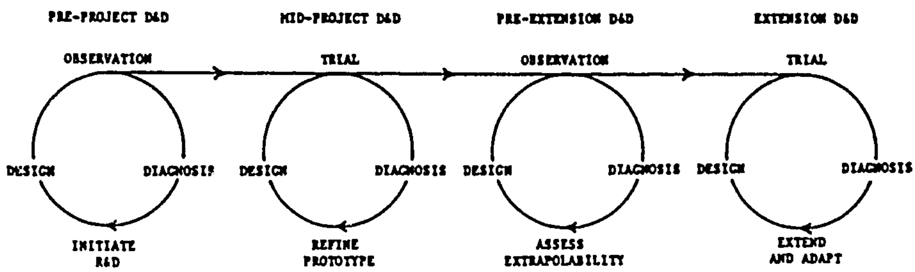
Faced with a diagnostic task of potentially great complexity, we have attempted to simplify the type of systems analysis required for agroforestry by defining subsystems in terms of the desired outputs. A "production subsystem" in this sense is comprised of any and all resources, activities and factors involved in the production of a desired output. As a kind of checklist for rapid entry into the diagnosis of any system (but particularly relevant to household production systems) we have taken a "basic needs" approach to the identification of subsystems. The following needs are considered basic and universal: food, energy, water, cash, savings/investments, raw materials for local processing industries, shelter and social production. The heuristic hypothesis is that, whatever else they might do, land use systems are organized so as to satisfy these basic needs. To describe the system it is merely necessary to identify the preferred products or forms of needs satisfaction (e.g. maize rather than sorghum, etc.) and describe the location, resources used, technology employed and activities involved in meeting the production objectives of the management unit.

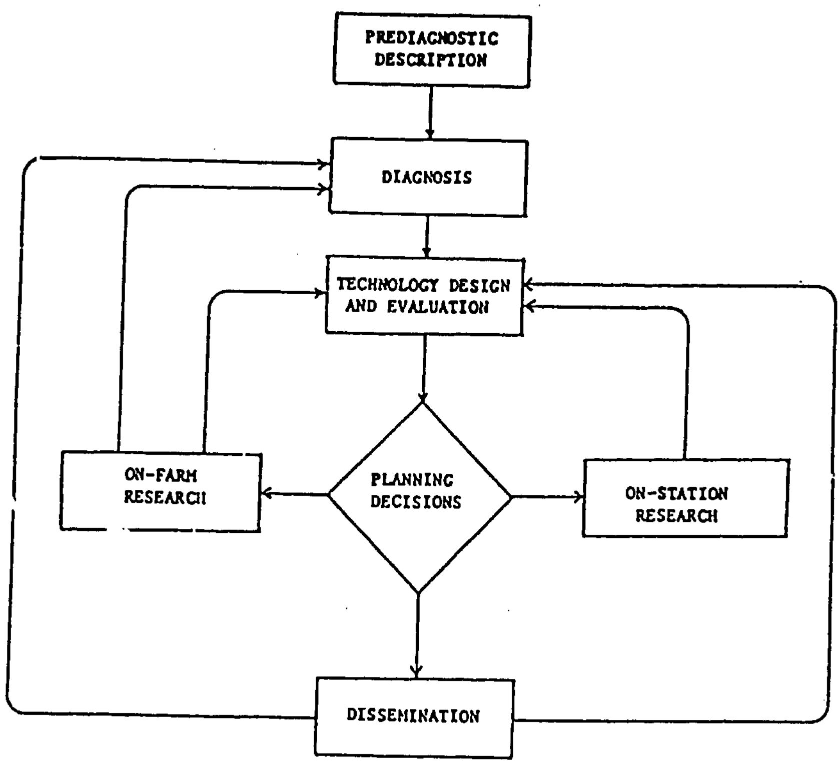
This approach provides a quick entry into the system and sets the stage for the assessment of problems and trouble-shooting exercise which follows in the diagnostic phase, but it may need to be supplemented by similar analyses at different levels in the nested hierarchy of system organization (watershed/community and intra-household levels). It has the advantage of clearly linking technical subsystems to the objectives of the producers and of streamlining the diagnosis to focus on those subsystems in which problems are evident. Of course, it always has to be broadened to deal with potentials not suggested by the analysis of presently percieved problems, but this is where the skills of the multidisciplinary team come into play in rounding out the diagnosis of problems and potentials. In agroforestry, where conservation is the other side of the coin of production, it is often necessary to make an independent assessment of resource degradation problems (particularly those amenable to an agroforestry solution). But this criterion can be operationalized in terms of the "sustainability" of the existing production subsystems, thus relating conservation objectives to the production objectives of the land user, and suggesting possibilities for technology "packages" which make use of the "piggy-back principle" to address a wider range of system needs and potentials than are currently percieved by the unit managers.

Again, there is nothing to restrict this kind of approach to agroforestry applications, but in agroforestry, where expermental systems take a long time to establish and test and where, once established, they are likely to be a long time on the ground, there is a higher premium on well conceived designs.

6, APPROACH

We think of Diagnosis and Design as a basic process which is fundamental to all problem-solving approaches and we have made a deliberate attempt to reduce it to its fundamental components and logical requirements, weeding out unproductive ideosyncracies as we've gone along, in response to user feed-back. We also think of it, in its elementary form, as an iterative process which continues throughout the life of a technology generating and disseminating project from formulation, through implementation of R&D activities, to dissemination and adaptive research. As such it becomes part of the "internal guidance system" of an applied "research for development" project. Uses of D&D at different stages in the life cycle of such a project and the basic structure of feedback linkages are suggested by the following illustrations.





Diagnosis-and Design is an iterative process which continues throughout the life of a project as part of its internal guidance system. Note feedback linkages.

In presenting the D&D methodology to potential users we have encountered different responses to the level of detail in the guidelines we are currently able to provide. Some users want only minimal guidelines, the basic bones and logic of the basic procedures, with full freedom to workout the details themselves. Others want detailed "recipies," step by painful step. We also note that interest in more detailed procedural suggestions increases with exposure to and familiarity with the methodology in the field (we notice the same effect with all of our training materials).

Accordingly, the current documentation (relating mainly to the project formulation process) is presented in terms of a four stage breakdown of the procedural logic (level 1, "minimal guidelines," summarized in the following table), a further subdivision into twelve steps (level 2, "semi-detailed guidelines," given in outline form in the succeeding pages), and a companion "resource" document (level 3, "detailed guidelines" which also contains a substantial number of optional resource materials keyed to the different steps). (cf. Raintree, 1984, ICRAF 1983a and 1983b, respectively.) Comparable guidelines for the later phases of the project cycle have yet to be developed, due to the longer time required to gain experience with these phases on the ground. Four case studies of the D&D project formulation process, undertaken in collaboration with national and in some cases international (CGIAR) partners, have been published in the ICRAF Working Paper series and others are in preparation. A computerized D&D databank is being established at the Nairobi offices to record D&D results for comparative analysis and generalization.

In the next phase of the D&D development effort it is hoped that we may find national partners to collaborate in revising the current guidelines to incorporate adoption facilitating adaptations to local needs and resources and to simplify the presentation and cast it in the local research idiom.

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Table 1. Summary of level 1 guidelines for project formulation based on a four stage breakdown of the 'minimal' logic of the D&D process.

R&D STAGES	BASIC QUESTIONS TO ANSWER	KEY FACTORS TO CONSIDER	MODE OF INQUIRY
PREDIAGNOSTIC	HOW THE SYSTEM WORKS (what does it look like, how is it put together, how does it work?)	PRODUCTION OBJECTIVES AND STRATEGIES	SEEING THE SYSTEM
DIAGNOSTIC	HOW WELL THE SYSTEM WORKS (what are its problems, limiting constraints and problem-generating syndromes?)	PROBLEMS IN MEETING OBJECTIVES CAUSES OF IDENTIFIED PROBLEMS	TROUBLESHOOTING THE SYSTEM DERIVING SPECIFICATIONS
DESIGN	HOW TO IMPROVE THE SYSTEM (what is needed to improve system performance?)	PROBLEM SOLVING OR PERFORMANCE ENHANCING INTERVENTIONS	BRAINSTORMING AND EVALUATING ALTERNATIVES
PLANNING	WHAT TO DO TO DEVELOP THE IMPROVED SYSTEM (what specific R&D actions are needed to develop and implement the envisaged improvements?)	R&D PRIORITIES	PROJECT PLANNING AND RESEARCH DESIGN

Level 2 'Semi-detailed' Guidelines

To give greater detail to the suggested procedures, ICRAF (1983a) has further subdivided the basic four-stage process into a set of 12 steps, 3 for each of the above listed stages. These are presented in outline form below, along with the suggested *output* of each step, *sources of information*, the *main factors to consider*, and an optional list of *useful tools* and resource materials which the user might wish to consult at the various steps (the latter are found in ICRAF, 1983b).

PREDIAGNOSTIC STAGE

Step 1. Environmental Description of the Study Area

Output: A descriptive understanding of the diagnostically relevant characteristics and organization of the selected environment

Sources of information: Mainly existing documentation on the study area, supplemented by limited field survey and interviews with qualified informants

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Factors to Consider:
- Biophysical parameters
- Socioeconomic parameters
- Structure and function of the human ecosystem of the area

Useful Tools: Environmental Data Base for Agroforestry (Young, 1983); worksheets for relevant biophysical and socioeconomic data and guidelines for description of the human ecosystem (ICRAF, 1983b)

Step 2. <u>Differentiation of Land Use Systems Within the Study Area</u>

Output: Identification of distinctive land use systems requiring separate D&D treatment; selection of priority system(s) for D&D attention

Sources of Information: as above

Factors o Consider:
- Land units (possessing a similar set of biophysical characteristics)
- Management units (with similar production objectives and resources)
- Land use systems (distinctive combinations of land units and management units)
- Criteria for system selection

Useful Tools: Worksheet for differentiation of land use systems and suggested criteria for selection of systems for D&D attention (ICRAF, 1983b)

Step 3. <u>Preliminary Description of the Selected Land Use System(s)</u>

Output: A preliminary characterization of the objectives and the internal organization of the land use system(s) (for reference use by the D&D team at the Diagnostic Stage)

Sources of Information: As above

Factors to Consider:
- Structure and function of supply subsystems at the management unit level
- Additional descriptive information on production activities (agricultural, forestry, livestock and agroforestry practices; water management)

Useful Tools: Various worksheets, guidelines and appendices on the use of ICRAF's 'basic needs' approach for description and diagnosis of household production systems, with supplementary guidelines for forestry and watershed applications, input-output analysis, matrix tools, modeling techniqeus and other useful tools (ICRAF, 1983b).

DIAGNOSTIC STAGE

Step 4. <u>Diagnostic Survey</u>

Output: Information necessary for a diagnosis of land use problems and potentials (both agroforestry and non-agroforestry) at the management unit (farm) and ecosystem/community level

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Sources of Information: Area reconnaissance and diagnostic surveys of representative management units (the latter is based on a 'trouble-shooting' procedure for identification of the causes of problems within the supply subsystems)

Factors to Consider:
- Problems and potentials at the ecosystem level
- Problems and potentials at the management unit level (supply problems, causal factors involved in the creation of supply problems, present constraints and problem-causing syndromes, future sustainability problems, undeveloped potentials)
- Farmers' strategies for coping with identified problems

Useful Tools: Suggested survey techniques and interview guidelines, sample diagnostic survey instrument (ICRAF, 1983b)

Step 5. Diagnostic Analysis

Output: A diagnosis of major land use problems and potentials

Sources of Information: Findings of the diagnostic survey; information provided by all preceeding steps

Factors to Consider:
- Present problems and potentials at the ecosystem level
- Present problems and potentials at the management unit level
- Sustainability problems

Useful Tools: Analytical worksheets, detailed analytical guidelines and queries, causal and functional diagramming tools (ICRAF, 1983b)

Step 6. Derivation of Specifications for Appropriate Technology

Output: A reasonably complete set of design specifications for problem-solving and potential-realizing technologies appropriate to the needs and potentials of the diagnosed land use system

Sources of Information: All preceeding steps

Factors to Consider:
- General development strategy for the system
- Functional potentials for problem-solving interventions
- Potentials for improving resource utilization
- Possible constraints on candidate technologies

Useful Tools: Checklists and guidelines to assist in developing a complete set of specifications for appropriate AF technology (ICRAF, 1983b)

TECHNOLOGY DESIGN STAGE

Step 7. Technology Appraisal

Output: A relevant set of candidate technologies with potential for inclusion in a design for an improved land use system

Sources of Information: Review of the body of technical knowledge

Factors to Consider: Main criteria are given in the design specifications (output of step 6); state of the art with respect to the various candidate technologies (both agroforestry and non-agroforestry)

Useful Tools: Classification and examples of agroforestry systems and practices from around the world, lists and characteristics of multipurpose trees and shrubs, their uses and ecological requirements, selection considerations, design concepts, etc. (ICRAF, 1983b).

Step 8. Technology Design

Output: General design for an improved land use system and specific designs for component technologies

Sources of Information: Creative synthesis of relevant information from all preceeding steps; supplementary design information from additional sources, as needed

Factors to Consider:
- Design specifications (Step 6)
- Candidate technologies (Step 7)
- Function and location of components within the system, component species, number and spatial arrangement of components, and management of component combinations
- Overall productivity, sustainability and adoptability of the design

Useful Tools: General design principles for agroforestry systems, an iterative initial design algorithm, plant arrangement considerations, notes on shelterbelt design, etc. (ICRAF, 1983b) see also design materials listed under step 7

Step 9. Design Evaluation

Output: Ex ante evaluation of the design; improvements in the design suggested by the evaluation process

Sources of Information: Relevant information from all preceeding steps; farmers' preliminary evaluation of the design proposals; the D&D team's own experience and judgement

Factors to Consider:
- Productivity
- Sustainability
- Adoptability

Useful Tools: Design evaluation scoresheet, guidelines for ex ante economic, ecological and social evaluation (ICRAF, 1983b, Hoekstra, 1983; Etherington and Mathews, (1984).

FOLLOWUP PLANNING STAGE

Step 10. Research Needs

Output: Identification of the type of research needed to develop and test the component technologies and overall land use system designs

Sources of Information: Team review and assessment of the following factors

Factors to Consider:
- State of the technology art and the suitability of different classes of technology (notional, preliminary, validated) for different types of research (on-station, on-farm)
- Whether the envisaged followup to the D&D exercise is essentially research-oriented or development/dissemination-oriented
- Farmers' and research/extension officers' attitudes toward on-farm experimentation
- Riskiness of the proposed technologies
- Need for candidate technologies to be exposed to a wider or more realistic set of environmental and farming system conditions (than would be available on research station)

Useful Tools: Suggested criteria for initial state of the art evaluation, notes on experimental approaches in agroforestry (ICRAF, 1983b; Huxley, in preparation).

Step 11. Topics Requiring Further D&D Attention

Output: Identification of topics needing further diagnostic survey or design thinking, particularly in rapid appraisal applications where time constraints may have left gaps in the D&D outcome; suggested procedures for collection and processing of additional information required to deepen the diagnosis and/or refine the design

Sources of Information: Team review and assessment of D&D results

Factors to Consider:
- Requirements for additional diagnostic information and analysis
- Requirements for more complete information on candidate technologies needed to refine the initial design
- Requirements for in-depth economic, ecological and social evaluation of the proposed design

Useful Tools: N/A

Step 12. Project Implementation Plan

Output: Guidelines for implementation of followup project activities, at different levels of detail appropriate to different stages in the project cycle: a) a general outline of major project activities (research and/or dissemination), suggested by the D&D team; b) a more detailed project proposal suitable for submission to potential donors, prepared by a small pre-project working group; c) detailed project implementation plan, prepared by the project implementation team; d) revised mid-project working plans prepared by the implementation team from time to time, reflecting modifications in technology design suggested by experience in the field or from on-station research

Sources of Information: Results of previous D&D steps (a); pre-project followup activities (b&c); the iterative D&D process during the course of project implementation (d)

Factors to Consider:
- Topics needing further D&D attention (output of Step 11)
- Research needs (output of Step 10)
- Feedback from on-site trials (including farmers' evaluation and suggestions) and on-station experimental work in the course of the project (suggesting modifications and refinements in the technologies and the plan of work).

Useful Tools: Forthcoming; see also ICRAF (1983b).

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A SYSTEMS APPROACH TO AGROFORESTRY DIAGNOSIS AND DESIGN: ICRAF'S EXPERIENCE WITH AN INTERDISCIPLINARY METHODOLOGY

by

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Prepared for presentation at the VI WORLD CONGRESS FOR RURAL SOCIOLOGY Working Session No. 27: Interdisciplinary Collaboration in Rural Development - Dream or Reality? Manila, 15-21 December 1984

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ICRAF

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A SYSTEMS APPROACH TO AGROFORESTRY DIAGNOSIS AND DESIGN:
ICRAF'S EXPERIENCE WITH AN INTERDISCIPLINARY METHODOLOGY

SUMMARY

Agroforestry is an ancient system of land management, but a new field of organized scientific activity. Recently arisen to fill the gap in applied science created by the time honoured but artificial separation of agriculture, forestry and allied disciplines, agroforestry is an inherently interdisciplinary field. Although agroforestry research by multidisciplinary teams is the order of the day, the high degree of interdisciplinary synthesis which is needed to realize the full po[illegible]l of agroforestry is not an easy goal to achieve. To complete [illegible] emerging paradigm for agroforestry research and de[illegible]lopmen[illegible] number of interdisciplinary methodologies are needed.

To answer part of this need, the multidisciplinary staff of the International Council for Research in Agroforestry (ICRAF) have been working since 1981 to develop a methodology for agroforestry Diagnosis and Design (D&D), as an aid to the identification of research and development priorities and as a basis for a coordinated interdisciplinary approach to project planning and implementation. Based on more than twenty test applications with international collaborators in a wide range of sites around the world, ICRAF has published two draft D&D methodology manuals and a number of case studies for wider review and comment.

This paper presents an introduction to the evolving D&D methodology and discusses key features of the interdisciplinary systems approach on which it is based. Beginning with a review of the requirements which must be satisfied by any methodology which seeks to catalyze an interdisciplinary approach to the improvement of land management systems, the paper goes on to explain the general conceptual and procedural framework of the D&D methodology, and concludes with an overview of ICRAF's experience in developing and disseminating this interdisciplinary approach.

A SYSTEMS APPROACH TO AGROFORESTRY DIAGNOSIS AND DESIGN: ICRAF'S EXPERIENCE WITH AN INTERDISCIPLINARY METHODOLOGY

1. AGROFORESTRY AS AN INHERENTLY INTERDISCIPLINARY FIELD

1.1 Agroforestry Defined

It is customary to begin a paper on a new subject area with a definition of the field. As much as one would like to offer a universally accepted definition of agroforestry, alas, it must be acknowledged that there are almost as many definitions of agroforestry as there are people who deal with the subject (Editors, *Agroforestry Systems*, 1982). This diversity of viewpoint is in part due to the interdisciplinary nature of the field and, in fact, the history of attempts to define agroforestry reveals something of the disciplinary forces at work in the development of the field.

The first widely acknowledged attempt to outline the scope of the subject defined agroforestry as:

> ... a sustainable management system for land that increases overall production, combines agriculture crops, tree crops and forest plants and/or animals simultaneously or sequentially, and applies management practices that are compatible with the cultural patterns of the local population (Bene *et al.*, 1977).

This definition gives explicit recognition to the variety of biological components which may be combined in agroforestry systems and implicitly acknowledges the various historical roots of the agroforestry tradition in agronomy, tree crop horticulture, forestry and livestock sciences. By explicitly citing "sustainability" and "cultural compatibility" as criteria of agroforestry, this early definition also gives testimony to the formative role in agroforestry of two other disciplinary traditions: environmental/conservation and social science/rural development disciplines.

It is a *normative definition*, which states not merely what agroforestry is but what it *should be*, i.e. a land management system that is, by definition, *productive*, *sustainable* and *culturally appropriate*. Problems have arisen subsequently in maintaining a literal interpretation of this early normative definition. Strictly speaking, there is little justification for assuming that all land management systems which qualify as "agroforestry" from the standpoint of the combination of biological components (trees with herbaceous crops and/or animals) would *automatically* fulfill the above mentioned normative criteria. Poorly designed agroforestry systems, in fact, may fail on one or even all of these counts.

As scientific agroforestry emerges from the "awareness and enthusiasm" stage and begins to settle down to serious work, the tendency has been to retain these criteria as *attributes of good agroforestry design* while noting, however, that they must be *achieved* by the developers of agroforestry systems rather than merely *ascribed* to any system which happens to meet the minimal definition of agroforestry. A more neutral and widely acceptable definition has been advanced which conceives of agroforestry as:

> ... an approach to land use in which woody plants are deliberately combined on the same land management unit with herbaceous crops and/or animals, either in some form of spatial arrangement or in sequence. The concept of an agroforestry system implies both ecological and economic interactions among the components of the system (after Lundgren, 1982).

The elevation of agroforestry to a field of study in its own right is based on the recognition of the need for an *integrated* approach to land use and the observation that many existing or yet to be developed land use systems all have, in their particular combination of components, a common denominator that is worth exploring and developing in a more systematic and scientific manner;. namely, the deliberate use of the special productive and protective features of woody plants to increase, sustain and diversify the total output from the land (Lundgren and Raintree, 1983).

1.2 Multidisciplinarity and Interdisciplinarity in Agroforestry

A certain minimal degree of multidisciplinarity is virtually assured in agroforestry by the very nature and complexity of the subject, but the degree of interdisciplinary thinking that is needed to develop the full promise of the approach is not often easily acheived. In a field of applied science characterized by the study of interactions which cut across the traditional lines of disciplinary specialization it is not enough to understand each component in isolation. Nor is it sufficient, or even necessary, for purposes of good research to catalogue and study all conceivable interactions in detail — an impossible objective in any event. What *is* needed for agroforestry to progress as an applied science is an interdisciplinary research paradigm which is capable of identifying crucial research priorities, based on a structured but flexible and cost-effective methodology for understanding those *critical interactions* which determine the ability of land management systems to achieve the purposes for which they are designed.

The need for this type of an approach to the organization of agroforestry research is clearly stated in the charter of the International Council for Research in Agroforestry (ICRAF) and the means for addressing it have been carefully built into the Council's institutional strategy (Steppler, 1981; Steppler and Raintree, 1983; Lundgren and Raintree, 1983) and its programme of work (ICRAF, 1983c). Other institutions and individuals active in agroforestry are coming to similar conclusions, but everyone faces the same general constraints on the achievement of a coherent interdisciplinary approach: *disciplinary biases* in the training of researchers, *institutional constraints* on the conduct of agroforestry research, *communication problems* between members of multidisciplinary research teams, and *lack of appropriate interdisciplinary methodologies.*

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To elaborate briefly on these constraints, the traditional *disciplinary biases* in the training of researchers has created a situation of acute shortage of well-rounded scientific manpower for broadly based approaches to agroforestry research. Although educational programmes are beginning to be developed to broaden the interdisciplinary training of agroforestry researchers (ICRAF, 1983), in the short and medium term most of the scientific and technical manpower available for agroforestry research and development will have been trained along traditional disciplinary lines. Even in the longer term it is likely that agroforestry workers will still need, in addition to their interdisciplinary training, a strong foundation in at least one of the major traditional disciplines. Discipline grounded "agroforestry generalists" may in time emerge from educational institutions, but the main strategy for meeting the scientific manpower requirements of agroforestry for the forseeable future will most likely be based on the fielding of *well-rounded multidisciplinary teams*, coordinated by interdisciplinary-minded team leaders. This trend is evident today in the multidisciplinary team approach which is becoming a standard feature of agroforestry project planning.

The ability to field such teams, however, is currently hampered by severe *institutional constraints*. In government institutions and universities, departments dealing with different aspects of land use are often separated by rigid institutional boundaries, often accentuated by fierce competition for scarce resources. Agroforestry as such typically has no single institutional base and the recruitment of an adequate multidisciplinary team must often depend upon fragile ad hoc arrangements for inter-institutional cooperation. While long term arrangements for institutionalizing agroforestry on a more permanent basis will have to be made (Steppler, 1981; Lundgren and Raintree, 1983; Catterson, 1982). the best hope for the short and medium term may be in the form of *projects* of prescribed duration, each with its own agroforestry-oriented budget and programme of work (Torres, 1983).

Even when these problems can be overcome and a secure framework established for a multidisciplinary team approach to agroforestry research and development, once the team is in the field enormous *communication problems* set in which, if not solved, will prevent the team from making the transition from *mere multidisciplinary* to *genuine interdisciplinarity* in its approach. With a few rare exceptions perhaps, any one who has ever sat down with a multidisciplinary group of scientists to thrash out a common interdisciplinary perspective will be familiar with the frustrations of trying to resolve the traditional differences of interest or perspective which are inherent in such groups. The problems are both cognitive and motivational in nature, but one has the feeling that the latter may be of overriding importance. Perhaps the best antidote to the pointless and often poisonous debates which arise in such contexts is to shift the whole activity out of the academy and into a real life field situation. Only when confronted by real and complex problems in urgent need of solution will individual team members be able to cross the *motivational threshold* which prevents them from submerging relatively minor disciplinary differences in favour of productive teamwork on the really major interdisciplinary problems and opportunities with which the field situation confronts them. There is nothing like a healthy dose of undiluted reality in the field to generate a completely new and refreshing set of problem-oriented priorities. Very often this is the *only* feasible way of integrating the human dimension into agroforestry research.

If this transition is successfully made, there may be no turning back. Scientists involved in this problem-solving or "mission-oriented" type of work often express a deeper sense of personal satisfaction with their work. Real problems are *harder*, not easier to solve than those derived from a purely theoretical or disciplinary orientation. Moreover, the inspiration afforded by the field situation for substantive theoretical or "pure science" contributions can be quite significant. Although the current emphasis on the interdisciplinary team approach in applied land management science can be seen as part of the larger society's strategy for coping with unprecedented human challenges (i.e. nothing less will suffice at this hour in human history), the high level of personal stimulation inherent in interdisciplinary work can itself provide sufficient psychological impetuous to keep the process going, once the threshold has been crossed.

All this is well and good, but experience indicates that *catalysts* are needed to assist multidisciplinary teams to cross the threshold of interdisciplinary activity. The field situation itself is one such catalyst, good will and a shared problem-solving motivation are also needed, but in the end little progress will be made unless the team can arrive at a shared and detailed blueprint of *how to proceed* in its investigation of the land management system at hand. This is where the need for an interdisciplinary *methodology* comes into the picture. A good methodology can bring the other catalysts into operation. Without such a methodology, no amount of good will and motivation will enable a multidiciplinary team to achieve a coherent interdisciplinary approach to the solution of complex land management problems.

The remainder of this paper is devoted to a discussion of one such methodology, the Diagnosis and Design (D&D) approach developed by ICRAF in collaboration with agroforestry workers around the world as a tool for agroforestry research and development projects.

2. AGROFORESTRY DIAGNOSIS AND DESIGN: AN INTERDISCIPLINARY SYSTEMS APPROACH

2.1 The State of the Art

How do you identify priorities and organize applied research in a field which has no research tradition? How do you insure a conscientious research-for-development orientation in a nascent subject like agroforestry which poses so many fascinating and unanswered questions of a purely academic nature? How do you avoid disciplinary or pet technology biases when designing agroforestry systems for rural development? What is the most efficient and logical sequence of steps to follow in analyzing existing land use situations to identify the real needs and potentials for agroforestry?

These are some of the questions faced by ICRAF's multidisciplinary staff in trying to develop a methodology for agroforestry Diagnosis and Design (D&D) as an aid to the formulation and implementation of relevant and cost-effective research and development programmes in agroforestry. Work to develop such a methodology was initiated at ICRAF in 1981. Now, after trial applications in over twenty sites in Kenya and elsewhere around the world (though ICRAF's Collaborative and

Special Projects Programme), the methodology has been tested and adapted to a wide range of environmental and socioeconomic circumstances and brought to a preliminary stage of completion in two draft manuals (ICRAF, 1983a, 1983b) which are currently being circulated for review and comment before being revised for wider distribution and testing. The object of this open-ended process is to continue to develop and refine the methodology on the basis of trial and user feedback until it reaches its potential as a genuinely useful and practical tool for agroforestry researchers and development workers in the field.

Examples of practical field applications of the methodology are given in a complementary series on *Case Studies in Agroforestry Diagnosis and Design*, published within ICRAF's Working Paper series in order to facilitate rapid dissemination of D&D results from around the world (see for example Raintree, 1983a; Torres and Raintree 1984; Hoekstra, 1984; Rocheleau and van den Hoek, 1984). The series also provides opportunities for publication of selected case studies resulting from application of the methodology by researchers outside of ICRAF.

To facilitate access to and comparison of D&D results from a wide range of sites, a computerized data bank of global D&D information is being set up at ICRAF offices in Nairobi. From time to time, analyses and book length collections of case study materials relating to particular environmental or problem-oriented themes will be published. Over time, hopefully, the analysis of case study information will assist in the development of agroforestry in a way which is analogous to the role played by case studies in the development of medical science.

The various outputs from the Diagnosis and Design Project at ICRAF represent one aspect of a coordinated effort to develop a full range of useful methodological tools and information banks to service the needs of the global community of agroforestry workers (see ICRAF 1983c for information on other developments).

2.2 Requirements for an Interdisciplinary Methodology: Ends and Means

The considerations evoked in the first section of this paper touch on fundamental aspects of the "charter" of interdisciplinary teams, but what specifically could we expect of an interdisciplinary methodology for agroforestry? What specific *ends* should it address, and what *means* might it use to achieve these ends? These questions from part of the essential background to the D&D methodology. Indeed, the working out of appropriate means-ends linkages is the fundamental core of any methodology development process. Before proceeding to more detailed methodological considerations, it may be useful to first indicate the general requirements which the D&D methodology attempts to meet. For the sake of brevity the various requirements are listed under only four major headings. An interdisciplinary methodology for agroforestry should:

1. Provide a neutral, comprehensive and generally acceptable overall framework for collaboration between all disciplines relevant to the identification and implementation of applied research to develop agroforestry's potential as a source of appropriate technology for improved land management systems.

2. Institutionalize an effective applied focus in technology-generating research by providing mechanisms for feedback and coordination between rigorous on-station experimentation and participatory on-site research and testing with the intended users of technological innovations.

3. Provide practical procedures for timely and cost-effective inputs to the identification, planning and implementation of interdisciplinary research and development projects

4. Suggest ways of completing the research-for-development cycle by following through with adequate extension followup and continued adaptive research within the recommendation domain for new or improved technology.

Many other criteria could be listed but most of these, I would submit are already implicit in the above short list of major objectives, or are explicitly elaborated in the specific methodological strategies and tactics which have been developed as means for achieving the identified ends (ICRAF, 1983a, 1983b; Raintree, 1983b). For example, learning from farmers, technology evaluation by adoption, and ability to assess the technological needs and opportunities of resource-poor farmers are all key elements of the new research-for-rural-development paradigm (Chambers, 1983) and critical elements of any adequate methodology for applied agroforestry, which are given priority and dealt with in some depth at various stages of the D&D process. In this brief introduction to the D&D methodology most of the crucial methodological detail must remain implicit. More detail is provided in the draft manuals (ICRAF, 1983a, 1983b), but even there the emphasis has been on describing *how* to implement the objectives of applied research-for-development in the case of agroforestry, rather than *that* these objectives should be addressed.

In partial fulfillment of the first of the criteria listed above, the emphasis in the D&D methodology on providing a basis for appropriate technology-generating and testing research is a direct consequence of the mission-oriented, impact-maximizing strategy which must be adopted if interdisciplinary activities are to have the kind of material effect on the land management scene which is expected of agroforestry (Raintree, 1983b). People are not fed, housed, kept warm or provided with the means to cook their food and satisfy other basic needs by journal articles or successful scientific careers. While technology is not the solution to every rural development or conservation problem, without technology there can be no lasting solutions; moreover, improperly conceived technologies may generate more problems than they solve. To be fruitful, research on improvement of land management systems must result in the *concrete technical means* by which people may be enabled to take greater control of their destiny and satisfy their primary production objectives. The ultimate practical aim of the D&D methodology is to get agroforestry out of the lecture halls, off the drawing boards and into the landscape of rural development. Hence, the D&D emphasis on generation of appropriate component technologies and land management systems.

With regard to the first and second criteria, it is crucial, for an impact-maximizing approach, to achieve a proper balance between *systems research* on the one hand and *component research* on the other. It is at the *technology interface* that these two types of research come together.

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We will return to this point shortly, but for the moment let it be said that the failure of institutions to achieve a smooth running integration of these two types of research may be the single most important reason for the relatively low yield of society's investment in rural development through applied land management research.

Let us examine a familiar case in point. The adoption over the past decade of a Farming Systems Research (FSR) approach (Collinson, 1981; Hildebrand, 1981; Zanstra *et al.*, 1981; Shaner, *et al.*, 1982) by many international and national agricultural research institutions may be seen as part of society's effort to improve the return on its investment in applied agricultural research. Faced with mounting and interrelated problems of resource degradation and failing production systems throughout the developing world, international support for the Farming Systems approach is part of the global society's response to a crisis situation. In essence, the introduction of FSR as part of the overall research strategy of these institutions is an attempt to bring about a proper balance between systems research and component research, the lack of which was recognized as a constraint on the achievement of applied research and development goals.

The attempt to correct existing imbalances and broaden the research approach to focus more effectively on neglected aspects of farming systems has, in most cases, required the addition social scientists to existing multidisciplinary research teams. Unfortunately, the inevitable institutional "growing pains" involved in the adoption of FSR methodologies and the close association of social scientists with this institutional adjustment has in many institutions tended to divert the debate on the proper balance between systems and component research into unproductive lines based on a *false dichotomy* between social scientists and biotechnical scientists. Be that as it may, the real issue in the Farming Systems debate is not between the social vs. the biotechnical sciences, but between *discipline-oriented* vs. *systems-oriented* scientists of any disciplinary background. In other words, while the adoption of the FSR approach does indeed involve a very necessary and productive debate on the overall balance of disciplines in applied scientific research, the real issue is between *those applied scientists who derive their research objectives and satisfactions from disciplinary traditions and incentives* vs. *those who get their inspiration from attempting to satisfy the technological needs of real world farming systems.*

Until the real issue is taken up, the intrinsic complementarity between systems and component research in the technology generation effort will not be perceived, the interdisciplinary threshold will not be crossed, and multidisciplinary teams will fail to achieve "takeoff" to sustained interdisciplinary interaction. Ultimately, of course, the real losers will be the rural people themselves, insofar as this lack of institutional coherence retards the development of adequate interdisciplinary approaches to the solution of the complex land management problems which they are facing.

As the history of science tells us, obsolete paradigms are rarely ever conclusively "disproven," they are merely abandoned in favour of newer and more adequate ones (Kuhn, 1962). Agroforestry, lacking an established research tradition of its own, is in a unique position to learn from past experience and build a more adequate interdisciplinary approach into

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the very foundations of its emerging research paradigm. What is needed to avoid unproductive impasses is a clear understanding of the conceptual basis for fruitful collaboration between component researchers and systems reseachers in the technology generation effort.

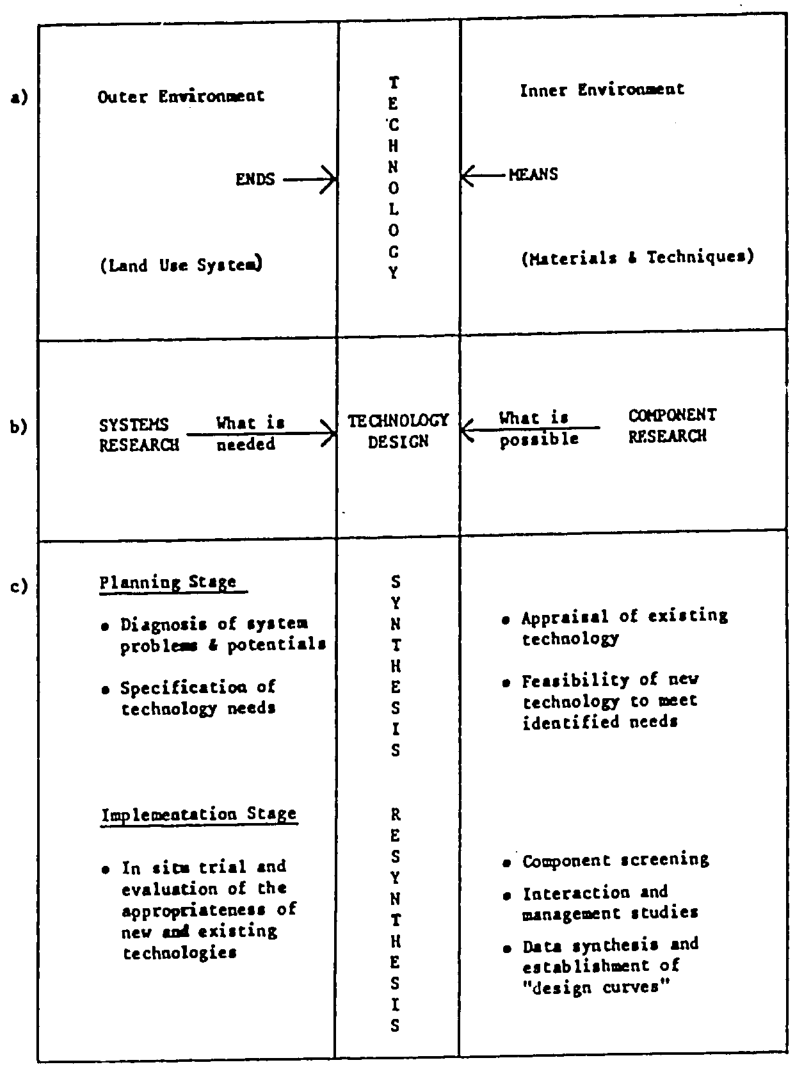

Figure 1. Complementarity between systems and component research with respect to a) the definition of a particular technology, b) specifications for technology design, and c) inputs to the technology generation effort at project planning and implementation stages. The lefthand "systems" and righthand "component" portions of this diagram correspond, respectively, to the upper and lower circles of Figure 2 and, somewhat less precisely, to the lefthand "on-site" and righthand "on-station" boxes of Figure 3.

The conceptual basis for the synthesis behind the D&D methodology was laid some years ago by Herbert Simon (1981) in his lucid discussion of the nature of technical artifacts. The essential complementarity between systems research and component research is revealed when we consider what is needed to define any particular technology (Figure 1). Any piece of technology in this sense (or specific application of technological knowledge) can be seen as an *interface between two environments:* an *outer environment* which defines the purpose and functional requirements which the technology serves within the larger system (for our purpose, the "land management system" of which the technology is a part) and an *inner environment* which is defined by the particular arrangement and mode of action of the constituent elements (components) by which it serves its purpose (i.e. the "nuts and bolts" of the technology). Both sets of specifications are necessary to completely define any particular piece of land management technology, one corresponding to the information provided by systems research (system requirements and functional specifications) and the other to that which is provided by component research (component selection and management specifications).

As a research manager at one of the CGIAR centres once put it, "You cannot have systems without components, but components without systems are meaningless" (Nores, personal communication). The methodological corollary to Simon's interface concept is that, in the effort to generate appropriate land management technology, the respective roles of *systems researchers* (social scientists, economists, land resource specialists, climatologists, cropping systems specialists, etc.) and *component researchers* (foresters, agronomists, horticulturalists, livestock specialists, plant pathologists, etc.) should be seen as entirely *complementary* and *mutually supportive.* If either input is neglected, the technical specifications remain incomplete and the likelihood of the technology finding a niche in the intended system is correspondingly lowered. Without both sets of specifications, the technology generation effort remains a hit-or-miss affair.

The schematic conception given in Figure 2 illustrates the role of diagnostic and design activities in a research-for-development programme based on active complementarity between component technology and systems research. Fruitful collaboration at the "technology assessment" interface might take the form of the following dialogue: Systems researcher to component researcher, "What have you got for System X?" Component researcher to systems researcher, "What do you need for System X?" A lively discussion would then ensue on the specifications (external "system" and internal "component") for technology which would be appropriate and feasible in the context of System X. In due course this would lead to the design of appropriate technology and the planning of research to develop and test the identified technology.

Needless to say, it is neither necessary nor likely that individual scientists can be neatly classified once and for all under one of these two researcher categories. In practice individual scientists may contribute to both types of research. In the final analysis, the conceptual synthesis which is necessary to generate appropriate technology must take the form of a shared construct in the minds of all concerned, but some division of labour between members of an interdisciplinary team may be invoked in the development of this construct.

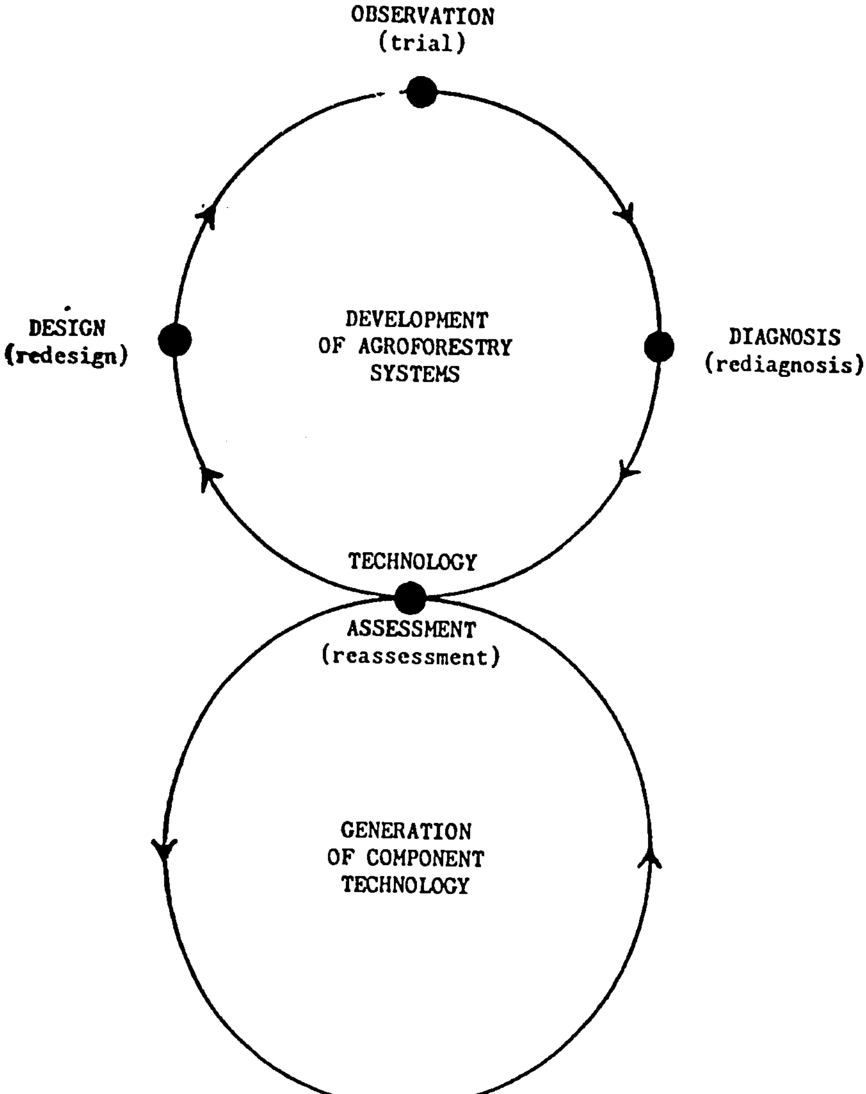

Figure 2. Schematic conception of a research-for-development programme based on complementarity between on-site systems research involving the iterative D&D process and component technology research involving rigorous experimental work on-station mainly but also, for some purposes, on-site. After the first round of the upper cycle (activities indicated in caps), the process is repeated as many times as needed to develop the system (activities indicated in parentheses). Interaction between the two circles at the "technology assessment" interface is designed to insure that the two mutually reinforcing types of research activity move in concert toward the shared goal of developing the system through the generation and application of appropriate technology.

If in principle there are no insuperable problems of interdisciplinary collaboration between researchers operating within the framework of the complementarity concept, there are nevertheless certain practical logistical constraints and requirements. The main one, which is implied the third criterion in our list of methodological requirements, is the limitation on time and personnel resources available for the type of survey work which is normally part of the discovery procedure needed to define the functional attributes and other system specifications for technology appropriate to a given land management system. We may refer to this as the "rapid appraisal" constraint, which has been the subject of considerable attention in recent years (Chambers, 1981; Longhurst, 1981; Pearce and Jones, 1981). Where research planning is a resource limited activity and where opportunities to accurately determine the appropriate direction for technology development are pre-empted by decisions taken in the press of time, systems researchers who ignore the rapid appraisal constraint do so at great peril to the success of their role in providing adequate system specifications for technology design.

Experience would indicate that lengthy survey work is neither necessary nor, in itself, sufficient to the information needs of the research planning phase of project development. The premium really is on *adequate analysis* of the system, rather than on any preconceived notion of the amount of survey work which ought on principle to be undertaken. Where the target land management system is already fairly well documented, very little survey may be needed to fill in the gaps in the knowledge required to derive appropriate technological specifications. Maximum use of available information can be made, but even where there is little or no baseline data, the information requirements of D&D can be rapidly met by steamlined survey procedures which involve senior members of the multidisciplinary R&D team directly in the collection of the essential information on which they will ultimately base their technology designs. Recalling what was previously said in section 1.2 about the need to focus on critical interactions, *essential information* may be defined as that which is needed to a) understand the critical means-ends linkages which govern the functioning of the target system (i.e. how the existing system works, its objectives, resources and technical means), b) diagnose its inherent problems and constraints (i.e. how *well* the system works), and c) assess the potential of the system to accommodate and benefit from discrete technological interventions of various types (leading to the development of design specifications).

The rapid appraisal approach to agroforestry Diagnosis and Design pertains mainly to the initial D&D exercise which is undertaken at the research planning stage to formulate an agroforestry R&D project. But diagnosis and design is a continuing, iterative process which can be repeated throughout the life of a technology-generating project to progressively deepen the diagnosis, assess the impact of introduced technology, and refine the prototype design to fit better the needs and potentials of the system. Once the project is on the ground with coordinated research activities on-station and on-site with farmers representative of the target land management system, the rapid appraisal constraint is no longer operative but the principles of efficient diagnosis and design continue to be applied as part of the projects "internal guidance system" (the basic mechanism in D&D for meeting the feedback requirements of criterion 2). Continuation of this same process into the

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adaptive research activities of the extension stage of the project cycle is part of the D&D approach to satisfying the requirements of criterion 4.

The generalized flowchart given in Figure 3 illustrates the movement of information between the various research and development activities in an R&D project incorporating the D&D process, first as a basis for project formulation, then later as a means of coordinating feedback between on-going research activities (on-station and on-site) during the mid-project implementation stage, and finally as a means for handling feedback from a wider range of adaptive research trials at the dissemination stage. Figure 4 elaborates on the various roles served by the D&D process at different stages in the life cycle of a research and development project. The resulting process of "zeroing in" on an optimized land management system or component technology which the iterative use of D&D procedures can facilitate is illustrated by Figure 5.

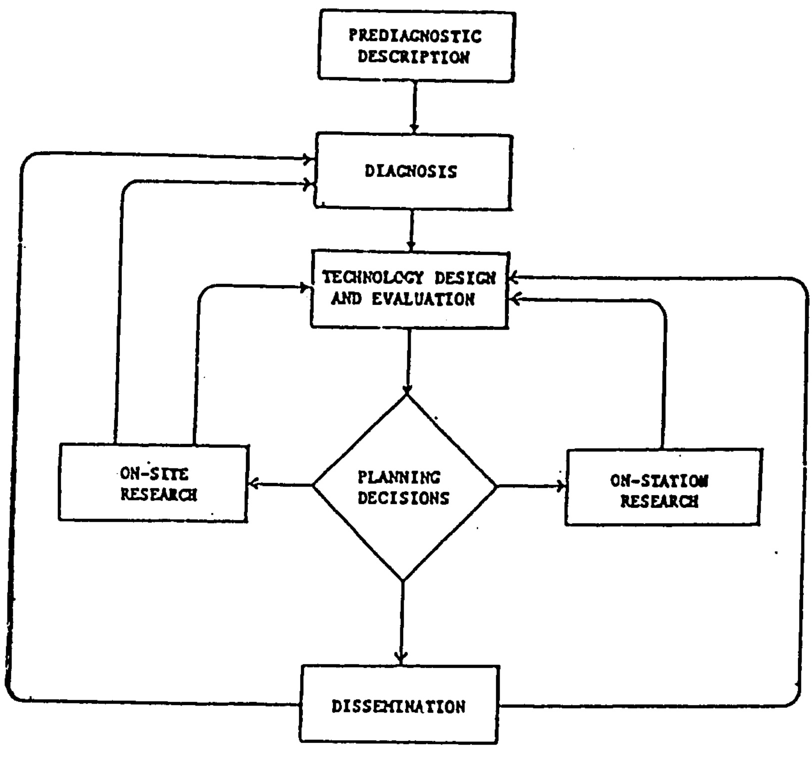

Figure 3. Components of project design incorporating the D&D process as part of the project's internal guidance system. Note feedback linkages.

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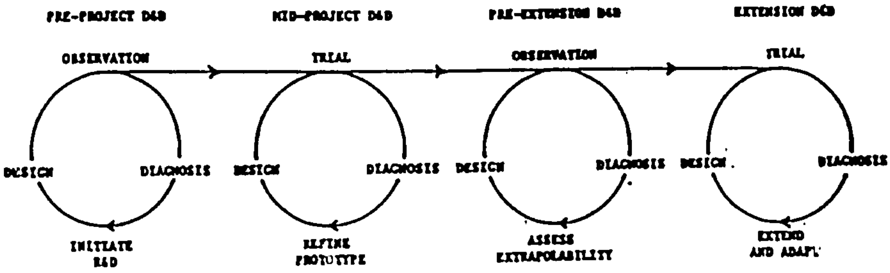

Figure 4. Repetition of the basic D&D process in different forms for different purposes at successive stages in the life of a technology generation and dissemination project.

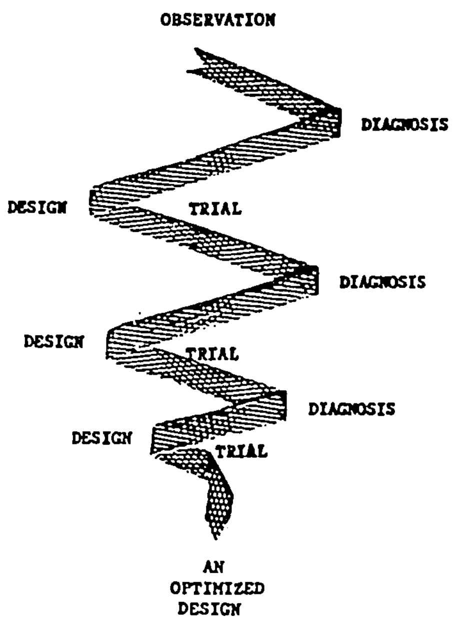

Figure 5. Beginning with an initial "best bet" design for a *generally appropriate* technology, the iterative D&D process leads, through a series of trial-and-error-reducing steps, toward the goal of a *specifically appropriate* technology for the target land use system.

2.3 Key Conceptual and Procedural Elements of the D&D Methodology

The foregoing discussion of methodological requirements and the general means by which the D&D methodology attempts to answer them has brought out some of the main principles of the approach. For purposes of this brief introduction to the methodology it still remains to give slightly more specificity to key elements in the conceptual and procedural framework of D&D applications.

Definition of "the System" for D&D Purposes

Given the concept of agroforestry as an approach to the improvement of land management systems, one of the prerequisites for successful application of the D&D methodology is a clear idea of what is meant by a "land management system." The concept adopted by the D&D methodology is based on the notion of a concrete, self-organizing "living system" as developed in General Systems Theory and widely applied in the biological and social sciences. This conception emphasizes analysis of the interactions among concrete system elements governed by the organized flow of matter, energy and information. It is distinguished from the alternative concept of "abstract systems" which deals with system variables at a more abstracted or idealized level of analysis (e.g. systems of causal relationships between components or states of concrete systems). Both types of systems analysis figure prominently in the D&D methodology, but the *definition* of "the system" for D&D purposes is based on the concrete systems approach.

Figure 6 illustrates the concept of the "land management system" which underlines the D&D approach. As shown in the illustration, the land management system, represented by the central pyramid, is part of the larger Man-Environment complex or "human ecosystem," represented by the square. At the top of the pyramid is Man, the manager, whose organizing influence (advertant or inadvertant) is felt throughout the human ecosystem but most clearly and directly expressed through the land management system. The base of the pyramid consist of those aspects of the Environment which are directly manipulated by Man to achieve his production objectives. The critical intervening variable in this interaction is the set of existing technical means by which the resource base is exploited to satisfy a given set of human purposes. In the functioning of the land management or production system, management flows down from Man (a movement of organizing information and energy) and production flows up from the resource base to Man (a movement of informed matter and energy).

The central point of this rather generalized dynamic model is that if any of the three main elements (human purpose, technology, resource base) were absent, the system would not function. The methodological corollary is that if any of the three essential elements are ignored, it will be impossible to *understand* how the system functions. Without such understanding, the effort to generate appropriate technology for the system will remain a hit-or-miss affair. Of course, it is not necessary to understand *everything* about the system in order to meet the information needs of good agroforestry design. What the model attempts to convey is a general notion of the kind of information that is essential for D&D purposes, i.e. an adequate knowledge of the means-ends linkages by which the land management system is organized to use available technology to exploit the resource base to satisfy human purposes.

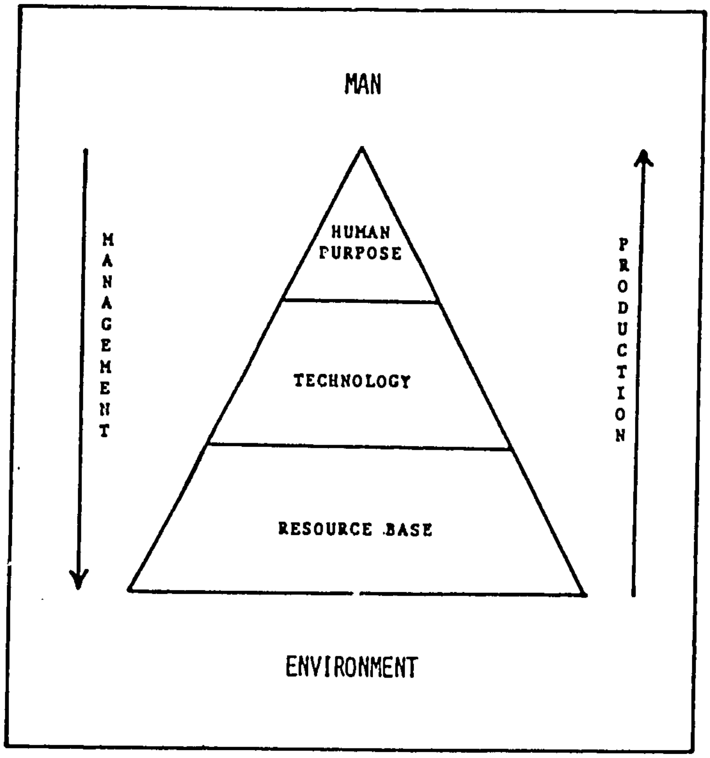

Figure 6. Concept of "the system" for D&D purposes. Within the "human ecosystem" represented by the square, the "land management system" which is the focal point of D&D activities is represented by the pyramid, illustrating the functional linkage of human purpose, technology and resources. An incomplete understanding of the system results if any of these three elements is ignored.

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Just how the D&D methodology approaches this task is taken up shortly. For the moment another key aspect of the definition of "the system" for D&D purposes needs to be explained. Given the importance accorded in the above model to the central organizing role of human purposes, it follows that the analysis of the system must focus on the activities of the relevant *decision-making units* within the local human ecosystem. Identification of the focal units for D&D purposes gives additional specificity to the definition of the "land management system" and also defines the scale of relevant diagnostic and design procedures. Because the nature and composition of relevant decision-making units may vary widely from one geographical location to another, the D&D methodology has adopted a variable scale approach.

In most cases the primary focus for D&D activities will be on the *household land management unit*, i.e. the family farm, the household herd, or other elementary kinship-based production unit, for the simple reason that in most systems *this is where most of the major land management decisions are made* and it is these decisions which must be affected if agroforestry is to have any visible impact on the landscape.

Having said this, it must also be acknowledged that the household management unit may not be the only relevant decision-making unit to address in many cases. Agroforestry is an increasingly important management alternative for larger scale forest management units with their own forms of organization which must be taken into account. Even in farming systems applications many problems require a *larger-than-farm* scale of diagnosis and design. Watershed problems are a typical case in point, where erosion processes on one farm may originate or have impacts on other farms in the watershed. Boundaries between farms, roadsides, communal grazing areas, etc. are areas which may have problems which cannot be assigned to individual households and which may require larger scale landscape and community level solutions (Rocheleau and van den Hoek, 1984).

Smaller scale approaches to D&D may also be required to deal with *intra-household* level problems and potentials associated with the internal division of production responsibilities and opportunities (usually along sex role lines). These aspects may be particularly significant for agroforestry in regions where women, in addition to a heavy burden of domestic chores (food preparation, water supply, child care, etc.), may also have primary responsibility within the household for firewood collection, care of livestock and subsistence food production (Hoskins, 1980; Fortmann and Rocheleau, forthcoming).

For all of these reasons, a flexible variable scale approach to D&D is required. A systematic attempt to assess the role of scale factors in agroforestry diagnosis and design is currently underway at ICRAF (Rocheleau, 1984) to supplement the basic guidelines for variable scale analysis given in the current D&D documentation (ICRAF, 1983b).

A Diagnostic Approach to Design

There is a saying in the medical profession that *"Diagnosis should precede treatment."* We wouldn't dream of entrusting our health to a medical practitioner who made a habit of prescribing treatments without first diagnosing what ails us. We expect the same approach from automobile mechanics. What a strange anomaly it is, then, that we have tended to accept a lesser standard of practice when it comes to treating problems arising from man's use of the earth. The fundamental rationale for a diagnostic approach to agroforestry design, and indeed to all systematic attempts to rectify land management problems, is that this same standard of professional practice should apply when devising strategies for technological interventions in existing land management systems. The time, if ever it existed, when we could settle for a hit-or-miss approach to land management is long past.

Diagnosis, however, is not an end in itself. To have *impact* on the land use scene a diagnosis must be followed by an appropriate technological prescription. The diagnostic process, conceived as a "discovery procedure" is, nevertheless, usually the most direct and logic route to an appropriate agroforestry design. Intuitive leaps leading to very good agroforestry designs can, of course, occur, but the essential point is an epistemological one: how does one *know* that the design addresses the real needs and potentials of the system unless it is substantiated by a diagnosis of the system? For a careful, professional approach to agroforestry, it must be acknowledged that the ability to solve a problem begins with the ability to define precisely what the problem is (Steppler, 1981).

It is a common experience (grounded, one suspects, in some fundamental and evolutionarily significant feature of human cognition), that the very act of seeing a problem clearly can itself suggest the nature of the required solution. One could perhaps go so far as to suggest a methodological corollary to this observation: *If the analysis of a problem does not suggest at least the general outlines of a solution, then the analysis is not yet adequate and should be pursued further.* The D&D approach is, in essence, a kind of algorithm for evoking insights of this type into the connection between problems and solutions. As such, it really contains nothing fundamentally new, but merely suggests an efficient procedure for taking advantage of the remarkable human capacity for problem-solving which is somehow wired into the very nature of our thought processes. Troubleshooting the system: The particular form of the algorithm used in the D&D approach is suggested in a general way in Figures 2 - 5 and described in more detail for the project formulation stage of the D&D process in section 2.4 of this paper.

Criteria of Good Agroforestry Design

There is no substitute for good design. The world is littered with land management schemes that have failed because the intended users of new technologies did not take them up. Numerous factors are cited as reasons for failure, but one suspects that in most cases it is due, at base, to faulty design. The criteria adopted by the D&D methodology for good agroforestry design are threefold: *productivity, sustainability* and *adoptability.*

The *productivity* criterion is a self-evident and virtually universal measure of the success of any technological innovation. There is no need here to elaborate much on this criterion except to note that the D&D approach embodies a somewhat broader type of productivity assessment than is normal, partly due to the broad range of productivity improvements which are within the scope of agroforestry to address, and partly as an attempt to correct for an implicit bias in conventional productivity assessments toward commercialized systems of production. It is often tacitly assumed that the raising of cash income will automatically improve the ability of farmers to satisfy their consumption needs. Cash, in todays world is certainly a basic human need, but it will not solve the problem of food and firewood shortage in areas characterized by *absolute scarcity* of these commodities. In other words, cash is not *always* readily convertible into forms which satisfy other basic needs. These needs must often be addressed directly and, since it is in many cases within the scope of agroforestry to do so, the survey protocols of the D&D methodology encourage its users to make an *independent assessment* of problems with respect to each of the several "basic needs supply subsystems" and the ability of the land management system to meet these needs either directly through home production or indirectly through cash transaction.

The needs which are considered basic and universal, and which therefore enter explicitly into the D&D protocols are: *food, water, energy, shelter, raw materials* for local industry, *cash* (for normal expenses), *savings/investments* (for extraodinary expenses or development), and *social production* (for ceremonial exchanges and the like). Although the adoption of this "basic needs approach" does give the D&D methodology the capability to effectively address the needs and problems of resource-poor farmers, it does not necessarily imply an anti-commercial bias. The assessment categories are there to be used as needed. In highly commercialized production systems, the D&D methodology directs attention mainly to improvement of the cash subsystem; in poorly developed market economies, the methodology may suggest opportunities to satisfy the basic needs more directly. Agroforestry can contribute in various ways to each of the above listed subsystems (see ICRAF, 1983b, pp. 157-160 for elaboration of this point).

The *sustainability* criterion in agroforestry design reflects the special ability of agroforestry to solve or mitigate resource degradation problems in respect to deforestation, soil and water conservation, fertility maintenance, pasture regeneration, etc. In the D&D methodology the conservation objectives of agroforestry are expressed in terms of *sustaining production* for the simple but expedient reason that most smallholders are primarily concerned with production objectives and only secondarily concerned, if at all, with conservation objectives. To awaken interest in new technology it is often necessary (and with multipurpose agroforestry systems, entirely possible) to offer packaged solutions which meet both conservation and production objectives simultaneously. Assessing the sustainability of the existing system and designing for sustainable agroforestry systems is, therefore, a primary feature of the D&D approach. It could be argued that this is a neglected aspect of other diagnostic methodologies in the land management field. In agroforestry, certainly, it is one which is harder to ignore.

The *adoptability* criterion is simply a way of operationalizing all of those social and economic factors which interact with the particular attributes of any given technology to determine whether or not the technology is acceptable to the intended users. If a given technology is not in fact adoptable by the intended users, there is not much point in it. An analogous observation is made by nutritionists in noting that the nutritional value of any food that is not eaten is zero, regardless of its chemical composition. It has been more or less standard practice in the applied land management sciences for researchers to take their inspiration for new technology from the research tradition itself, rather than from an assessment of the chances for a specific technology in a given land management system. The result, all too often, has

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been the failure of the intended users to adopt the new technology because it simply does not fit their system (with its inherent technology biases, resource limitations and other constraints). Unfortunately, the tendency in such cases has usually been to blame the intended recipients or, in many cases, the extension system for failing to sell the new technology to the farmers. In most cases, however, it will be more productive to take cognizance of adoptability criteria in the *design* of technological innovations, in the first instance, and to build the appropriate characteristics into the new technology from the very start of the R&D process. This, in fact, is the explicit rationale behind the incorporation in the D&D methodology of adoptability as a criterion of good agroforestry design, on an equal footing with productivity and sustainability (see Raintree, 1983b for further discussion of adoption strategies in agroforestry).

2.4 Procedures for Project Formulation

As indicated above, the D&D methodology recommends an iterative process of diagnosis and design which continues throughout the entire life cycle of a research and development project, from the project planning stage, through the technology generation stage to the final stage of technology dissemination and adaptive research. In its present state of development, the existing draft documentation on the methodology gives primary emphasis to a set of general guidelines (ICRAF, 1983a) and optional detailed procedural suggestions and resource materials (ICRAF, 1983b) for the project planning stage of the project cycle. Additional guidelines and resources are currently being developed for later stages and will be incorporated into revised editions of the manuals. This staggered process of methodology development is partly due to the longer time required to gain experience with the latter stages of the project cycle, but partly also to the *priority* placed in this early period in the development of scientific agroforestry on the *formulation* of well-conceived projects.

In order to fit the needs, resources and levels of interest of the widest possible range of potential users, the D&D guidelines for project formulation are presently offered at three levels of detail.

Level 1. Minimal Guidelines

Guidelines at this minimal level of detail consist of little more than urging scientists and development workers to adhere to the basic principle that *diagnosis should precede treatment.* In applying this principle, there are many possible ways to proceed and workers are encouraged to use their ingenuity in devising ways and means appropriate to their own needs and resources. As long as one first takes the time to diagnose the target land use system *before* starting to design improvements for it, the minimal requirements of the D&D approach will be satisfied. Still, it may be helpful to pass along some useful hints and suggestions, based on ICRAF's experience with the approach, on how one might organize one's thinking in approaching this task. Table 1 suggests a four stage breakdown of the D&D process and the basic questions and key factors which ICRAF field teams have found useful to consider at each stage.

Table 1. Summary of level 1 guidelines for project formulation based on a four stage breakdown of the 'minimal' logic of the D&D process.

D&D STAGES	BASIC QUESTIONS TO ANSWER	KEY FACTORS TO CONSIDER	MODE OF INQUIRY
PREDIAGNOSTIC	HOW THE SYSTEM WORKS (what does it look like, how is it put together, how does it work?)	PRODUCTION OBJECTIVES AND STRATEGIES	SEEING THE SYSTEM
DIAGNOSTIC	HOW WELL THE SYSTEM WORKS (what are its problems, limiting constraints and dysfunctional syndromes?)	PROBLEMS IN MEETING OBJECTIVES CAUSES OF IDENTIFIED PROBLEMS	TROUBLESHOOTING THE SYSTEM DERIVING SPECIFICATIONS
DESIGN	HOW TO IMPROVE THE SYSTEM (what is needed to improve system performance?)	PROBLEM SOLVING OR PERFORMANCE ENHANCING INTERVENTIONS	BRAINSTORMING AND EVALUATING ALTERNATIVES
PLANNING	WHAT TO DO TO DEVELOP THE IMPROVED SYSTEM (what specific R&D actions are needed to develop and implement the envisaged improvements?)	R&D PRIORITIES	PROJECT PLANNING AND RESEARCH DESIGN

Level 2. Semi-detailed Guidelines

This is the level of detail contained in the draft *Guidelines for Agroforestry Diagnosis and Design* (ICRAF, 1983a, 25 pp.). At this level of detail the suggested procedures for project formulation emphasize a "rapid appraisal" approach (Chambers, 1981) and consist of a series of information gathering and analytical steps, leading logically from one to the next. This stepwise procedure entails an hierarchical progression from the general to the particular, which is designed to economize on time and effort by excluding irrelevant information from further consideration while developing a progressively sharper focus on *essential information*. By means of this structured but open-ended approach the level 2 guidelines attempt to avoid the seemingly endless and needlessly detailed data gathering task which is often characteristic of less structured approaches to systems analysis. In the level 2 methodology the four stage procedure suggested at level 1 is further subdivided into a series of 12 discrete steps, as follows:

Prediagnostic Stage (Steps 1 - 3)

This stage covers 1) background description of the study area, including diagnostically relevant aspects of the biophysical and socioeconomic environment, 2) differentiation and selection of land use systems within the study area for further D&D attention, and 3) preliminary description of diagnostically relevant aspects of the selected systems.

Diagnostic Stage (Steps 4 - 6)

This stage includes 4) diagnostic survey of the selected systems and relevant aspects of the environmental setting, 5) diagnostic analysis and identification of major land use problems and potentials, and 6) derivation of specifications for appropriate technology (including non-agroforestry options but with special attention to agroforestry potentials).

Technology Design Stage (Steps 7 - 9)

This stage involves 7) appraisal and selection of candidate technologies for possible inclusion in the design, 8) synthesis of a general design concept for an improved land use system and development, if possible, of initial 'best bet' designs for component technologies, and 9) ex ante evaluation and refinement of the proposed design. The activities of this stage may involve reiteration of the above steps.

Follow-up Planning Stage (Steps 10 - 12)

This stage covers 10) identification of research needed to develop and/or test the identified agroforestry technologies, 11) identification of areas needing further D&D attention in followup activities and 12) development of a detailed project implementation plan to carry out the envisaged R&D programme.

Table 2 presents a summary overview of the four stage process in slightly greater detail than Table 1. The *Guidelines* document itself goes a little further than what is shown here in the form of a step-by-step outline which suggests ways to proceed at each step, listing the expected *output* of each step, the relevant *sources of information*, a more detailed list of *factors to consider*, and a brief catalogue of *potentially useful tools* and materials.

Level 3. Detailed Guidelines

For users of the methodology who, when developing their own set of adapted procedures, might be desirous of having the benefit of the full range of detailed methodological suggestions which ICRAF's experienced multidisciplinary staff is currently able to provide, a third level of detail is given in the draft *Resources for Agroforestry Diagnosis and Design* (ICRAF, 1983b, 383 pp.). This collection of optional resource materials contains a more detailed set of procedural suggestions for each of the 12 steps in the level 2 methodology, along with over 35 resource modules describing useful diagnostic tools, analytical techniques and design materials for possible consultation at appropriate steps in the project formulation process. It would be unlikely, and indeed impossible in a "rapid appraisal" type of project formulation exercise, that all of the suggested procedures, tools and materials would be needed or used.

What must be emphasized, in any case, is that users of the D&D methodology in its more detailed form will almost always need to modify and adapt the suggested procedures to fit the particular application. This resource collection is designed to serve as a source of ideas to aid the user in this process. Many of the resource modules may also have value for agroforestry independent of the D&D process.

Table 2. Summary overview of level 2 project formulation guidelines showing how the D&D process relates to the concepts of the "land management system" and the "human ecosystem" illustrated in Figure 6. Stages of the D&D process are shown at the top of the table, the major analytical techniques at the bottom, and the key questions and factors to consider in each of the internal cells of the table.

HUMAN ECOSYSTEM / LAND USE SYSTEM	PREDIAGNOSTIC DESCRIPTION	DIAGNOSIS OF PROBLEMS & POTENTIALS	TECHNOLOGY DESIGN	FOLLOW UP PLANNING
MAN	WHO IS INVOLVED? - LAND USERS - GOVERNMENT AUTHORITIES - OTHER INTERESTS	WHO HAS WHAT PROBLEMS? INTERACTIONS	FOR WHOM IS THE TECHNOLOGY INTENDED?	WHO SHOULD CARRY OUT THE NEEDED R&D WORK?
PURPOSE	MANAGEMENT (PRODUCTION/ CONSERVATION) OBJECTIVES OF THE DIFFERENT INTEREST GROUPS	PROBLEMS IN ACHIEVING MANAGEMENT OBJECTIVES, INAPPROPRIATE OBJECTIVES, STRATEGIES	SPECIFICATIONS FOR RELEVANT TECHNOLOGY	INSTITUTIONAL ARRANGEMENTS
TECHNOLOGY	OVERVIEW OF TECHNICAL MEANS IN CURRENT USE	TECHNICAL CAUSES OF IDENTIFIED PROBLEMS, FUNCTIONAL POTENTIALS FOR TECHNICAL INTERVENTION IN THE SYSTEM	APPROPRIATE DESIGNS FOR IMPROVED LAND MANAGEMENT TECHNOLOGY	PLAN FOR TECHNOLOGY GENERATING R&D
RESOURCES	OVERVIEW OF RESOURCE BASE	RESOURCE USE SUSTAINABILITY ASSESSMENT	RESOURCE REQUIREMENTS SUSTAINABILITY PROJECTION	PROJECT RESOURCES
ENVIRONMENT	STRUCTURE AND FUNCTION OF THE HUMAN ECOSYSTEM/ LOCAL COMMUNITY	WIDER ENVIRONMENTAL IMPACTS	WIDER ENVIRONMENTAL IMPACTS	IDENTIFICATION OF WIDER RECOMMENDATION DOMAIN
	BASIC NEEDS ANALYSIS	TROUBLE-SHOOTING ANALYSIS; PRODUCTIVITY, SUSTAINABILITY, ADOPTABILITY CRITERIA	MEANS-ENDS ANALYSIS	ITERATIVE D&D PROCESS

(Side labels: HUMAN ECOSYSTEM spans MAN to ENVIRONMENT; LAND USE SYSTEM spans PURPOSE to RESOURCES; D&D METHODOLOGY spans MAN to ENVIRONMENT.)

Even in its most detailed form the D&D methodology cannot anticipate and provide answers (or even suggest ways to find answers) to every question which could arise in site-specific applications. At its present stage of development the D&D methodology is really a tool for an interdisciplinary *group process* approach to agroforestry diagnosis and design by a multidisciplinary team of experts (or, in some cases, by an interdisciplinary-minded individual with backup from a multidisciplinary pool of experts). Like all tools, the successful application of the D&D methodology relies heavily on the flexibility, competance and creativity of its users.

Level 4 Guidelines?

It is not clear just how far it is practical or useful to go in developing methodologies like D&D. Perhaps after the draft manuals are revised to incorporate user feedback it will be decided that ICRAF has gone far enough in this effort and the emphasis will then shift to the accumulation and analysis of case studies and the development of broader geographical perspectives on agroforestry needs and potentials. Certainly, it is only through *application* that the methodology will bear fruit in concrete form and have the kind of impact on the landscape of rural development that is intended. However that may be, it is still conceivable that this type of a methodological approach could aspire to a higher level of rigor and detail, as would be required to achieve the capability of *positive diagnosis* and *precision design*, with less reliance than at present on the knowledge and skill of particular multidisciplinary teams. Such a methodology, essentially an elaboration and refinement of level 3 procedures, would involve the use of system specific "diagnostic keys" and detailed "design algorithms," but it would require an empirical and theoretical understanding of agroforestry, indeed of land management systems in general, that is well beyond the present capabilities of the field. Whether or not this is an attainable, or even desirable, goal is a moot point, but perhaps it is one that should be kept in mind for the future.

3. PRELIMINARY EVALUATION OF ICRAF'S EXPERIENCE WITH THE D&D METHODOLOGY

It is much too early to give anything more than a very preliminary account of ICRAF's experience with the interdisciplinary D&D methodology. It is difficult, moreover, to evaluate that experience without sounding self-serving. Nevertheless, it does seem possible at this early stage to draw certain tentative and reasonably objective conclusions about ICRAF's experience in developing and applying the D&D methodology. It should be noted, however, that the perspective expressed here is the sole responsibility of the author and, while I have no reason to anticipate substantial disagreement from my colleagues, the following statements have not been subjected to systematic in-house review and, therefore, do not necessarily reflect the considered institutional judgement of ICRAF as a whole.

Let it be said straightaway that any success which may be attributed to the D&D methodology effort at ICRAF is in large measure due to the very favourable climate created for such work by the Council's mandate, institutional strategy and programme of work. The ultimate goal of ICRAF's work, as stated in its Charter, is "to improve the nutritional, economic and social well-being of the peoples of developing countries by the promotion of agroforestry systems designed to result in better land use without detriment to the environment." As a research council without extensive field research facilities of its own, ICRAF's role is mainly to assist national and international institutions to develop and implement well-conceived research-for-development programmes in agroforestry The current programme of work, thus, emphasizes three main focal points:

1) the development of methodologies for identifying social, economic and ecological constraints in land-use systems and for assessing the potential of agroforestry technologies to overcome such constraints;

2) the systematic collation and assessment of agroforestry knowledge and the development of methods of studying and evaluating agroforestry technologies;

3) the efficient dissemination of methodologies and knowledge to scientists and development planners in the tropical and sub-tropical developing world (ICRAF, 1983c).

The need for a methodology to assist agroforestry workers to identify research and development priorities, based on a clear-eyed assessment of agroforestry-related constraints and potentials in existing land use systems, was identified as a priority focus for the Council early in the development of its institutional strategy (Steppler, 1981). Consequently, the D&D work was initiated in 1981 and later formalized as a project which received a major share of ICRAF's personnel and financial resources within the overall programme of work. A key element of ICRAF's strategy was to recruit a multidisciplinary team of 15 or 16 scientists whose first task would be to pool their collective experience to develop such a methodology.

3.1 In-House Development Phase

A brief discussion of some of the key elements of the institutional milieu in which the D&D methodology was developed may be of some relevance to the theme of this congress. In the first instance, the very complexity of agroforestry as an approach to the development of improved land management systems created an unusually favourable climate for a systems perspective among ICRAF's scientific staff. The newness of the field, lacking strong disciplinary conceptions of business-as-usual and, indeed, possessed of a kind of revolutionary elan, was no doubt another important and very favourable factor in the setting in which D&D developed. Few, if any, of the current systems methodologies in the land management field have enjoyed such a favourable institutional setting.

At the initiation of concerted D&D development activities in early 1981, the senior staff consisted of the Interim Director General and four scientists. While this might seem an inordinantly small staff complement for an organization with such a large mandate, it did promote an unusually intense and fruitful interaction among the scientific staff. The long, almost continuous, and sometimes very animated discussions which occured in this "think tank" atmosphere laid a sound foundation of shared interdisciplinary understanding which has formed the basis for much of ICRAF's subsequent work.

Early in the D&D methodology development two of ICRAF's scientists joined forces to spearhead the methodology development effort: an ecological anthropologist (later named project leader) with training in tree crop horticulture and psychology and a strong technology bent, and a livestock/range management scientist with an early background in agronomy and considerable experience in the management field. Two points are worth noting here: First, the interdisciplinarity of the individuals themselves, and secondly, the basic social science-biological science complementarity between these individuals, which in effect invoked the "pairing principle" which has figured so prominently in many of the Farming Systems methodologies. Another important element in the early D&D equation was the strong committment of this core team to the "new professionalism" (Chambers, 1983) of the research-for-development paradigm. The general committment of the Council as a whole to the ideal of an *applied* agroforestry science and the critical support of the other staff members (a horticulturalist and an agronomist) constituted a rich nutrient broth for the nascent D&D methodology. It was during this period that the basic framework for the D&D methodology was laid down.

One further element of the early methodology development work which was absolutely *crucial* to its success was exposure of the D&D team to realistic field conditions. Most of the early applications took place in Kenya at a variety of sites representing a range of ecological and socioeconomic conditions. One of these sites was developed as a special project site for in-house methodology development work and is now into its fourth year of on-farm agroforestry trials (Lundgren and Raintree, 1983; Rocheleau and van den Hoek, 1984; Vonk, forthcoming).

Gradually as other disciplines were added, notably a farm economist who brought fresh insights and greater rigor to the methodology and a forester who supplied an essential missing element, the basic framework of the methodology was fleshed out in greater detail and multidisciplinary rigor. It was not until 1983, however, that the full complement of disciplines originally envisaged for ICRAF's multidisciplinary team was reached (see ICRAF, 1983c for a listing of the more than 10 disciplines represented in ICRAF's current complement of 18 senior scientific and professional staff members). With the addition of a bioclimatologist, a land evaluation expert and a geographer/systems ecologist, the D&D methodology project was able to draw on a multidisciplinary staff whose breadth and sophistication is unlikely to be equalled anywhere else in the agroforestry field. This might, at first glance, seem to indicate a constraint on the application of the D&D methodology outside of ICRAF where such well-rounded multidisciplinary teams are rare, but this would be an erroneous conclusion since, as everyone knows, there is an enormous difference between the *development* of a methodology and its *application* by users. Right from the beginning, ICRAF's institutional strategy has distinquished three phases in the development of any of its methodologies:

Phase 1: Development of the in-house *capability* to accomplish a particular methodological objective

Phase 2: Expansion of ICRAF's in-house *capacity* to carry out a sufficient amount of methodology application work (as a service to clients)

Phase 3: Attainment of the status of a fullfledged *methodology* by transfer of the developed methodological capability to others for independent application (i.e. through documentation and/or training)

The D&D methodology is in the early stages of Phase 3. Conceived from the start as an activity which would involve the collaboration of potential users of the methodology in its development, the D&D methodology will not be complete until the current review period is over and suggested improvements have been incorporated into revised versions of the present draft manuals.

3.2 Dissemination Phase

There has been a high degree of overlap between the development and dissemination phases of the D&D methodology, inasmuch as the development of the methodology was largely accomplished through trial application and refinement at a range of sites around the world. Most of these applications have been organized under the umbrella of ICRAF's Collaborative and Special Projects Programme (COSPRO) and have involved collaboration of ICRAF scientists with local multidisciplinary teams of national and international scientists and, therefore, automatically involved dissemination of the evolving methodology. This repeated exposure to new ecological and socioeconomic circumstances, along with the feedback received from scientists representative of the methodology's main client group, has been a key element in the elaboration and refinement of the methodology. Few farming systems methodologies have been exposed to such a wide range of geographical conditions and user feedback.

For the purposes of this congress it may be instructive to consider how scientists exposed to the D&D methodology as part of the COSPRO project formulation experience have responded to the approach. The typical initial reaction to the methodology has been one of scepticism. "Is all this really necessary?" is the typical initial comment, recently expressed by an Indian scientist at the beginning of a D&D exercise in the Himalayas. Scientists have been formulating research projects without the benefit of the D&D methodology for years and the initial response is characteristic of scientists' reaction to what they often perceive as an intrusion on "business-as-usual" in a form which, at least implicitly, seems to call their professional competance into question. For the most part, the scientists recruited by their superiors for participation in ICRAF led D&D training-cum-project-formulation exercises are there not because of a burning interest on their part in improving their ability to identify meaningful priorities for applied agroforestry research, but because the need for such improvement has been recognized by higher management levels in their organizations. This is what one would expect. Research managers are more directly exposed to political demands for practical "results" that are part of society's response to the crisis situation facing many developing countries; while scientists, still relatively secure within the present system of disciplinary rewards, are sheltered from these pressures.

Be that as it may, given the long gestation period for the agroforestry technologies initiated by the D&D process, one of the few sources of empirical confirmation of the validity of the D&D process which we can presently offer is the fact that scientists initially expressing scepticism regarding the methodology, at the conclusion of the typical two week field exercise consistently express acceptance of and often real enthusiasm for the approach. Quite often it is the most vociferous sceptics who become the most vigorous champions of D&D. The phenomenon is so striking that one is tempted to compare it to the psychology of the classical "conversion experience."

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The typical comment at the conclusion of a D&D field experience is on the order of "You know, I really wasn't too impressed with all this D&D business to start with, but I really did learn a whole new way of thinking about my research AND it wasn't really all that complicated or time consuming. It will be useful to me in my future agroforestry work."

Of course, the reaction is not always so positive. Individual scientists are differentially susceptible to innovations in methodology. In trying to discover whether there are any patterns in the response to D&D, we don't seem to find any clear cut disciplinary biases. Some soils scientists and foresters are as receptive to D&D as many economists and sociologists. The only clear pattern of resistance to D&D that we can presently discern is in cases where the individual has a strong personal committment to some "rival" methodology or deep ego involvement in previous work of a similar nature at the site. In the former case, the resistance may be misplaced, since ICRAF has never claimed to be in exclusive possession of the methodological holy grail. There are many ways to skin a cat, and the D&D methodology has always been presented as only one, perhaps more than usually systematic and efficient, example of what is after all a very general and fundamental problem-solving approach. In the latter case, we are confronted with a more delicate problem, which may indicate the need for caution in accepting the host country's nomination of a D&D training site at which there is a long history of prior scientific involvement, particularly when demonstrating the methodology for the first time in a country. In some cases it won't matter, but normally such sites involve psychological complexities that are best avoided in training exercises.

What, in fact, do participants in ICRAF led D&D demonstrations actually take away with them from the experience? What indications are there that D&D is being successfully adopted and adapted for independent service in host country institutions? Several D&D-based agroforestry research and development projects are underway at various places in the developing world and certain countries and regional research organizations have expressed the intention of adopting the D&D methodology as a basis for project formulation in national and regional agroforestry research networks but it is simply too early for the methodology to have diffused outward from its point of introduction and, therefore, too early to evaluate the actual adoption and adaptation process. Likewise with the ultimate impact of the methodology on the agroforestry landscape.

It is not too early, however, to profit in the methodology refinement process from early feedback on the D&D approach received from collaborators in the field, participants in ICRAF training courses which prominently feature the D&D methodology, and comments and suggestions received from reviewers of the current draft methodology documents. The positive aspects of the methodology more-or-less speak for themselves. Let us concentrate, instead, on the negative feedback, since this is the source of valuable course correction information. What are the difficulties users have with the methodology and/or its current forms of presentation?

One relevant point is based more on observation of first time D&D participants rather than comments received. To handle the complexity of the on-the-spot data processing task involved in the rapid appraisal of complex land management problems and potentials, the D&D methodology relies on a flexible but structured "first things first" approach. In

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developing the methodology through repeated trial application, we have arrived at what seems to be a logical sequence of steps for an efficient and timely procedure. While the methodology allows and suggests flexibility in dealing with this progression, the general direction of movement (i.e. from general to particular and from diagnosis to design) can be ignored only at great peril to the timely completion of a coherent exercise. Some such "blueprint" for the exercise, adapted and agreed upon by the participating scientists at the outset, is a crucial requirement for fruitful multidisciplinary collaboration. Without it, everyone simply goes off in a different direction. The problem is that, even after having agreed on the procedural agenda, many scientists seem to have trouble sticking to it. As with all "committee" processes, a strong chairman who is thoroughly familiar with the demands of his role as leader of a D&D exercise is a must. The larger the group, the stronger the leadership needed. ICRAF's experience, consistent with the general findings of small group psychology, is that a team of about 5 or 6 scientists is about right for a smooth application of the D&D group process methodology. If a larger group is involved, it is best broken down into teams of about this size.

Part of the problem, if one may be allowed a bit of speculation on the cognitive processes involved, seems to be a lack of prior training in structured approaches to data. The concept of "structured programming" in the computer field is the clearest example of what we mean by a structured approach to problem solving: to tackle a complex, non-linear data processing task, it is helpful to first break the problem down into a set of smaller problems, blockout the main analytical tasks, and *then* proceed to work out the details. The advantages of this "top down" structured progression from the general to the particular are so striking, as compared to just "muddling through," that it really must be considered an essential ingredient of a rapid appraisal approach to systems analysis. The more complex the system and the shorter the time allotted to the task, the greater the need to stick to a structured approach.

This doesn't necessarily mean following the detailed D&D guidelines to the letter, but it does require an understanding of the general concept and technique of structured systems analysis, at least on the part of the team leader, and the grace and goodwill of the team in sticking to the agenda. The most common problem, often causing great frustration to those team members who have caught onto the approach and are trying diligently to keep the discussion focused, is that every team seems to include at least some members who are unable or unwilling to stick to business. The major disruptive cognitive factor is the tendency to proceed directly into detailed treatment of one aspect of the system (often someone's speciality area) before bringing the analysis of other interrelated aspects of the system to a comparable point. While they may agree to it in principle, in practice many first time D&D participants have difficulty in setting aside a problem and coming back to it later. This is not an insuperable difficulty, but it is one that needs the attention of a good interdisciplinary-minded group leader.

As regards feedback on the current draft documentation of the D&D methodology, we have been confronted with a bit of a paradox. On the one hand, many reviewers have suggested that the documentation needs to be shortened and simplified, while on the other hand, there are some who have expressed the desire for *more detailed* guidelines on particular aspects. Before simply accepting Abraham Lincoln's dictum

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that "You can't please all of the people all of the time," ICRAF's writers will attempt to effect a reasonable compromise in the upcoming revision process. Our feeling is that both demands need to be satisfied, and that is why we will attempt to improve the documentation without changing the current two volume draft manual format (short form *Guidelines* plus optional *Resources* collection). In this regard, it is pertinent to note that the individual users' demand for written documentation seems to increase with increasing acceptance of the general approach. In the developing country context, where the printed word seems to exert a less dominant influence on the scientific subculture than in more developed countries, it may be too optimistic to expect first time D&D team members to read even the short form *Guidelines* before the field exercise; whereas, *after* the exercise, once the general approach has been grasped and the relevance of the more detailed guidelines and resource materials more readily perceived, the demand for more detailed documentation of the suggested procedures and analytical tools may be expected to rise sharply. This suggests the primacy of a "hands-on" approach to D&D training, in the first instance, with written documentation playing a secondary, backstopping role.

Once again, it may be worth pointing out the extraordinary impact of the *field situation* on scientists who have previously confined themselves to research stations. For many of them it may be the first time they've really *seen* a village in terms intimately related to their research concerns. The psychological impact of just being in the village (surrounded by real people with real and unignorable problems) is enormous, but the main impact comes with the realization that *one is there for scientifically respectable purposes* which may, in future, be a factor in the success of one's career. This reaction is often indicated by the somewhat bemused or occasionally stupified expressions one reads on the face of such scientists in the first day or two of fieldwork. What a relief it is then to discover, after another couple of days, that the research improving process really isn't that difficult to carry out.

Having said that, it must still be acknoledged that there may be a tradeoff in any methodology, as in the technology-generation process itself, between professional standards of *technical adequacy* and the pragmatic standard of *easy adoptability*. While the latter criterion must be satisfied if a methodology is to have any chance of widespread adoption by scientists, compromises with respect to the technical complexity of the methodology can only be pushed so far without endangering the overriding objective of *solving the complex land management problems of rural people*. The reason these problems have proven so resistant to more casual approaches is that, in many cases, they simply *are* rather difficult to diagnose and solve. It is a bit superficial to insist on too much simplicity in methodologies for solving complex problems.

Paradoxically, it often seems to be the representatives of aid *donor organizations* who argue most forcefully for the lowering of professional standards in order to ease the adoption of systems methodologies by developing country scientists. These same organizations have played a major role in promoting the general policy changes behind the new research-for-development emphasis in developing countries. It would be good of them now to follow through with well orchestrated support for the methodologies which have arisen to meet the more stringent objectives of the new policies.

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The "new professionalism" (Chambers, 1983) demands higher, not lower standards of applied scientific excellence. If, in the final analysis, methodologies like D&D entail an unavoidable conflict of interest between scientists and the people they are commissioned to serve, it is clear whom we must ask to shoulder the additional burden. In thinking about how much room there is for improvement in this regard, I am reminded of a developing country scientist who once asked me "When is ICRAF going to put out a *short* description of the D&D methodology?" "But the *Guidelines* are only 25 pages," I answered in bewilderment. "Ah yes," he said, "but they are A-4 size pages!"

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ANNEX 5

Working Paper II

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EVALUATION OF AGROFORESTRY POTENTIAL IN SLOPING AREAS

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November 1984

Paper presented to the International Workshop on Land Evaluation for Land Use Planning and Conservation in Sloping Areas, ITC, the Netherlands, December 1984

International Council for Research in Agroforestry,
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ACKNOWLEDGEMENTS

Being in the nature of a synthesis, this paper owes much to the work of the colleagues in ICRAF, to whom thanks are extended. In particular, I have drawn heavily on data gathered by the ICRAF agroforestry systems inventory, and would like to thank its Director, Dr. P.K.R. Nair, the regional co-ordinators and field collaborators, and Mr. E. Fernandes for his help in selecting appropriate examples and for discussion of methods for agroforestry system description. Where the present paper departs in detail from terms used in the systems inventory, the responsibility is my own.

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ABSTRACT

Eight examples of agroforestry systems in sloping areas are described with two examples of economic analysis of agroforestry systems. The ICRAF diagnosis and design methodology is outlined, exemplified and compared with land evaluation procedures. Distinctive features in land evaluation for agroforestry are that surveys commence with a phase of diagnosis; that the performance of systems, and hence the land use requirements, cannot be precisely specified at present; and that as a consequence, the output from agroforestry surveys is frequently a research programme. The ICRAF/FAO project, Land Evaluation for Agroforestry, is outlined. Classification of an agroforestry land utilization type as highly suitable for a given area is not related to environment alone but depends on existing land use systems and problems. The major benefit that agroforestry can bring to sloping areas lies in its capacity to combine soil conservation with productive functions. Agroforestry may often be the preferred form of land use in sloping lands which have problems of soil erosion, soil fertility decline and shortages of fuelwood or fodder. Sloping areas should be a priority environment for the application of research and development in agroforestry.

1. QUESTIONS

The title of this paper covers three entities: land evaluation, agroforestry and sloping areas. Since relations between two of these, land evaluation and sloping areas, is the subject of this symposium, this leaves two other sets of relationships as the primary questions, namely:

i. How can land evaluation be applied to agroforestry?

ii. What benefits can agroforestry offer as a kind of land use in sloping areas?

Anticipating that the answers to these are broadly positive, that is, that agroforestry does have a potential in sloping areas and that this potential can be evaluated, then two further and more specific questions can be asked:

iii. Under what circumstances, and in what respects, is agroforestry superior to other kinds of land use in sloping areas?

iv. Are sloping areas a priority environment for the application of research and development effort in agroforestry?

2. AGROFORESTRY

2.1 Agroforestry as a major kind of land use

Agroforestry refers to land use systems in which trees are grown on the same land as agricultural crops and/or animals, either in a spatial arrangement or a time sequence, and in which there are both ecological and economic interactions between the tree and non-tree components (Lundgren, 1982, modified). Note that 'tree' is here used as an abbreviation for woody plants, comprising trees, shrubs and bamboos.

The second part of this definition, the need for interactions, is an essential feature of agroforestry land use systems. Economic interactions can mean simply that the tree and the crop (and/or animal) each supply part of the farmers' needs; or could involve, for example, the tree harvest providing capital which is put into improvements to crop production. Ecological interactions are numerous; examples are fertilization with litter from nitrogen-fixing trees, feeding of high-protein leaf litter to cattle, the manure from which is then applied to crops, or the soil conservation functions of trees.

Is agroforestry more closely related to agriculture or forestry? Neither. Most agroforestry, probably over 90%, is carried out on agricultural land, and by farmers; as will be illustrated below, the commonest starting point for agroforestry developments is farm-land that has problems. Yet it is the distinctive features and functions of trees which are the essence of agroforestry. Given that the concept of a major kind of land use is in any case loosely defined, agroforestry can usefully be regarded as such.

2.2 Terminology

Agroforestry components refer to the three elements of a land use system, the tree (= woody perennial), herb (agricultural crop or pasture plants) and animal. The first two are always present, the last sometimes. This leads to a simple classification of agroforestry systems:

Agrosilvicultural systems:	crops and trees
Silvopastoral systems:	pastures, animals and trees
Agrosilvopastoral systems:	crops, animals and trees (with or without pastures)
Other systems:	e.g. mangrove with fishing, apiculture in trees

The tree component is almost always a multipurpose tree. After extensive consideration of both concepts and examples it has been found that the land use system within which a tree is grown is an essential part of this definition. Hence multipurpose trees (MPTs) are those which are grown, or kept and managed, for more than one major purpose (product or service), economically and/or ecologically motivated, in an agroforestry or other multipurpose land use system (von Carlowitz, 1984, modified). Expressed more simply, multipurpose trees are those which provide more than one significant contribution to the production and/or service functions of the land use systems they occupy (Huxley, 1984). The main functions of multipurpose trees are listed in Table 1.

Thus the same tree species can be monopurpose where it is managed to optimize one output only, as in a forest plantation managed for timber products; or multipurpose where management is intentionally directed towards two or more outputs, e.g. fuelwood, fodder, shelter, conservation.

Agroforestry practices are the more common arrangements of components in space and time, coupled with the major functions of the tree component. This is more easily illustrated than defined, as in Table 2.

An agroforestry system is a set of agroforestry practices within a specified physical, economic and social setting; the land use system itself may be based on agroforestry, or the agroforestry system may fulfill certain functions within the broader context of the land use system as a whole. Agroforestry systems are described in terms of their biological, technical, economic and social aspects.

This term, widely employed in agroforestry literature, is so nearly equivalent to the standard definition of a land utilization type that agroforestry system and agroforestry land utilization type may be taken as synonymous. As with land utilization types, existing agroforestry systems are frequently specific to a local region but are potentially extendable to other areas with similar environmental, economic and social conditions.

Table 1 FUNCTIONS OF MULTIPURPOSE TREES. Adapted from the ICRAF multipurpose tree data sheet (von Carlowitz, 1984).

Wood	fuelwood (inc. charcoal) timber (sawnwood) poles (domestic timber) other (e.g. carvings)
Fodder	browse } inc. leaves, seeds, shoots cut-and-carry }
Food	fruit, nuts oils beverages other edible products
Other products	oils, gums, waxes, dyes, tannin fibres, thatching latex medicinal uses
Services	shade (from sun) shelter (from wind) soil conservation (inc. reclamation) soil improvement fencing (= barrier function) moisture conservation

Table 2 AGROFORESTRY PRACTICES. Adapted from the ICRAF agroforestry systems inventory (ICRAF, 1983d; Nair, 1984).

Improved tree fallow
Taungya
Alley cropping (hedgerow intercropping)
Boundary planting
Live fences
Multipurpose trees on:
- cropland
- rangeland
- pastures
- homesteads

Woodlots (with multipurpose management)
Trees as shelter for:
- crops (windbreaks, shelterbelts)
- animals
- homesteads

Trees for soil conservation:
- on bunds, terraces
- strips
- hedges

Tree gardens
Agricultural tree/shrub crops with:
- lower-storey tree/shrub crops
- herbaceous crops
- upper storey trees
- pastures and livestock

Aquaforestry (mangrove)
Apiculture with forestry

3. SLOPING AREAS AND THEIR ENVIRONMENTS

Sloping areas are here assumed to refer to slope classes c and bc on the FAO/UNESCO Soil map of the World, that is, areas with dominant slopes over 17°/30% or a combination of this with areas of 5° - 17°/8 - 30%. This paper is largely concerned with sloping areas in tropical and subtropical latitudes.

It may be remarkable in passing that the slope classes on the world soil map are not the outcome of a primary inventory of landforms, but are supplementary to classes and map units determined primarily on the basis of soil type. Since there are now also satisfactory world or continental maps of geology, climate and vegetation, the lack of a treatment of landforms at comparable intensity and coverage is deficiency in the inventory of land resources, which could lead to substantial errors in world-scale land evaluation or other estimates of production.

Within the tropics, sloping areas may be grouped on the basis of temperature and altitude into lowland and upland, separated at 1200 m altitude. These correspond approximately to the division between Köppen A (hot) and B (warm) climates, and between the 'warm tropics' and 'cool tropics' of the FAO agroecological zones inventory. On the basis of amount and duration of rainfall, these lands may be further subdivided into humid climates (Köppen Af, Am and Ca, growing period >270 days), and subhumid climates (Köppen Aw and Cw, growing period 120-270 days). Sloping lands with semi-arid climates are mainly of very low potential and will not be considered. This gives the following classes of sloping land in the tropics and subtropics.

i. Lowland humid tropics Hot, humid for all or most of the year, vegetation evergreen or semi-evergreen rain forest. Relief commonly either V-shaped valleys with narrow interfluves or convex interfluves, steepening downslope until they pass abruptly into flat valley floors ('demi-orange relief'). Soils are normally ferralsols or acrisols, with nitic properties if on basic rocks.

This is by far the most extensive tropical sloping-land environment, found in all continents but particularly in Central America, at lower altitudes in the Andean states of South America, in the West and East Indies, the south-east Asia mainland, Pacific islands and eastern tropical Australia.

Common land use systems in this environment are:

- extractive forestry;
- perennial, non-food crop plantations;
- shifting cultivation of annual food crops, cereals or roots; often with shortened fallow and consequent soil degradation;
- terraced cultivation, including swamp rice (especially in Asia);
- ranching (especially in South America).

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The principal environmental hazard is the very severe rainfall erosivity. Others include rapid oxidation of soil organic matter, high soil acidity with associated P fixation and aluminium toxicity (the last especially, for reasons not well understood, in South America), and rapid leaching. Besides soil erosion, there may be a hazard of accelerated landsliding.

The most common land use problems are the cutting of rain forest faster than natural or managed regeneration, and shortening of fallows with consequent soil degradation and over-grazing, the two latter sometimes leading to soil erosion. Shortening of fallows is particularly likely in areas which lack the flat valley-floor land that permits swamp rice cultivation.

ii. Highland humid tropics This is a less widespread environment, since most high-altitude regions have a dry season of sufficient length to fall into the subhumid zone. It occurs in parts of the Andes, and the highlands of Malaysia and the East Indies. A high proportion of relief is sloping. Soils become humic ferralsols and humic acrisols at higher altitudes.

Land use systems are similar to those of the lowland humid zone except that commercial forestry is less common. Land use problems include shortening of fallows with soil degradation; overgrazing and pasture degradation; and over-cutting for domestic fuelwood and timber leading to reduction in area and species depletion of remaining forests.

ii. Lowland subhumid tropics This is the savanna zone of Africa and the cerrado of South America, with one or two wet seasons (Köppen Aw or Aw" respectively) and at least one long dry season. A high proportion of this climatic region is not sloping, other than on isolated inselbergs. Areas of sloping lands occur, however, particularly in escarpment zones separating erosion surfaces.

Common land use systems include:

- cultivation of annual crops, often more or less without soil rest periods;

- certain perennial crops, mainly towards the more humid margins;

- extensive grazing (ranching or nomadic);

- afforestation.

Although rainfall erosivity is less than in the humid zone, the soil erosion hazard is almost as high, owing to the slower growth and less complete cover of the vegetation. Drought becomes a hazard in the drier parts of the zone (mean annual rainfall <800 mm). The most widespread land use problems are first, decline in soil fertility brought about by over-cultivation; secondly, degradation of natural deciduous woodlands through over-cutting with consequent fuelwood shortage; and thirdly, erosion, which is particularly common on grazing land.

iv. Highland subhumid tropics This distinctive environment, sometimes loosely called the 'highland tropics', is extensive in the Africa (especially Kenya and Ethiopia), the Andes and the Himalayas, in the last of which it occurs under a climate of monsoonal origin and regime. Much of this climatic zone is not sloping, being either upland plateau or intermontane basins, but sloping land occurs at the borders of these. Notable examples are the extensive, steeply-sloping and deeply dissected lands of Ethiopia, and the so-called 'foothills' of the Himalayas.

Land use systems include annual crops, perennial crops in the wetter parts of the zone, grazing and commercial afforestation. Terraced cultivation is common in the Himalayas.

Loss or degradation of natural forests is often considerable, and soil fertility decline and soil erosion are both common. The Ethiopian highlands combine severe soil erosion with almost complete destruction of natural forests. Systems of terraced cultivation have become poorly maintained or abandoned in some areas.

4. AGROFORESTRY IN SLOPING AREAS

4.1 Examples

To illustrate the range of agroforestry practices and their potential in sloping areas, eight cases will be described. The first five are existing systems, 'traditional' in the sense of being evolved largely by the farmers of the area concerned, although incorporating some relatively recently introduced crops. The sixth case is a development project, the seventh an example of experimental trials, whilst the last gives systems suggested in one of the ICRAF collaborative design projects. Two of these examples are drawn from Africa, three from south-east Asia, one from south Asia and two from South America. In these accounts, some added descriptors for land utilization types are employed, explained in Section 6.1 and Table 5 below.

i. Terraced hill farming, west Nepal The first case has been set out as a formal description of a land utilization type (Table 3). The Tinau watershed of west Nepal has a lowland subhumid climate, with the excessive concentration of rainfall into four very wet months that is a feature of climates of monsoonal origin. This still further increases the erosion hazard on the steep slopes. Despite the relief, the region is densely populated, and the remaining area of natural forest reduced and degraded. Most farming takes place on sloping land under rainfed conditions, although some farmers also possess a low-lying area of irrigated rice. Whilst giving the appearance of being based on annual crops, chiefly maize, livestock products also play an important role, both for subsistence and cash purposes.

The main agroforestry practice is the planting of trees as strips on two kinds of sites: along the risers of terraces and as vertical (downslope) rows along farm boundaries (Figure 1). These rows are quite densely planted and give the landscape a compartmented appearance. Over 30 species are recorded, nearly all having a function as fodder, most also as fuel, and a smaller number as fruit (not to mention the presumable medicinal use of *Wrightia antidysenterica*). Up to half the livestock feed comes from the tree strips, and there is a further interaction in that the manure from stall-fed animals is returned to the fields. The major service function of the trees is of course

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Table 3 DESCRIPTION OF AN AGROFORESTRY LAND UTILIZATION TYPE: TERRACED HILL FARMING, NEPAL.

Title	Terraced hill farming, western Nepal.
Environment	Lowland subhumid climate (Köppen Aw) of monsoonal origin, 7-8 dry months; slopes steep, 20° - 35° (36-70%).
Socio-economic setting	Dense population, severe land shortage, average farm size 1 ha, low income, poor infrastructure.
Summary description	Slopes ('bari' land) are terraced, with maize and other rainfed crops on sloping treads, MPTs on risers (contour strips) and farm boundaries (vertical strips) (Fig. 1).
LUT descriptors	
Outputs	Products: maize and other rainfed annual crops, cattle products, fuelwood. Services: soil conservation.
Market	Dominantly subsistence, plus local marketing.
Capital intensity	Low
Labour intensity	High
Technical knowledge	Of modern agricultural methods, low; moderately amenable to innovations.
Land holdings	Small, average 1 ha; some have separate lowland irrigated rice holding.
Tenure	Owner-cultivated.
Land improvements	Terracing; unlike some other parts of Nepal, terrace treads are initially sloping, older ones becoming level.
Infrastructure requirements	Low; family processing of products; need for road access to local markets.
Power	Ox-ploughing, plus much manual power.
Mechanization	None
Input level	Low; no artificial fertilizers, mainly local seed.
Cropping	Maize, with subsidiary wheat, finger millet, mustard and legumes. Numerous vegetables and fruit in home gardens. MPTs on terrace risers, over 30 spp..

(Table 3, continued)

Cultivation	Ox ploughing, hand weeding. Trees pruned for fodder, cut for fuelwood.
Conservation practices	Achieved through contour terraces, stabilized by trees.
Irrigation	Only on separate lowland fields, for rice.
Livestock	Cattle, buffalos, goats, poultry; for food, cash, draught, manure. Partly stall-fed, partly grazed. Contour tree strips may supply 40-60% of fodder.
Yields	Low; sample survey, maize 930 kg/ha, wheat 580 kg/ha.
Economics	No data
<u>Agroforestry descriptors</u>	
Type	Agrosilvopastoral (crops, trees, livestock).
Main interactions	Space, including off-site.
Time	Static, interpolated.
Space	Zonal, row.
AF practices	Main: MPTs for soil conservation, on terraces.
	Other: boundary planting, MPTs around homesteads, live fence
Functions of trees	Soil conservation, fodder, fuelwood food, fencing.

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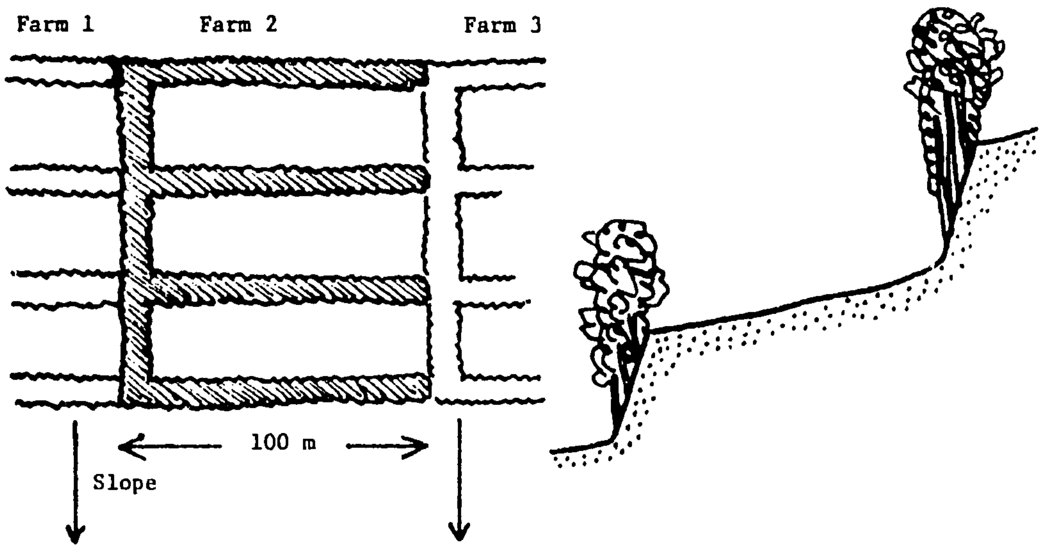


Figure 1 PLAN VIEW AND CROSS-SECTION OF TERRACED HILL FARMING, WEST NEPAL. After Fonzen and Oberholzer (1984).

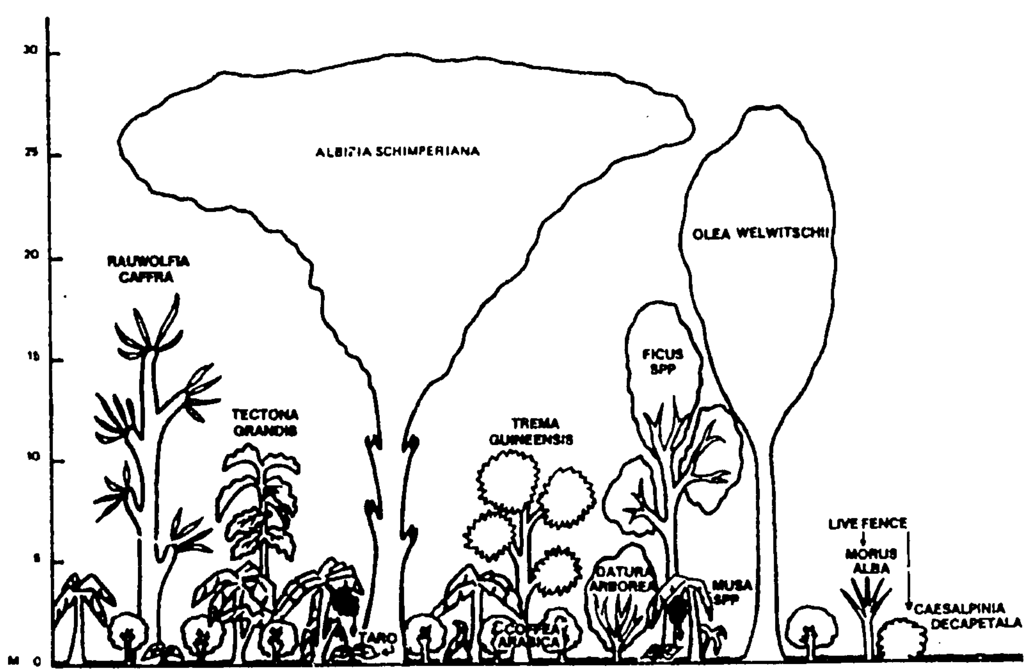


Figure 2 TYPICAL VERTICAL ZONATION IN A CHAGGA HOME GARDEN, MOUNT KILIMANJARO, TANZANIA (Fernandes et al., 1984).

soil conservation, through the medium of stabilizing the terraces. In addition, the tree rows form an effective barrier, permitting livestock to be let into specific fields, and keeping off those of neighbours.

Summarizing the agroforestry features, this is an agrosilvopastoral system (crops + trees + livestock), interacting in space, with the trees zoned, as rows. The main practice is trees on soil conservation works, in this case terrace risers: subsidiary practices are boundary planting and home gardens. The functions of the trees are particularly varied, namely fodder, soil conservation, fuelwood, food and fencing. (Source: Fonzen and Oberholzer, 1984.)

ii. Chagga home gardens, Mount Kilimanjaro, Tanzania This system occupies the south and east slopes of Mount Kilimanjaro, Tanzania, with a subhumid climate and an altitude range extending from lowland to highland. Land is scarce, income low to medium, capital scarce, marketing facilities and other infrastructure moderate. It is a mixed cash and subsistence economy, labour-intensive, owner-occupied.

The home gardens consist of a random and dense arrangement that includes food and cash crops, and herbaceous crops and trees of both plantation (agricultural) species and timber (Figure 2). The main cash crop is coffee, others being cardamom, and surplus bananas and food crops. Food crops include bananas, maize, beans, root crops, vegetables and fruit. Farmers deliberately retain and manage numerous species of tree (over 40). Cattle and poultry are kept, mainly stall-fed from tree fodder, banana and cultivated grasses.

This system is agrosilvopastoral, interacting in space, static in time and with a mixed, dense multistorey arrangement of the tree and shrub component. As its name indicates, it is an example of the home garden practice, widely found in humid to the moister subhumid environment (cf. e.g. the Kandy home gardens of Sri Lanka, and the example which follows). The trees fulfil productive functions of cash crop income, food, fuelwood and fodder; and besides the soil conservation achieved by the dense, multistorey canopy, there is a substantial element of soil improvement, or maintenance of fertility, through incorporation of leaf litter and manure from stall-fed cattle. (Source: Fernandes *et al.*, 1984).

iii. Hillside agroforestry, western Sumatra This is a further example of home garden practice, chosen for description as being in a different continent, a more humid climate and with differences of function. The area around Lake Maninjau, in the central part of west Sumatra, has a lowland humid climate (Köppen Af), with rainfall >3000 mm and no dry months. As the slopes are very steep, reaching to over 40° (84%), it need hardly be said that the erosion hazard is severe; there is also a serious hazard of accelerated land-sliding if the slopes are cleared. The forests which remain have been taken over by the State. The farmers grow swamp rice where possible, in conjunction with the tree gardens of the hillsides.

The gardens are largely multi-storey tree arrangements, with herbaceous crops being only subsidiary. Among the commonest species is the beloved durian, cinnamon, coffee, nutmeg, and many timber species. These are farmed in various combinations, at least partly planned, e.g. durian + cinnamon + timber species. It is an agro-silvicultural system, interacting mainly in space, although gardens are sometimes abandoned or new ones established, giving an element of long-term fallowing. As in all home gardens, the spatial arrangement is mixed and dense. The trees fulfil functions of food and cash crop production, fuelwood and timber production, and erosion and landslide control. (Source: Michon et al., 1984.)

iv. Coffee-Erythrina-Cordia systems, Costa Rica. Systems of coffee with an upper storey or trees, especially Erythrina poeppigiana and/or Cordia alliodora, are widespread in Central and South America, sometimes on gently-sloping land but often on sloping areas, in part because these provide some of the best sites for coffee. The same two species are also grown with cacao. Such systems are found in humid to the moister subhumid lowland and highland environments. They are exempilfied in the vicinity of Turrialba, Costa Rica. The typical socio-economic environment differs from the preceding examples. Land is only moderately scarce, income levels at a low-intermediate level and infrastructure moderate.

The farming system is based on cash-cropping of coffee. Erythrina and/or Cordia are planted in the cropland, in some areas as rows, in others on a mixed, random, open to moderately dense arrangement. Erythrina are pruned several times a year, keeping them as a low, stubby life form, and the prunings laid as mulch. Cordia are allowed to grow into tall trees. Erythrina is a nitrogen-fixing tree, and its use for soil fertility maintenance is intentional.

This is an agrosilvicultural system, interacting in space, with the components either in a mixed arrangement or as rows. The functions of the trees are:

Erythrina poeppigiana	Cordia alliodora	Coffee
Shade	Shade	Cash crop
Soil improvement	Timber	
Mulch	Fuelwood	
Soil conservation	Soil conservation	

(Sources: Budowski, 1983; Escalante, in press).

v. Improved tree fallow, Philippines In Cebu Province, Philippines, a system of improved tree fallow using Leucaena leucocephala (leuco) is found. Although lowland subhumid, it is wet enough (1620mm) for rapid growth of leuco. Part of the farm is under crops, part planted to leuco for about three years. The leaf production restores soil fertility. When the trees are cleared the wood serves two purposes: fuelwood, and to make pegs used in check-barriers to control erosion. The farmers recognize both the fertility maintenance and the soil conservation functions of the trees.

This example is included as a case in which the dominant interaction between the trees and non-tree components takes place in time, as a rotation. (Source: Eslava, 1984.)

vi. Alley cropping with soil conservation, Rwanda The project Agro-Pastoral is a development project in Nyabisindu, Rwanda. The environment is highland subhumid and described as 'mountainous'. Land is very scarce, income very low and infrastructure poor. There are problems of soil erosion, soil fertility decline and deforestation. The efforts to combat these problems by the project include a wide range of methods, only some of which involve trees namely:

i. Afforestation of denuded hilltops and badly degraded farmland.

ii. Planting of fruit trees

iii. Planting of fuelwood species along roadside and boundaries.

iv. Alley cropping with soil conservation

In this last practice, trees are planted in field as rows, with 10 m between rows and 3.5 - 4.5 m between trees, giving a canopy of approximately 10%. There are planned to be felled for fuelwood and replanted on an 8-year rotation. Using Grevillea robusta, 300 trees/ha cut after 8 years are estimated to produce 6 m^3 ha^{-1} per year of fuelwood, enough for one family. Early results from trials of Grevillea have given results that it is hard to believe will be maintained, namely three times the growth rate when planted as tree rows than that from classical afforestation on similar soils. The cropping component is mainly mixed cropping and includes fodder crops, livestock being part of the farming system as a whole. Tree leaves, particularly from the boundary planting where there is a greater variety of species, are cut as fodder.

Thus the farming system as a whole is agrosilvopastoral, with three agroforestry practices and at least six functions of trees. The alley cropping practice has the main functions of soil conservation and fuelwood. (Source: Behmel and Neumann, 1982.)

vii. Soil conservation hedges, Philippines Distinct in appearance from the previous example of alley cropping, although fulfilling the same functions on sloping land, is the practice of leuco conservation hedges tested under experimental conditions in the Philippines. The environment is lowland humid, and the socio-economic context one of moderate levels of land shortage, income and infrastructure. Leuco is planted as narrow hedges, sown very close; in the experimental example described, spacings of 10, 15 and 20 trees per metre were tried. They are pruned several times a year, keeping the form of a low but dense hedge, 30-50 cm high; prunings are laid on the soil around intervening crops. As has commonly been found desirable with leuco fertilization, low levels of artificial fertilizer should be added for best results. In one rather extreme experimental trial, leucaena hedges 1.5 m apart were planted alternately with single rows of maize, with a control plot of maize only. The yield per plant was 70 g with leuco as against 49 g with maize only, but owing to the larger number of plants in the control there was no significant difference between total yields (in the short term), at

2.5 t ha^{-1}. The ICRAF collaborative project with Philippines recommended a similar system, with its dual functions of soil conservation and fertility improvement. Designing a research programme to test the system, it recommended first, that trials should be conducted with 1.5, 3, 4.5 and 6 m spacings between hedges, and 1-5 intervening rows of maize; and secondly, that studies should be made to see if cash crops could be included in the hedgerows, namely black pepper, ginger and pineapples, thereby increasing the number of functions. (Sources: de la Rosa, n.d., and Torres et al., 1984.)

viii. Design of agroforestry practices for Pucallpa, Peru The final example to be given consists of the recommendations of the ICRAF collaborative project with Peru. Since this illustrates also the ICRAF diagnostic and design methodology, it will be described in the following section. It is listed as a case study also, partly so as to include the only example of sylvopastoral practices reported.

4.2 Summary

Table 4 is a summary of the eight examples described. It has no statistical value, but illustrates first, the range of agroforestry practices commonly found in sloping areas, and secondly, the most common functions fulfilled by the tree component.

Eight practices are represented, with three variants of trees for soil conservation. Of these, tree fallows, plantation crop combinations, boundary planting, live fences and MPTs on pastures might equally be found on non-sloping lands, the last-named more commonly so. Alley cropping systems can be designed for non-sloping areas, where they would be directed towards soil improvement, fuelwood and/or fodder; but where found on sloping lands, they are intentionally designed with soil conservation as a major function. The various conservation practices are clearly of greatest applicability in sloping areas, whilst tree gardens are one way of creating a sustainable and productive system on land which would otherwise have a severe erosion hazard.

Of the various functions of the tree component, only that of soil conservation is specific to sloping lands. The other functions are those inherent in multipurpose trees and thus agroforestry systems. The fact that fuelwood provision and soil improvement appear so frequently reflects the problem-solving aspect of agroforestry: both are problems typical of sloping areas in which the initially high soil fertility, perhaps coupled with socio-political factors, has led to high population with consequent problems of over-cultivation and forest clearance.

5. RELATED METHODS

5.1 General

The preceding descriptive accounts give a qualitative indication of the benefits that agroforestry can bring, or in some cases that it is hoped it can bring, to problems of land use in sloping areas. They do not answer two of the key questions in land evaluation, namely which are the best sites for any specified land utilization type, and which is the best kind of land use on any given site?

<u>Table 4</u> CHARACTERISTICS OF EIGHT AGROFORESTRY SYSTEMS ON SLOPING AREAS. For explanation of terms, see Tables 1, 2 and 5.

	Feature	Nepal	Tanzania	Sumatra	Costa Rica	Philippines (1)	Rwanda	Philippines (2)	Peru
Type:	Agrosilvicultural			✓	✓	✓		✓	
	Silvopastoral								✓
	Agrosilvopastoral	✓	✓				✓		✓
Interactions:	Space	✓	✓	✓	✓		✓	✓	✓
	Time					✓			
Practices:	Improved tree fallow					✓			✓
	Alley cropping						✓		✓
	Boundary planting	✓					✓		
	Live fences		✓						✓
	MPTs on pasture								✓
	Conservation: terraces	✓							
	strips						✓		
	hedges							✓	
	Tree gardens		✓	✓					
	Plantation crops with trees				✓				
	Shade		✓		✓				
Tree functions:	Fuelwood	✓	✓	✓	✓		✓		
	Timber		✓	✓	✓				
	Fodder (cut)	✓	✓						
	Food	✓	✓	✓					✓
	Cash crop		✓	✓	✓				
	Soil conservation	✓	✓	✓	✓	✓	✓	✓	✓
	Soil improvement		✓		✓	✓		✓	✓
	Fencing	✓							✓

It should be said once that ICRAF is not yet able to offer firmly-based answers to either of these questions. Perhaps surprisingly, to the present audience, it has not so far applied the standard procedures of land evaluation to its field projects. Instead, these have been based on a set of procedures known as the diagnosis and design methodology. This latter has many points of contact with land evaluation; indeed, it is thought possible that the two sets of procedures may prove to be convergent when applied in similar circumstances. A brief outline of the diagnosis and design approach is therefore a necessary preliminary to considering how land evaluation can be applied to agroforestry.

One aspect of evaluation, namely analysis in economic terms, has been applied to agroforestry systems, and some examples of this are also given.

5.2 Agroforestry diagnosis and design

The diagnosis and design methodology is one of a family of 'farmers first' approaches to rural land development. Its ultimate purpose is to design agroforestry land use systems which will help to solve the problems of rural land use. However, since the technology of agroforestry is in many cases not fully proven, the proximate objective is usually to design a research programme that will test systems which are believed to have this problem-solving potential.

Diagnosis and design is a methodology of some complexity, to which the present very brief summary cannot do justice. Those who are interested are urged to discover more about it, from the following:

- Guidelines for agroforestry diagnosis and design (ICRAF, 1983a). A 25-page summary of the approach, including an outline of procedures as 12 steps. This might be compared with the Framework for land evaluation (FAO, 1976).

- Resources for agroforestry diagnosis and design (ICRAF, 1983b). A 383 page vade mecum of procedures, including proformas. Comparable with the Guidelines on land evaluation for rainfed agriculture (FAO, 1983).

- Technology and research considerations in ICRAF's "diagnosis and design" procedures (Huxley and Wood, 1984). Amplifies the technology design stage of procedures.

- One or more examples of application of the methodology. Comparable with reports on land evaluation studies. Those at present most accessible are based on Kenya (Raintree, 1983; Hoekstra, 1984a) and the Philippines (Torres et al., 1984).

In barest outline, the phases in a diagnosis and design study are:

i. Diagnose the land use problems of an area.

ii. Formulate agroforestry land use systems that have the potential to ameliorate those problems and which are sustainable and adoptable.

iii. Design a research program which will test and optimize these systems.

These phases lead potentially to a fourth, in which the improved and tested systems are implemented in the area through a programme of extension and development.

Set out in slightly more detail (but still simplified) the steps become:

1. Identify and describe the land use systems with the study area. A land use system has the same meaning as in land evaluation terminology, namely a combination of a land unit with a kind of land use. This is an initial stratification of the study area, the remaining phases being applied potentially to each of the land use systems but in practice, to those which have the most serious problems and/or the greatest apparent scope for agroforestry assistance.

2. Conduct a diagnostic survey of the problems faced by farmers, or other land users, in the area. These may be supply problems, that is, shortfalls in the farmers' needs for food, fuel, shelter, cash, capital and social needs; or sustainability problems, e.g. soil erosion, pasture degradation, reduction in area of forests. Although the farmers are the focus, the land itself may also be regarded as having problems.

3. Analyze the causes of these problems. This is done by a causal network in which some of the initiating factors are socio-economic whilst others derive partly or mainly from the physical environment. Examples of causal chains taken from such networks are:

   Land scarce → reduction in length of fallows → decline in soil fertility → low crop yields → food shortage

   Land scarce → cultivation of steep slopes → soil erosion → low crop yields

   Seasonal decline in feed quality → low animal productivity → low cash income

   Rainfall variability → recurrent crop failure → recurrent food shortage

   Population growth → destruction of forests → fuelwood shortage

   More complex relationships, including branching or Y-shaped chains and feedback loops, are also examined.

4. Derive specifications for systems suited to the area. These must: (i) have the capacity to ameliorate some of the identified problems, through interventions in the causal networks; (ii) be sustainable; (iii) be adoptable, that is, within the financial and technical capabilities of the farmers, implementable within the available (or a modified) infrastructure, and acceptable to them (i.e. 'if .... would you try this?').

5. Based on the system specifications, identify technologies which appear to have potential to make a contribution. These may include both agroforestry and non-agroforestry technologies; the report on the study draws attention to the latter, but does not proceed further with them.

6. Analyze the candidate agroforestry technologies and select the most promising from among them. Based on these, design a land use system which, if it works, will help to solve the problems.

7. Make a preliminary ex ante evaluation of this land use system, including environmental, economic and social aspects.

8. Decide what is known with confidence about the functioning of the proposed system, and what needs to be tested through research. Those elements, if any, about which there is reliable information can immediately be recommended for adoption.

9. For the remaining elements, design a research programme which will test the functioning of the proposed systems, and so lead to their improvement. This usually consists of a combination of on-farm research and on-station research.

10. Make the necessary institutional arrangements for implementing the research programme.

Stages 8 and 9 incorporate a three-way switch, between implementation, on-farm research and on-station research. Immediate implementation can be embarked upon where technological elements which make up a proposed system are adequately proven. On-farm research is appropriate where the technology is less firmly proven, but the consequences to the farmer if it goes wrong are not too serious (e.g. boundary planting of fruit trees); it should also be adopted where there remains an element of doubt about the capacity or willingness of the farmers to put the system into practice. On-station research has numerous functions, for example, the testing of unproven technologies, species and provenance trials of multipurpose trees, or specialized studies of particular elements, such as pruning practices on soil moisture competition.

5.3 Diagnosis and design: an example

The diagnosis and design procedure may be illustrated from one of the two areas, the most steeply sloping, in the ICRAF collaborative programme in the Peru. The following account is necessarily highly simplified.

The Pucallpa region lies in the Peruvian section of the Amazon Basin, latitude 8°30' S, altitude 250 m. It has a lowland humid tropical climate (Köppen Am) and rain forest vegetation; strongly acid acrisols are the dominant soil type, and slopes are moderate to steep. The main land use systems are fallow-based cultivation of upland rice and cattle ranching.

The main problem of the upland rice system is low crop yields brought about by a combination of low inputs with progressive shortening of the fallow period. One those farms for which land area was limited, the cattle ranching system suffered from low productivity of the natural pastures. A further problem common to both systems was shortage of capital for investment in improvements. Constraints to the design of interventions were that they should have low capital requirements; not make use of inputs inaccessible to farmers; and be consistent, in the case of cash crops, with marketing potentials of the area. The constraint of capital shortage prevents adoption of the high-input systems developed for annual cropping at the Yurimaguas Research Station (e.g. Valverde and Bandy, 1982).

For the cattle system, one improvement which meets all the specifications is not agroforestry, namely pasture improvement and development of productive and persistent legume-grass associations. Possible agroforestry improvements are:

- improved tree fallows, based on N-fixing trees;
- as an alternative to this, alley cropping with N-fixing trees, using a design which combines soil conservation;
- an increase in the number and variety of fruit trees, for extra cash income;
- substitution of a herbaceous shrub in legume-grass pastures, as a way of trying to avoid competitive exclusion problems common to such mixtures.
- live fences on pastures, permitting some degree of pasture rotation.

Of these possibilities, that of forest trees requires first, assessment of environmental suitabilities and secondly, study of marketing potential. If these can be completed, implementation can begin quite soon. The remaining practices are not well tested for this environment, and a substantial programme of on-station research is recommended. (Source: Torres and Raintree, 1984.)

5.4 Economic analysis of agroforestry systems

As with the treatment of social aspects, economic analysis of agroforestry systems may be said to have reached a more advanced stage than evaluation in relation to environment. A recent bibliography lists 90 such economic analyses (Hoekstra and van Gelder, 1983). A computer software package has been developed, MULBUD, which enables users to model and analyze agroforestry systems (Etherington and Matthews, 1982). It should be made clear that as the package stands at present, all data on crop and tree performance, yields, etc., is input by the user; there is no element of biophysical modelling.

Two examples may be given. A recent collaborative project between ICRAF and Malaysian institutions led to a design for an agroforestry system for moderately-sloping dissected lowland, with a humid climate, on dissected lowlands north-east of Kuala Lumpur. This differs from the examples previously described in that it was designed for land presently in, and intended to remain as, forest reserve. In part because the main aim was to produce fast-growing softwoods, and in part owing to a constraint set by the Forestry Department, that perennial agricultural crops could not be planted, the design was directed towards modications of the taungya system. Two variants were produced, both based on combinations of the planting of fast-growing timber trees with annual crops during the first year, sheep grazed beneath the trees for a further period, then trees only when their crown cover becomes dense. The farmers move to a new area each year, felling the secondary jungle, planting annuals plus trees, and tending the latter. Unlike most taungya systems, in which the dominant interaction takes place in time, this design involves substantial spatial interaction as well. (There are reservations concerning these designs, but these need not be discussed here.)

Two variants of this system were analyzed on the MULBUD package: a mixed system in which the trees were regularly spaced, and a zonal system in which the trees were planted as broad belts along the contour. These were compared with a straightforward timber plantation, using existing methods of the Forestry Department. The results are expressed in two ways: returns per unit area of land, as net present value in Malaysian dollars per hectare over a 15-year cycle; and as costs per unit volume of timber produced, in Malaysian dollars per cubic metre. The first is relevant from the national aspect of maximizing land productivity, the second from the point of view of the Forestry Department for which costs, and not land, is the primary limiting factor.

Land use system	NPV, M$ ha^{-1}		Timber cost M$ m^3
Timber plantation	7960		9.15
Agroforestry, mixed system	11030		-
of which forestry component		8470	7.33
Agroforestry, zonal system	7130		-
of which forestry component		4000	9.00

The differences between agroforestry and forestry are not dramatic in economic terms; but given that there are strong social pressures to allow farmers to have a stake in this area, the economics are sufficiently promising, even from the partial point of view of the forestry component alone. The major saving to forest operations lies in lower establishment costs. In the mixed model there is no loss of timber and a gain from the crop and livestock elements; in the zonal model, the latter compensates for a lower timber yield and revenue. (Source: Hoekstra, 1984b.)

The second example is unusual among economic analyses in that it includes an element of environmental differentiation, based on different tree growth rates for rainfall regions. It is taken from a study by the Beijer Institute of the fuelwood supply and demand projections for Kenya (Openshaw, 1981). The agroforestry model is based on achievement of a 15% crown on farmland, without loss of crop production, yielding 4.5 m^3 ha^{-1} per year in the high rainfall area and 2.6 m^3 ha^{-1} per year with medium rainfall. There is a sensitivity analysis of different assumptions for labour rates and fuelwood prices, but taking the same set of assumptions for each case, the internal rates of return are as follows:

Land use system	Rainfall region	IRR %
Fuelwood plantation	High-medium	9½
Taungya system plantation	"	14½
Trees on farmland (agroforestry)	High	29
" " " "	Medium	17½
Peri-urban plantation	Medium-low	4½
Industrial timber plantation	High	13½
" " "	Medium (low alt.)	8
Fuelwood from natural forests	High	54

Agroforestry comes out as markedly superior to various forest plantation systems. This is just as well, for it makes an economic virtue out of a practical necessity: Kenya's semi-arid lands do not possess the growth potential to satisfy its projected fuelwood demands, whilst its humid lands (many of which are sloping) are fully occupied by farmers. The highest return, as would be expected, comes from using natural forests, but the incremental growth from these falls considerably short of fulfilling even present-day fuelwood demands.

6. LAND EVALUATION FOR AGROFORESTRY

6.1 Modifications to procedures

With the above account of diagnosis and design methods as a background, coupled with field experience of agroforestry projects, let us review the procedures of land evaluation, pointing out to what extent they appear to need special treatment when applied to agroforestry. The diagram of procedures in Land evaluation for forestry (FAO, 1984) will be taken as a basis (Figure 3). As compared with that in the rainfed agriculture volume this has an added box, 'Economic and social data: collection, analysis'. Note should also be taken of the three points for input of economic and social data given in the forestry volume (p.94), namely at the stages of determination of objectives, formulation and refinement of land utilization types, and economic and social analysis in the comparison of land use with land.

"PLANNING THE EVALUATION: objectives"

Right at the beginning of land evaluation procedures comes the first major point of difference. The Framework and its successor volumes basically assume that the objectives of the survey are known before fieldwork starts, and can be established by preliminary discussion, "between ... agriculturalists, engineers, economists, sociologists, planners, government officials" (oh, and also) "representatives of the local population likely to be affected" says the Framework airily.

The first feature of agroforestry is that the objective is often problem-solving: that is, advice on the potential of agroforestry is called upon for an area which has land use problems. Most commonly, these are soil fertility decline, soil erosion, fuelwood shortage (actual or projected) or pasture degradation.

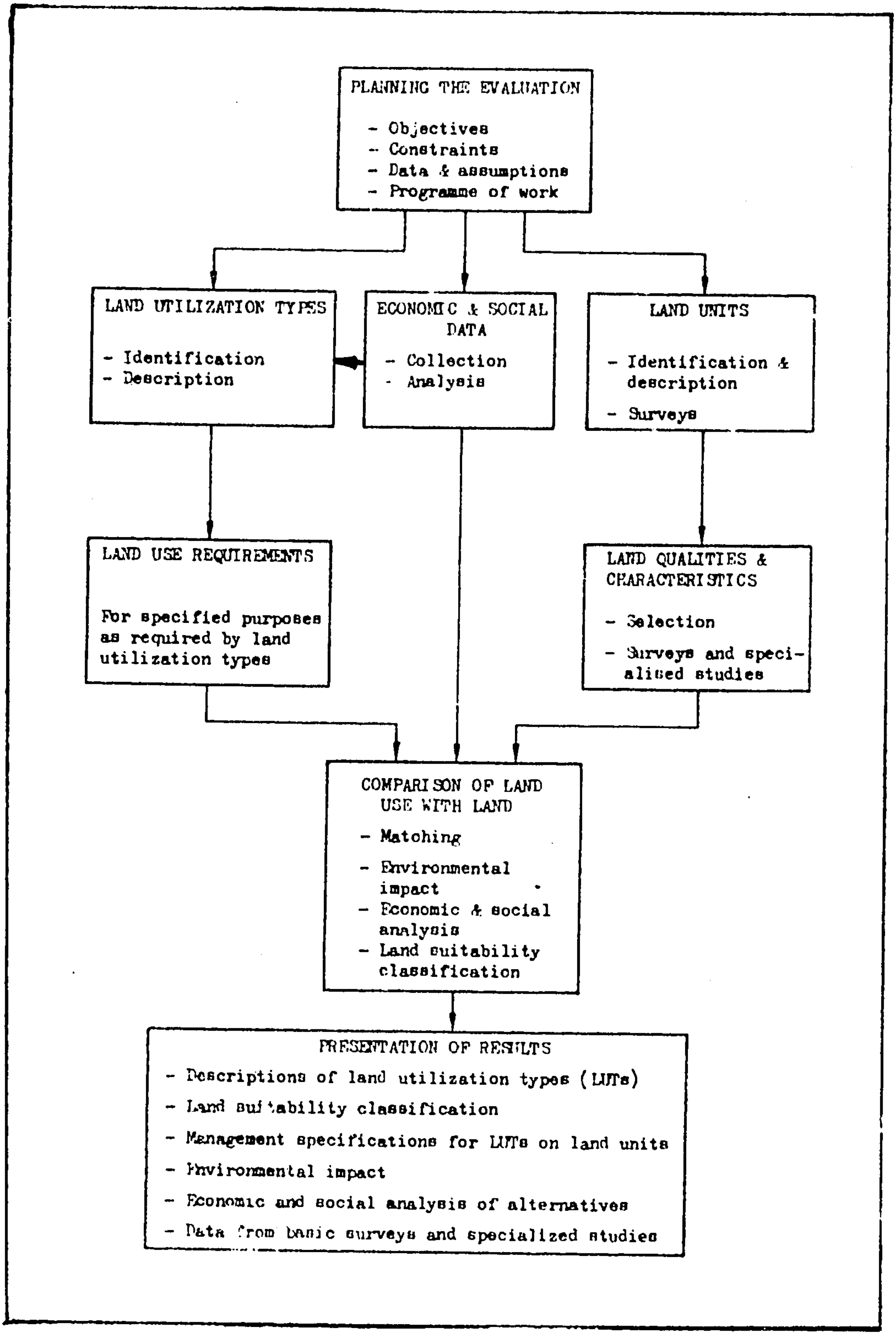


Figure 3 PROCEDURES IN LAND EVALUATION. After FAO (1984, p. 27). As compared with the source, an arrow has been added showing the use of economic and social data in the formulation of land utilization types.

Secondly, a fundamental principle is that diagnosis must procede treatment. That is, given that an area is known to have land use problems, a substantial period of field survey is necessary in order to find out in detail the nature of these problems and analyze their causes. There is no such principle in the Framework.

"LAND UTILIZATION TYPES: formulation and description"

A feature of agroforestry land utilization types is that they are often conceived and formulated as interventions into the existing land use, usually agriculture. Thus the approach is predominantly that of improvement rather than transformation. Closely related is the fact that practicability and acceptability is built into the proposals at an early stage. This avoids the subsequent problem of "We've done the research: now how are we going to get the farmers to accept the system?". Based on the diagnosis of the present land use system and the constraints under which the farmers are operating, acceptability is built into the design of the proposed agroforestry systems. There is no reason, of course, why this should not be done for non-agroforestry land utilization types.

"LAND UTILIZATION TYPES: description"

The standard list of descriptors for land utilization types (outputs, market orientation, capital intensity, etc.) are almost identical in the guidelines on rainfed agriculture and on forestry, apart from minor changes in wording, e.g. cultivation practices/silvicultural practices. The same list appears in the guidelines on irrigation with the addition of headings specific to water management. All of these descriptors are relevant to agroforestry systems, as has been illustrated in Table 3. In the current world inventory of agroforestry systems being conducted by ICRAF, care was taken to include each of them in the computerized summary of characteristics.

There are, however, additional features that are of particular significance in the description of agroforestry land utilization types. These could indeed be included under the standard headings, Outputs, Cropping characteristics and Cultivation/Sylvicultural practices, but as they define the essential distinguishing features of agroforestry, namely the tree/non-tree interactions and the roles of the tree component in the land use system as a whole, it is better to isolate them as a separate set of descriptors, as in Table 5.

"ECONOMIC AND SOCIAL DATA"

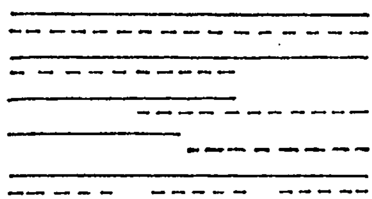
No special features for data collection. Data are incorporated into objectives and design of land utilization types as well as during comparison of land use with land.

"LAND UNITS"

No special features.

Table 5 DESCRIPTORS FOR AGROFORESTRY LAND UTILIZATION TYPES. Based on Torres (1983), Huxley (1983) and the ICRAF agroforestry systems inventory.

TYPE OF SYSTEM	Agrosilvicultural, silvopastoral agrosilvopastoral, other (see Section 2.2).
DOMINANT INTERACTION (between tree and non-tree components)	Space: trees and other components are grown simultaneously, in a spatial arrangement. Time: trees follow crops or pasture in a rotation. Both: the system includes substantial interactions in both space and time.
ARRANGEMENT IN SPACE	Mixed, dense (e.g. home gardens) Mixed, sparse (e.g. most systems of trees in pastures) Row (single line of trees) Strip (belt more than one tree in width). Boundary (trees on edges of fields roads, etc.) Block (as in tree plantations)
ARRANGEMENT IN TIME	Coincident Concomitant Overlapping Separate Interpolated (Time-dominant systems are necessarily separate; space-dominant systems with annual crops are usually interpolated; with perennial crops may be in various time arrangements).
AGROFORESTRY PRACTICES	See Table 1
FUNCTIONS OF THE TREES	See Table 2



"LAND USE REQUIREMENTS"

Performance of agroforestry utilization types is often not known, hence neither are precise land use requirements. To meet this situation, there is need for a period of research, and hence design of a research programme.

"LAND QUALITIES AND CHARACTERISTICS"

No qualities or characteristics additional to those applicable to agriculture and forestry have been found necessary. This applies to qualities for management and conservation as well as those for plant growth.

"COMPARISON OF LAND USE WITH LAND"

PHYSICAL REQUIREMENTS	Not precisely known, see above.
ENVIRONMENTAL IMPACT	Important in agroforestry systems; information available.
SOCIAL ANALYSIS	Important in agroforestry systems; methods available
ECONOMIC ANALYSIS	Methods available; has been done many times, on an <u>ex ante</u> basis.
LAND SUITABILITY CLASSIFICATION	Has not yet been attempted.

In summary, the main differences between land evaluation methods as set out in the FAO guidelines for rainfed agriculture and forestry, and those practised in, or appropriate to, the evaluation of agroforestry systems are:

i. The objective is often problem-solving.

ii. Surveys commence with a stage of diagnosis or problems and their causes.

iii. To describe agroforestry land utilization types, a set of additional descriptors is needed.

iv. The performance of agroforestry systems, in relation to land qualities, is frequently not firmly established, and thus the land use requirements cannot be precisely specified.

v. In part due to the uncertainties over performance, the output from agroforestry studies is frequently a design for a research programme, incorporating on-station and on-farm research, together with a variable element of immediate implementation.

vi. In agroforestry surveys to date, there has been a relatively greater emphasis on social features and less on environmental features, as compared with most land evaluation studies.

6.2 The ICRAF/FAO Project, Land Evaluation for Agroforestry

Recognizing that there is a need to applied methods of land evaluation to agroforestry, and that simple adaptation of existing methods will not be sufficient, ICRAF has embarked upon a project in land evaluation for agroforestry (with the serendipitous acronym of LEAF). It has been fortunate to secure the technical co-operation of FAO in this activity. The rationale for the project as a whole has been set out in a Working Paper, Land Evaluation for Agroforestry: the tasks ahead (Young 1984). The necessary stages in the development of such a methodology are as follows:

i. An environmental data base.

ii. The formulation of appropriate land utilization types, as a basis for suitability analysis.

iii. Land use requirements, for agroforestry components (trees, crops, livestock) and technologies.

iv. Biophysical models of interactions between trees and other components of agroforestry systems.

v. An assessment of the environmental impact, and hence sustainability, of agroforestry systems.

vi. A methodology for comparison between agroforestry and other land use systems, on a given site.

vii. Case studies to test the above.

viii. The holding of an international workshop.

No specific research needs are included for economic analysis nor for the examination of social impact, since satisfactory procedures for this aspects already exist.

6.3 The ICRAF environmental data base

Since it is the particular interest of land evaluation, brief details may be given of the environmental data base of information on agroforestry. Further details, with examples of computer outputs, are given in Young (1983 and 1984).

There are two main files to the data base, a sites file and a requirements file. The sites file contains records of the complete range of environmental conditions to be found at sites associated with agroforestry. These include locations of ICRAF's collaborative research programme, sites of existing agroforestry systems and sites of agroforestry experimental work. The fourth kind of site that can be entered is any area of interest to a user. By storing all such data in a standardized form, it will be possible to identify and compare sites with similar environments.

The requirements file is intended to store the environmental requirements of agroforestry components and land utilization types. At present it contains only requirements of multipurpose trees. Crop requirements will be added by assembling data from FAO and other surveys. In course of time it is hoped to include the environmental requirements of agroforestry land utilization types, but that achievement is some way in the future.

A diagram showing the structure of the environmental data base, together with an explanation of the structure of the requirements file and examples of outputs, is given in Young (1984, Fig. 3 and Tables 1 and 2).

7. DISCUSSION AND CONCLUSIONS

The four questions posed at the outset can now be reviewed in the light of the information presented.

7.1 How can land evaluation be applied to agroforestry?

The first question is the adequacy and appropriateness of existing procedures of land evaluation when applied to agroforstry. The standard descriptors for land utilization types are all applicable, but need to be supplemented by aspects distinctive to agroforestry systems; the origin of these aspects lies in two features of such systems, the interaction between the tree and non-tree components and the multipurpose role of the trees. Comparison between land and use can already be achieved satisfactorily in terms of environmental impact, social aspects and economic analysis. It can only be carried out for physical requirements on a generalized basis, owing to lack of sufficient performance data for agroforestry systems in relation to environmental conditions. This situation means that in many cases, the output from an agroforestry study is a combination of a research programme combined with a variable amount of direct implementation.

There is a further aspect. It seems likely that the classificiation of a particular agroforestry land utilization type as highly suitable for a given area is not related to the environmental conditions of that area alone; it depends to a substantial extent on the existing land use systems in the area and their problems. For example, an agroforestry practice that combines soil conservation with fuelwood production is highly suitable for a certain area not only because its land has a high erosion hazard but also because of a fuelwood shortage among its people.

A consequence is that, in the author's present perception, the "Guidelines on land evaluation for agroforestry" will not be simply an adaptation, following the same outline, of the guidelines for rainfed agriculture, forestry and irrigated agriculture. There are likely to be some substantial modifications in principles and procedures, possibly including some element of integration with the diagnosis and design methodology. This question is further discussed in Young (1984).

7.2 What benefits can agroforestry bring to sloping areas?

Generalizing from the examples in Section 4, there are a range of benefits, provided that the agroforestry practices and systems are based on sound design and their performance is proven by trials. The major element is that sloping areas invariably have a substantial hazard of soil erosion, and well-designed agroforestry has the capacity to combine conservation with productive functions. Since fuelwood production is the most commonly called-for output from multipurpose trees, then insofar as sloping areas have an inherent tendency towards a situation of fuelwood shortage, then agroforestry has a further role in this respect. More generally, whereas crops present serious problems for cultivation on slopes, trees do not, leading to potential benefits from making use of interactions between the two.

7.3 Under what circumstances is agroforestry likely to be preferred form of land use in sloping areas?

Converted to the approach of land evaluation, the third question could be expressed as follows: if for a sloping area, a land evaluation were conducted which included one or more systems of agriculture, agroforestry and forestry, under what circumstances would agroforestry be classified as more highly suitable?

Suppose that a watershed fulfilled an important role as a water catchment, that it was presently uninhabited, and that there was no strong land pressure in the area; then clearly, the preferred use would be to retain that watershed under protective forestry. It is harder to conceive of a set of circumstances in which agroforestry should be equally clearly excluded in favour of agriculture, but perhaps a well-maintained system of terraced ricefields, their fulwood and fodder needs adequately provided from other nearby land, would qualify - if such a case exists.

The circumstances in which agroforesry appears to have the potential to make a considerable contribution to the welfare of the people is in those sloping lands of the humid and subhumid tropics which suffer from one or more of the problems of soil erosion, over-cultivation and soil fertility decline, or shortage of fuelwood or fodder. These are land use problems which agroforestry, with its particular capacity to combine productivity with sustainability, has special potential to ameliorate.

7.4 Should sloping areas be a priority environment for application of agroforestry research and development effort?

From the two preceding subsections, it is apparent that the answer to this final question is a clear "Yes". Sloping areas frequently have problems of land use of the kinds that agroforestry can assist. Clearly, therefore, this should be an environment towards which effort is particularly directed. It would go beyond the scope of this paper to carry out a comparative review of other environments, but it appears possible that there are none in which the combination of need with potential for improvement is so clearly present.

There is some more or less independent confirmation of this situation. The ICRAF collaborative programme is one in which agroforestry research is carried out by institutions in a network of countries, with ICRAF playing a role in design and co-ordination. The programme is based on the diagnosis and design methodology, applied to selected target areas. These areas have not been chosen by means of land evaluation surveys. They are selected primarily by the collaborating countries, on grounds which vary in detail but which are broadly that they possess land use problems which it is thought that agroforestry could assist. To date there have been eight such study areas. Of these, only one is classed as gently sloping; two are moderately sloping whilst four include areas of both moderate and steep slopes. The most recent, the Bhaintam watershed for the Himalayas is Uttar Pradesh, India, has been covered by a survey of slope class; 92% of the watershed has slopes over 19^{o} (34%), i.e. steep, whilst 56% has slopes over 27^{o} (50%) and 16% at over 45^{o} (100%)!

There is no doubt an element of chance in this concentration of requests for collaborative assistance on sloping lands, but it is strongly indicative. Among requests to the recently-formed ICRAF Advisory Unit, those from sloping areas again appear, for example areas in Rwanda and Indonesia.

8. DESIGN, RESEARCH AND IMPLEMENTATION

It is well to end on a note of caution. Great as the potential benefits of agroforestry to sloping lands may appear to be, it would be unwise in most cases to proceed with immediate large-scale implementation. Whilst some traditional agroforestry systems have been functioning successfully for many years, most modern designs for introductions have been subject to only a limited degree of testing - and still less to testing under specific local environmental conditions. Hence the way ahead that is normally to be recommended at the present state of technology is a well-designed research programme, tailored to the needs of the area and incorporating both on-station and on-farm research, coupled with a limited amount of immediate implementation.

If an introduced agroforestry technology system or is to be successful, it is necessary to ensure:

i. That the trees selected will grow well in the area. This is a fundamental requirement, without which all other functions of agroforestry will fail.

ii. That the system is well designed. The altitude 'trees are wonderful, plant them' is not enough. Trees alone do not even achieve soil conservation: it is the design which they are planted and the subsequent management that matters (Wiersum, 1984). Every aspect of a proposed agroforestry technologies needs to be subject to careful analysis, to minimize adverse interactions and to obtain the desired balance of beneficial functions.

iii. That the system has been tested. The design must be tested under controlled field conditions; if it has been found satisfactory in other regions, trials are necessary under local environmental conditions (and with locally realistic inputs and management practices). This imposes a delay of some 5 years, but implementation of an unproven technology which fails can cause an equal delay, at considerably greater cost.

iv. Finally, that the system meets the needs of the people. That is, the research programme itself should be designed such that its output is a set of technologies, or one or more agroforestry systems, that is adapted to the environment of the area, helps to ameliorate its land use problems, and can be implemented by, and is acceptable to, its people.

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COMPUTERIZED SYSTEM REGISTER No.1

I C R A F, Nairobi Date: 01/16/85

AGROFORESTRY SYSTEM DESCRIPTION Rec. No: 1/1

CODE NUMBER: 0001/ECMF **SOURCE:** Fernandes et al (1984).

SYSTEM NAME: Chagga homegardens: coffee-banana-multipurpose trees/shrubs ar d stall-fed livestock.

COMPONENTS ASSOCIATION : Trees: Crops: Animals

AGROFORESTRY PRACTICES : MP trees on cropland: MP Trees around Homesteads: MP Fodder Trees: MP Fuelwood Trees: Trees Sheltering Crops : Trees Sheltering Homesteads: Live Fences: Tree Garden s: Apiculture with Trees

EXTENT OF SYSTEM: 1200 Sq Km

MEAN MANAGEMENT UNIT: 0.68 HA **RANGE OF MANAGEMENT UNIT:** 0.20 - 0001.20 HA

GEOG"APHICAL LOCATION

AFSI REGION: Africa (E.C & W) **COUNTRY:** Tanzania

PROVINCE: Northern **AFAREA :** Mt. Kilimanjaro

LATITUDE: 02.9 - 03.0 S **LONGITUDE:** 037.2 - 037.5 E

ALTITUDE: 900 -1900m

AGROFORESTRY SYSTEM DESCRIPTION Rec. No: 1/2

BIOPHYSICAL DATA

KOPPEN CLASS: Sub humid tropics 2 wet seasons

MEAN ANNUAL RAINFALL: 1000-1700mm MEAN ANNUAL TEMPERATURE: 22.9 - . C

SOILCLASS : Latosols: Immature: Temperate Types

LANDFORM: Moderately sloping DRAINAGE: Well drained

SOCIO-ECONOMIC DATA

MARKET ORIENTATION: Subsistence with subsid commercial

NUMBER OF PEOPLE INVOLVED: 500000 POPULATION DENSITY: 350/Sq.Km

ETHNIC GROUP: Chagga/bantu DOMINANT RELIGION: Christians

LAND AVAILABILITY: Scarce LAND TENURE TYPE: Freehold

MARKET FACILITIES: Good CREDIT FACILITIES: Fair

INFRASTRUCTURE: Fair COOPERATIVES: Present

CAPITAL INTENSITY: Low LABOUR INTENSITY: High

MECHANIZATION LEVEL: Hoe & spade LEVEL OF INPUTS: Low

INPUTS : Labour: Seed: Pesticide: Capital

SYSTEM OUTPUTS: Coffee, bananas, milk, vegetables.

INCENTIVES TO UNDERTAKE AGROFORESTY

AGROFORESTRY SYSTEM DESCRIPTION Rec. No: 1/3

COMPONENT ARRANGEMENT DATA

WOODY PERENNIAL-HERB ARRANGEMENT

DOMINANT FEATURE: Space

ARRANGEMENT OF WOODY SPECIES IN TIME: Static

HORIZONTAL ARRANGEMENT OF WOODY SPECIES: Mixed dense

VERTICAL ARRANGEMENT OF WOODY SPECIES: Multistorey

WOODY-WOODY ARRANGEMENT

ARRANGEMENT IN TIME: Static

HORIZONTAL ARRANGEMENT: Mixed

VERTICAL ARRANGEMENT: Multistorey

HERB-HERB ARRANGEMENT

ARRANGEMENT IN TIME: Rotation

HORIZONTAL ARRANGEMENT: Mixed

VERTICAL ARRANGEMENT: Multistorey

WOODY-ANIMAL ARRANGEMENT

DOMINANT FEATURE: space

ANIMAL ARRANGEMENT IN TIME: static

LOCATION OF WOODY SPECIES: outside animal management unit

HORIZONTAL ARRANGEMENT OF WOODY SPECIES: n/a

VERTICAL ARRANGEMENT OF WOODY SPECIES: n/a

ANIMAL FEED METHOD: Stall-fed

FACTORS DEGRADING THE SYSTEM: Land shortage, high population, low productivity

AGROFORESTRY SYSTEM DESCRIPTION Rec. No: 1/4

SPECIES DETAILS

TYPE	COMMON NAME	SCIENTIFIC NAME	USES/FUNCTION
Woody		*Albizia schimperiana*	/fuelwood/building material/crop shade
Woody		*Bridelia micrantha*	/fodder leaves/fuelwood/building material/drug
Woody		*Caesalpinia decapetala*	/soil conservation/live fence
Woody		*Calpurnia aurea*	/building material/crop shade/anti-pest/tools & utensils
Woody		*Carica papaya*	/food fruit/food vegetables/drug/latex/insect repellent/anti-pest
Woody		*Cassia didymobotrya*	/drug
Woody		*Cedrella mexicana*	/fuelwood/timber
Woody	Mvuli	*Chlorophora excelsa*	/fuelwood/timber
Woody	Coffee	*Coffea arabica*	/fuelwood/beverage/mulching
Woody		*Commiphora sp.*	/fodder leaves/fencing material/drug/insect repellent/live suppor
Woody		*Cordia abyssinica*	/fuelwood/building material/crop shade/beehive construction
Woody		*Croton macrostachys*	/fodder leaves/fuelwood/insect repellent/anti-pest
Woody	Moonflower	*Datura arborea*	/bee forage/anti-pest
Woody		*Diospyros mespiliformis*	/fuelwood/timber
Woody		*Dracena usambarensis*	/soil conservation/live fence/boundary marker
Woody		*Dracena afromontana*	/soil conservation/live fence/boundary marker
Woody	Cardamoum	*Eletteria cardamomum*	/food spices/soil conservation
Woody		*Ehretia sp.*	/building material/tools & utensils
Woody	Loquat	*Eriobotrya japonica*	/food fruit/building material/windbreak/live fence/tools & utensil
Woody	Fig	*Ficus sp.*	/food fruit/fodder leaves/fuelwood
Woody		*Gardenia sp.*	/insect repellent/anti-pest/tools & utensils
Woody	Australian silky oak	*Grevillea robusta*	/fuelwood/timber/building material/crop shade
Woody		*Iboza multiflora*	/drug/soil conservation/live fence/anti-pest
Woody		*Markhamia platycalyx*	/fuelwood/building material
Woody	Mulberry	*Morus alba*	/food fruit/fodder leaves/fuelwood/live fence
Woody		*Newtonia buchananii*	/fuelwood/timber
Woody		*Olea welwitschii*	/fodder leaves/timber
Woody	Avocado	*Persea americana*	/food fruit/fuelwood
Woody	Guava	*Psidium guajava*	/food fruit/fuelwood/live fence
Woody		*Rauwolfia caffra*	/fuelwood/drug/insect repellent/anti-pest
Woody		*Rauwolfia inebrians*	/fuelwood/drug/insect repellent/anti-pest
Woody	Castor plant	*Ricinus communis*	/essential oils/drug/anti-pest
Woody		*Syzigium africanum*	/food fruit/fuelwood
Woody	Teak	*Tectona grandis*	/timber/building material
Woody		*Trema guineensis*	/fodder leaves/fuelwood/drug/insect repellent/anti-pest
Woody		*Trichilia emetica*	/food oils/fats/fuelwood/anti-pest
Woody		*Uvaria sp.*	/fuelwood
Woody		*Vangueria tomentosa*	/food fruit/drug/anti-pest
Herbaceous	Banana	*Musa spp.*	/food fruit/food vegetables/food starch/fodder leaves/beverage/fib lching
Herbaceous	Beans	*Phaseolus vulgaris*	/food seeds
Herbaceous	Cabbage	*Brassica oleracea*	/food vegetables
Herbaceous	Cow pea	*Vigna unguiculata*	/food seeds
Herbaceous	Maize	*Zea mays*	/food seeds/fodder leaves/mulching
Herbaceous	Onion	*Allium cepa*	/food spices
Herbaceous	Potato	*Solanum tuberosum*	/food starch
Herbaceous	Sweet potato	*Ipomoea batatas*	/food starch
Herbaceous	Taro	*Colocassia sp.*	/food starch
Herbaceous	Taro	*Xanthosoma sp.*	/food starch

...ctd.

...Species details continued

Herbaceous	Tomato	*Lycopersicon esculentum*	/food fruit
Herbaceous	Yam	*Dioscores spp.*	/food starch
Herbaceous	Finger millet	*Eleusine coracana*	/food seeds/beverage
Herbaceous		*Aloe volkensis*	/drug/anti-pest
Herbaceous		*Cynodon dactylon*	/fodder leaves/soil conservation
Herbaceous		*Pennisetum purpureum*	/fodder leaves/soil conservation
Herbaceous		*Senecio kilimandscharica*	/drug
Herbaceous		*Setaria sphacelata*	/soil conservation
Herbaceous	Vetiver grass	*Vetiveria zizanoides*	/insect repellent/soil conservation.
Animal	Cow	*Bos indicus*	/meat/milk/hides/manure
Animal	Sheep		/meat/hides/manure
Animal	Goat		/meat/milk/hides/manure
Animal	Pig		/meat/manure
Animal	Chicken		/meat/eggs
Animal	Bees		/honey

I C R A F, Nairobi Date: 01/18/85

AGROFORESTRY SYSTEM DESCRIPTION Rec. No: 2/1

CODE NUMBER: 0002/ECMF **SOURCE:** Sabine asp 02

SYSTEM NAME: Gum gardens: Acacia senegal - millet - bush fallow.

COMPONENTS ASSOCIATION : Trees: Crops: Animals

AGROFORESTRY PRACTICES : Improved Fallow: MP trees on cropland: MP Fodder Trees: MP Fuelwood Trees: Tree Gardens

EXTENT OF SYSTEM: 600000 Sq Km

MEAN MANAGEMENT UNIT: 0.00 HA **RANGE OF MANAGEMENT UNIT:** 0.00 - 0000.00 HA

GEOGRAPHICAL LOCATION

AFSI REGION: Africa (Sahel & S) **COUNTRY:** Sudan

PROVINCE: Central **AFAREA :** Kordofan

LATITUDE: 12.0 - 13.5 N **LONGITUDE:** 027.5 - 032.0 E

ALTITUDE: 350-500 m

AGROFORESTRY SYSTEM DESCRIPTION Rec. No: 2/2

BIOPHYSICAL DATA

KOPPEN CLASS: Semi-arid,hot

MEAN ANNUAL RAINFALL: 250-500 mm MEAN ANNUAL TEMPERATURE: 28.0 - . C

SOILCLASS : Desert Soils

LANDFORM: Depositional/flat DRAINAGE:Well drainned

SOCIO-ECONOMIC DATA

MARKET ORIENTATION: Subsistence with subsid. commercial

NUMBER OF PEOPLE INVOLVED: 0 POPULATION DENSITY: 100/Sq.Km

ETHNIC GROUP: Arabic/nubian DOMINANT RELIGION:Muslim

LAND AVAILABILITY: Scarce LAND TENURE TYPE:Communal

MARKET FACILITIES: Fair CREDIT FACILITIES:No data

INFRASTRUCTURE: Poor COOPERATIVES: No data

CAPITAL INTENSITY: Low LABOUR INTENSITY: Medium

MECHANIZATION LEVEL:Hoe & spade LEVEL OF INPUTS:Low

INPUTS : Labour: Seed

SYSTEM OUTPUTS: Gum arabic

INCENTIVES TO UNDERTAKE AGROFORESTY : Not applicable

AGROFORESTRY SYSTEM DESCRIPTION Rec. No: 2/3

COMPONENT ARRANGEMENT DATA

WOODY PERENNIAL-HERB ARRANGEMENT

DOMINANT FEATURE: Time

ARRANGEMENT OF WOODY SPECIES IN TIME: Managed rotation

HORIZONTAL ARRANGEMENT OF WOODY SPECIES: Mixed-sparse

VERTICAL ARRANGEMENT OF WOODY SPECIES: Multistorey

WOODY-WOODY ARRANGEMENT

ARRANGEMENT IN TIME: Static

HORIZONTAL ARRANGEMENT: Mixed
VERTICAL ARRANGEMENT: Multistorey

HERB-HERB ARRANGEMENT

ARRANGEMENT IN TIME: Static

HORIZONTAL ARRANGEMENT: Mixed

VERTICAL ARRANGEMENT: Multistorey

WOODY-ANIMAL ARRANGEMENT

DOMINANT FEATURE: time

ANIMAL ARRANGEMENT IN TIME: rotation

LOCATION OF WOODY SPECIES: inside animal management unit

HORIZONTAL ARRANGEMENT OF WOODY SPECIES: mixed

VERTICAL ARRANGEMENT OF WOODY SPECIES: multistorey

ANIMAL FEED METHOD: Browsing,grazing

FACTORS DEGRADING THE SYSTEM:Long fallow,drought,poor gum price,land shortag

AGROFORESTRY SYSTEM DESCRIPTION Rec. No: 2/4

SPECIES DETAILS

TYPE	COMMON NAME	SCIENTIFIC NAME	USES/FUNCTION
Woody	Gum arabic tree	*Acacia senegal*	/fodder leaves/fodder fruit/seeds/fodder shoots/fodder flowers/bee forage/fuelwood/fencing material/gum/resin/soil conservation/dune fixation
Woody	Baobab	*Adansonia digitata*	/food fruit/fibre/rituals
Woody		*Acacia seyal*	/fodder leaves/fodder fruit/seeds/fodder flowers/fuelwood/fencing material/gum/resin/soil conservation
Woody		*Acacia campylacantha*	/fuelwood/soil conservation
Woody		*Acacia nubica*	/fodder leaves/fuelwood/fencing material
Woody		*Acacia mellifera*	/fodder leaves/bee forage/fuelwood/fencing material
Woody		*Zizyphus spina-christi*	/food fruit/fodder leaves/fuelwood
Woody		*Balanites aegyptiaca*	/food fruit/fodder leaves/fuelwood
Herbaceous		*Cenchrus biflorus*	/fodder leaves/soil conservation
Herbaceous	Bullrush millet	*Pennisetum typhoideum*	/food seeds
Herbaceous	Sorghum	*Sorghum vulgare*	/food seeds
Herbaceous	Sesame	*Sesamum indica*	/food seeds
Herbaceous	Groundnut	*Arachis hypogeae*	/food nuts
Animal	Camel	*Camelus dromedarius*	/meat/milk
Animal	Goat		/meat/milk/hides
Animal	Cattle		/meat/milk/hides

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

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

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.

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.

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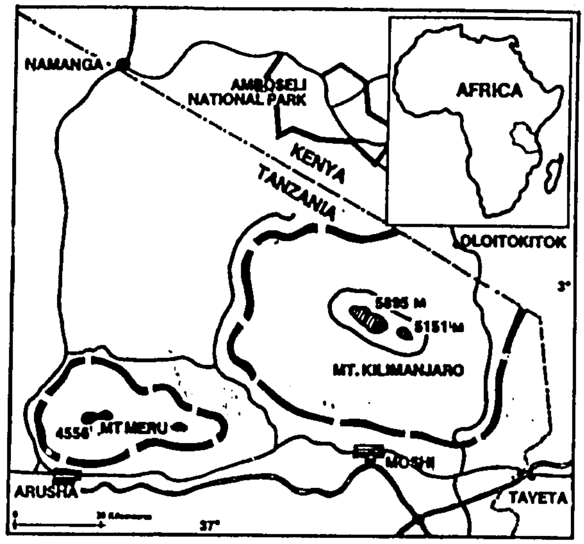

Figure 1. Location of Mt. Kilimanjaro in northern Tanzania.

2. General description of the area

2.1 Geographic location

The Chagga homegardens are found on Mt. Kilimanjaro in northern Tanzania (2.9–3.3 °S, 37.0–37.5 °E) (Figure 1). The bulk of the mountain covers about 3100 km² and the highest peak is 5895 m above sea level. The area above the 1900 m contour is a designated forest reserve 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

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In general, these volcanic soils are fertile with a high base saturation and cation exchange capacity. A major limitation is the step slopes which prevent mechanization and require substantial 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 kiliman dscharica.* 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 north-eastern 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 Figure 2.

Figure 2. Chagga homegarden showing large trees, e.g. *Cordia abyssinica, Albizia* spp. and *Grevillea robusta* in the uppermost storey. Next are the banana and coffee canopies and here the lowest layer is comprised of fodder herbs and grasses. (Photo: E.C.M. Fernandes).

3. Structure of the system

The Chagga homegardens ('vihamba') cover about 1200 km² (120,000 ha) on the south and east slopes of Mt. Kilimanjaro. Recent estimates indicate that 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 (Figure 1) being the nearest major market and a good road linking Moshi with Arusha, Tanga and Dar es Salaam.

The homegardens are located mainly between 900–1900 m 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*), 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.).

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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 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).

3.2 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 Figure 3. In terms of canopy depth, the lowest zone (0–1 m) consists of food crops like taro, beans, and fodder herbs and grasses. Included in this zone is the regeneration of the overstorey trees/shrubs. The next zone (1–2.5 m) comprises mainly coffee with a few young trees/shrubs and medicinal plants. Next is the banana canopy (2.5–5 m) with some fruit and fodder trees. Above the 'banana' layer, vertical zonation is less distinct with a diffuse zone (5–20 m) of the preferred fuel and fodder species and another zone (15–30 m +) 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.

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

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, mosquito repellent.
Cassia didmyobotrya	medicinal uses, poisonous to cattle.
Cedrela mexicana	fuelwood, timber.
Chlorophora excelsa	Valuable timber.
Citrus spp.	fruit.
Commiphora spp.	fodder, anti-insect properties, live support for yams, fencing material.
Cordia abyssinica	coffee shade, fuelwood, building material, beehive construction.
Croton macrostachys	coffee shade, fuelwood, fodder, anti-insect properties.
Datura arborea	bee forage, anti *Armillaria mellea*, anti-nematodes.
Diospyros mespiliformis	valuable timber.
Dracena usambarensis	live fence, boundary marker.
Dracena afromontana	live fence, boundary marker.
Ethretia 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 ar hung in its branches.
Rauwolfia inebrians	coffee shade, fuelwood.
Ricinus communis	seed oil used medicinally, seeds in bait as rodent poison.
Syzigium africanum	fuelwood, fruit.
Tectona 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.

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Table 1 (Cont.)

Species	Functions/Uses
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 separate publication [5]

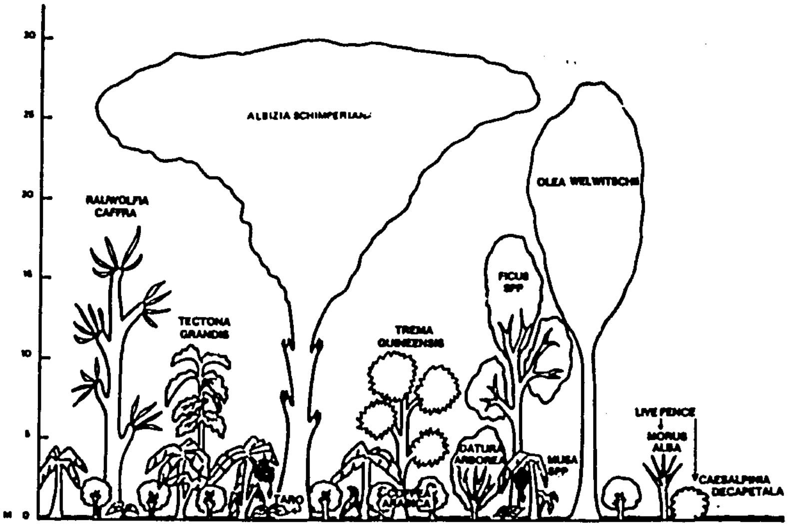

Figure 3. Typical vertical zonation in a Chagga homegarden.

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 Research 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.

3.3 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 repel 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 homegarderns 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 (Figure 4, bottom) 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

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Figure 4. (top) Valuable timber trees are found on most Chagga homegardens. Teak trees (to the left and centre of picture) are seen growing up through the banana canopy (bottom) Taro together with young coffee and banana plants in the lowest storey. Note the hoe used for tillage. (Photos: E.C.M. Fernandes).

branches. When appropriate, the overhead canopy is thinned to allow the tree to grow into the upper stories. Figure 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

4.1 Resource utilisation

4.1.1 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 buried 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.

4.1.2 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.

4.1.3 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.

4.2 Inputs

Seeds are mostly obtained from previous 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.

4.3 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 available for taro, yams cardamom and onions. Local sources indicate that crop failure involving coffee and/or maize and beans occurs once every 3 or 4 years. However, total failure involving in addition, bananas, other fruits, root crops and livestock has never occurred. 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 l per day), whereas improved cattle produce between 8–16 l 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^3 yr^{-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^3 yr^{-1}. Thus a homegarden supplies ¼ to ⅓ 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 Growth of system

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

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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 the 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 will have to be increased to cater for the rapidly increasing population.

6. Evaluation

6.1 Merits

(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 multistorey cropping systems.

In addition, the advantages attributed to intimate multispecies, multistorey 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.

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

(4) Introducing new 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 fertilizers. 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 practise less intensive multistorey 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

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the rows. Ground cover can be maintained by intercropping the maize with beans or cow peas.

6.4 Research needs

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.

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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.

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

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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: (1) to attract shifting cultivators and landless people to establish themselves in forest villages which offer improved facilities and greater stability than nomadic life; (2) 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.

General description of the area

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

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 km² 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

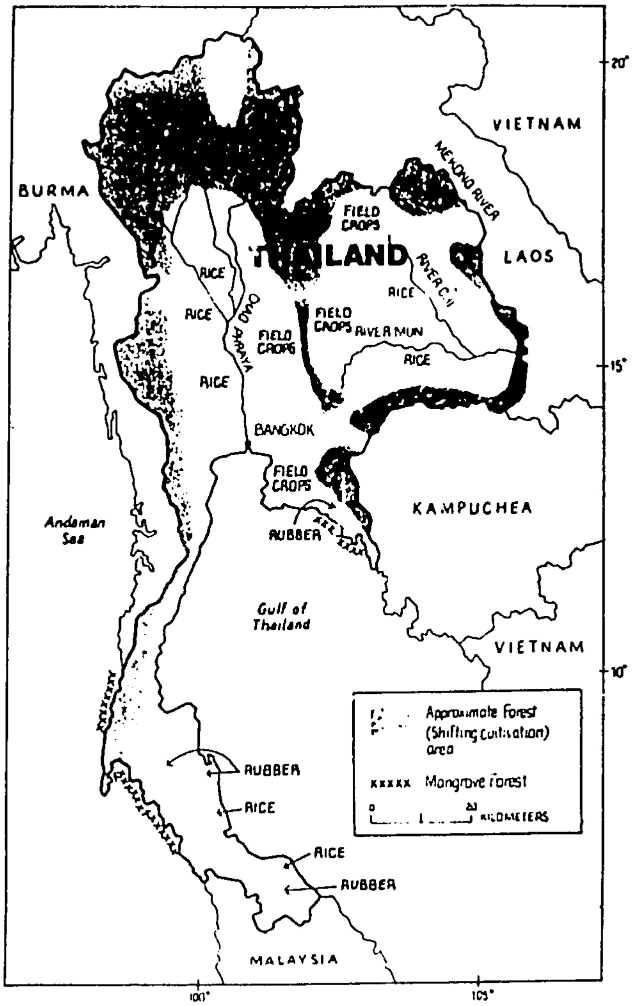

Figure 1. A rough land-use map of Thailand.

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.

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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% of its annual rainfall from the south-west 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
Fresh water swamp forests
Mangrove forests
Savanna forests
Bamboo forests
Beach forests
Coniferous forests
Scrub forests

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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, Thailands rice production was estimated at 15.6 million tonnes. Only 10% 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% of the country's total area [4]. This contrasts dramatically with a forest area of 57% 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
Intsia 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 gradis, 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; or in forest 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 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.

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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 (*Citrullus 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 (*Ipomoe... ...tas*), taro (*Colocasia antiquorum*), and yams (*Dioscorea* spp.); cucu... ...us crops such as cucumber (*Cucumis sativus*), loofah (*Lufa acutangu...* ...nd 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% 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.

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

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Table 1. Plant species other than the common agricultural species found in forests 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	insect 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

seedlings) and *Melia azedarach* (1 year-old-plants) and 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 villagers 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. Figure 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/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/year, i.e., a total of 153.63 ha annually per forest village.

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

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Figure 2. Photograph showing the houses and the homegardens surrounding them in a Forest Village in Northern Thailand. (Photo: P.K.R. Nair).

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 was 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;

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

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/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 of FIO for establishing forest plantation with and without forest villages.

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.

The soils especially in the dry northeastern region are generally poor. This tends to exaggerate the competitive interacter 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 Figure 3A and 3B respectively, illustrate this point.

Production of upland rice is typically of the order of 0.5–1.5 tons/ha/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.

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 4,500 villages undertaking plantation establishment

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, machinery, etc.)	74.00	74.00	74.00	74.00
[3]Stump or seedling and replanting charges[2]	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	66.86	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
Sixth to tenth years				
[4]Maintenance & protection per year	20.65	20.65	20.64	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

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

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/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 improvment of national and export wood sources.

2) The rehabilitation of the country's forest resource is being achieved by

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

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 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.

5.4 Potential

The concept and philosophy of forest villages represent a sound approach to tackling the problems of shifting cultivations vis-a-vis land degradation. The benefits accrued from the scheme can, however, be enhanced by removing

Figure 3. (top) First year of establishment of a teak plantation in the Forest Village with rice as the major agricultural crop. (bottom) 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 Figure 3 (top). (Photos: P.K.R. Nair).

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

Region	No. of villages	Mean no. of families per	Mean area (ha) cultivated per village	Mean area (ha) cultivated per family	Mean income (US $) for 1981					
					Per village					
					From agricultural crops	Reward	Bonus	Daily	Total	Income per family
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	4	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 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.

Today 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 reseach 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 wood species in association with plantation trees;

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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 of the extent possible even during the life of the project.

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DYNAMICS OF FALLOW SUCCESSIONS AND INTRODUCTION OF ROBUSTA COFFEE IN SHIFTING CULTIVATION AREAS IN THE LOWLANDS OF PAPUA NEW GUINEA

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ABSTRACT

The traditional shifting cultivation system in the lowlands of Papua New Guinea consists of mixed food crop gardens in which yams (Dioscorea spp.), bananas, taro (Colocasia esculenta) and sugarcane predominate. The cropping cycle is usually for 18 months, followed by a fallow cycle of up to 30 years. During the cropping cycle, two species of fruit trees, Pometia pinnata and Artocarpus altilis are also planted, the leaves of the former also being used as a mulch and green manure in yam cultivation. Fallow succession follows rather systematic patterns about which farmers have a thorough understanding.

Robusta coffee, a cash-crop component, has been added to the system in some areas since the late 1950s. It is usually grown in permanent blocks, but is interplanted with Leucaena as shade. Food crops are planted in the establishment stage, bananas and Xanthosoma being retained even in mature coffee gardens. The system seems to be a potentially promising one. But very little quantitative information is available on the production and performance of the system and practically no systematic research has been undertaken. Since the Papua New Guinea fallow gardeners are willing to accept innovations, it will be appropriate and timely to undertake serious studies so that the system can be improved. A few items that merit immediate research attention are indicated.

Keywords: Agroforestry Fallow successions, Papua New Guinea, Robusta coffee, Shifting cultivation

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INTRODUCTION

Systems of shifting cultivation have long been characterised as "primitive" and resource depleting. In situations where national and multi-national timber companies come into competition for forest resources with shifting cultivators, it is common to hear arguments that these primitive forms of land use should be replaced by permanent cultivation and the use of fertilisers and high yielding, introduced plant varieties. However, recent interest in agroforestry and sustainable systems of agriculture is giving support to arguments presented in the 1970s that many forms of shifting cultivation are viable systems of land use and are critically important in the context of increasing dependence on high inputs in modern agricultural systems. (4,5,7). Systems of shifting cultivation too are vulnerable to changes such as a shortening of the fallow period where a grass fallow replaces a tree fallow. It is in this context that the concepts of agroforestry and the development of viable, sustainable tropical agroforestry systems have much to offer towards the improvement of systems of shifting agriculture. The agroforestry system described here is such a traditional system of shifting agriculture, with a recently added tree crop component. A similar system involving open field cultivation of food crops, coffee and Casuarina oligodon has been described recently from the highlands of Papua New Guinea (PNG) (2).

2. GENERAL DESCRIPTION OF AREA

A general description of PNG in relation to agroforestry has recently been given by Bourke (2). Approximately one-quarter of the forested area of PNG is well developed secondary forest, created and maintained by shifting cultivation (11). The system being described here is located on the southern fall of the northwestern coastal mountains,

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which run northwest and southeast and separate a narrow coastal plain to the north, from the basin of the Sepik River, the second largest in the country, to the south.

The foothills of the coastal ranges are Pliocene mudstones interbedded with siltstones and sandstones, gently dipping to the south, which have been eroded into strongly slumped, polygonally branching hill ridges. The original lowland hill forest has been replaced with secondary vegetation ranging from gardens under cultivation, village coffee plantations, fallow garden regrowth (tall cane grass to tall secondary forest) to relatively undisturbed forest. Soils are brown forest soils, shallow dark clay soils, reddish clay soils (Eutropepts) and strongly weathered red and brown clay soils (Dystropepts), the latter two being widespread over similar hill country in PNG (1).

Mean annual rainfall increases along the ranges from west to east and is less seasonable in the west. For the station nearest the site under description, mean annual rainfall has been 2,159 mm (12 years of record). May to September is notably drier than November to March. Mean daily temperatures are 26 degrees C (mean max. 29.9, mean min. 22.2).

All land use systems in the region are a variation of a forest fallow system of shifting cultivation. To the east, fallow regrowth has been reduced to tall cane grass and scattered low tree species as a result of higher populations, lower total rainfall and greater seasonality, whereas to the west, gardens are cleared from well developed secondary forest. The system falls into two fairly discrete parts: mixed food crop gardens, which are cleared from forest each year, cultivated for a maximum of 18 months, and then fallowed for up to 30 years; and permanent blocks of Robusta coffee, from which almost all cash income is produced. Some land has been cleared of all forest and sown in pasture grasses for cattle, but in almost all cases attempts at cattle farming have failed. Pigs are the traditional livestock. Most pigs are now Papua New Guinea-European crossbreeds. Sows are allowed to roam in the forest and in fallow garden areas where they mate with feral boars.

3. STRUCTURE OF THE SYSTEM

Land is cleared of fallow vegetation using axes and machetes and the debris burned, at the end of the dry period. Planting then takes place at the beginning of the wet period. The cultivated plots, known as "gardens" consist of mixed crop stands in which yams (*Dioscorea spp*), bananas (*Musa spp*), taro (*Colocasia esculenta*), and sugarcane (*Saccharum officianale*) predominate, but in which at least 27 other species are also cultivated (Table 1). During the cultivation period seedlings of two tree species, *Pometia pinnata* and breadfruit (*Artocarpus altilis*), are planted and they form "orchards" along the upper margins of ridges used most often for gardening. Sago palms (*Metroxlyn sp.*), coconuts (*Cocos nucifera*) and *Gnetum gnenom* are the other tree species which are grown from seed.

TABLE 1 ABOUT HERE

Between 1942 and 1945 Japanese and Allied armies fought across this area with consequent severe disruptions to village life. After the war many people experimented with radical changes to traditional life. One experiment involved the cultivation of hill rice for sale as a cash crop. But the venture failed because of poor processing and marketing facilities. In the late 1950s the government introduced Robusta coffee as a cash crop, recommending that each family plant 500 trees in bush gardens, shaded with Leucaena.

Coffee has been widely adopted, but the average size of coffee gardens is small, consisting of 150 and 250 trees. It is, however, almost the only source of monetary income in the area, apart from government or mission salaried and wage employement. Coffee gardens and food gardens are located on discrete sites. However when forest is cleared for coffee, food crops are commonly planted during the Leucaena establishment stage, and when the garden is fully established bananas and Xanthosoma are often found amongst the coffee trees. At present coffee gardens are stable with little replanting or expansion. It is probable however that some people will shortly expand coffee planting onto 20 ha "communal" gardens.

Food gardens fall into three categories The first garden planted following forest clearing is the most important and contains a restricted number of species. Yams planted in these gardens provide tubers used in ceremonies and exchanges and the gardens have many ritual restrictions. After the first harvest, yams are replanted almost immediately in the holes left by the first crop. Thereafter fewer restrictions would apply and more introduced species planted. A third yam crop is sometimes planted following the second harvest, but this is a less common practice, because it involves a greater effort in weeding. After the last planting has been harvested the garden is allowed to return to fallow. But even in the fallow period the land continues to produce food crops such as bananas, Xanthosoma and sugarcane which can compete with the invading tall cane grasses for

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FIGURE 1 ABOUT HERE

The general arrangement of the system is shown in Figure 1. Garden Site A is the newly cleared garden, B the replanted garden and C the less common third planting. After the garden site is allowed back into fallow it is rapidly invaded by weeds and short grasses dominated by Imperata. Within a year the short grasses will be shaded out by the tall cane grasses dominated by Saccharum robustum. This is an important succession providing cool, damp, dark conditions for tree seedlings, particularly during the drier part of the year. After about 12 years tree successions begin to shade out the cane grasses and 25 years after clearing, a 10-15 m tree succession becomes established. The pattern of species succession in fallow regrowth is given in Figures 2 and 3. New gardens are cleared in from 15 to 25 year-old fallows, with land nearer the village being cultivated more often than land farther away. Fallow successions are categorised by type, not by time: fallows ready for re-cultivation are known as "ripe" fallows. Farmers avoid letting fallows go beyond the "mature" stage, because of the dangers involved in felling tall forest.

FIGURES 2 AND 3 ABOUT HERE

Yam gardens are established along the upper slopes of ridges. Many coffee gardens are also found in these locations, as a result of the extension advice to farmers to plant the introduced crop on their "best land".

A particularly interesting aspect of the system is the use of Pometia pinnata leaves during yam planting. The Pometia is a large handsome tree, related to the litchi, with similar fruit. The fruits are borne on the ends of the branches between November and February. Harvesting is accomplished by climbing and lopping off fruit bearing branches. Later, during yam planting, the then dry leaves are collected by women, carried to the gardens in large bundles and applied into the ground with the "seed" yams. Gardeners believe that the leaves "give the tubers room to grow", but the leaves, rich in nitrogen, provide a good mulch in addition to their nutrient value. The regular cutting back of the trees appears to have an effect similar to pruning and stimulates fruiting. Figure 4 illustrates the method used to carry Pometia leaves, and Figure 5 shows bundles of leaves in

FIGURES 4 AND 5 ABOUT HERE

4. SYSTEM FUNCTIONING

Almost all inputs into the systems come from within the village community. Land is occupied under laws which guarantee rights to customary owners and access to land is controlled by the leaders of extended families. Inheritance of land rights is normally from father to son, but daughters, particularly widows have no difficulty in obtaining land for food crops. Many food gardens are cultivated on a usufructory basis and land which is not being cultivated is open to all village residents for collecting fuelwood and building materials or for hunting. Land for coffee is more restricted, and some families have coffee gardens at a distance from the village. However most people build substantial "garden" house in which they stay while they work in gardens or coffee blocks away from the main village.

Most families clear land for gardens in co-operation with up to 15 other families. Once the heavy tasks of clearing and burning are completed, each family becomes responsible for its own individual block. Coffee blocks are established in a similar way. A very small amount of paid labour is employed in coffee gardens, usually small bands of youths or unmarried girls, raising money for such social activities as a sports club or a youth club. During the introduction of coffee, government nurseries were established, but now people raise coffee seedlings themselves from established trees.

Productivity measurement in mixed gardens of this nature is very difficult. Yields of individual species are highly variable within and between sites. Harvesting of some species occurs within a restricted time, while others are harvested continuously over the life of the garden. Yield estimates of the most important crop, <u>Dioscorea</u>, ranges from 10 to 20 t ha^{-1} for <u>D. esculenta</u> and 16 t ha^{-1} for <u>D. alata</u>. When rice was grown yields ranged from 0.45 to 2.8 t ha^{-1} and coffee yields are around 250 g per tree of dried parchment, or about 115 to 120 t ha^{-1} The average price of dry parchment at the farm gate" for 1982 was 0.55 kina per kg (1 kina=1.2 US$), thus coffee provided the average family with a cash income of around US$60 in 1982.

Production of the yam staple is markedly seasonal, but other crops such as sugarcane, taro and bananas are less seasonal. Coffee production occurs mainly between May and September (Figure 1). Variability from year to year is low and is dependent on rainfall as well as social demands. Production is increased to meet the requirements of large ceremonies, with planning occurring some years ahead to build up planting materials and to select sites which are known to produce good yam harvests.

All coffee production is for sale for cash and marketing is done through a regional cooperative society, which is involved solely in coffee marketing. Small amounts of food are sold in a bi-weekly periodic market on a nearby government station, where the main buyers are government employees.

An important feature of the system is that ground cover is maintained almost permanently, except for a short period between clearing and the development of the crops. Even during clearing and planting, the surface is disturbed as little as possible. Large trees are not felled, but are pollarded and the bases burned to prevent regrowth. Smaller trees, in particular some of the Ficus genera, do regrow and help speed the recovery of a tree cover. Branches from the taller trees are cut up and stacked for fuelwood and only the leaves are burned.

The proportion as well as the spatial arrangement of cleared land in relation to land in regrowth/secondary forest is such that broad scale erosion does not occur. Poles are laid along the contour, supported by pegs, to reduce surface run-off and yams are planted in individual holes upslope from the barrier. Other crops are spaced amongst the yams, also across the slope. However, much backward rotational slumping occurs in the area and many gardens are deliberately sited on slumps to take advantage of the recent soils found there. Thus small slumps within gardens are not uncommon. On the other hand, some gardens are sited on slopes over 30 degrees and little soil movement occurs.

Men and women share the labour of food and cash crop production relatively equally. Men carry out the heavier tasks of clearing while women sweep and arrange slash material for burning. Customarily women may not cultivate the soil with digging sticks or spades in the first yam garden, so men plant most of the yam crop, taro, sugarcane and bananas. Women plant restricted varieties of yams in piles of ash above the ground surface, and greens. Women do most of the weeding, while men attend to the other aspects of crop management such as tying up vines and covering exposed tubers with soil. The first yam crop is harvested by men and after that restrictions on women to harvest the crop are somewhat relaxed. Both sexes pick, process and sell coffee. Children also help with garden work. The major bottleneck in coffee production is the processing of the cherry to parchment.

5. SYSTEM DYNAMICS

The food production system is a very old one. Recent changes, in particular the introduction of malaria control programmes and modern medicines, have contributed to a decline in infant mortality, and that, coupled with a relaxation of customary restrictions on sexual activities, have resulted in an increase in population. Emigration has helped reduce the rate of increase in resident populations, but in areas with greater seasonality and population pressure, the system is degrading from forest fallows to cane grass fallows. The introduction of steel tools and implements has reduced the amount of labour required and allowed larger trees to be cleared.

The coffee production system is only 30 years old. It involves a tree cover and maintains sustained production without outside inputs such as fertilisers. However, most blocks are under-exploited, probably because of lack of incentives for higher production and the high labour costs of processing. Investigations are underway into the possibilities of producing either wet cherry, or dried cherry to encourage greater production. Meanwhile most people produce at a level which just satisfies their day-to-day cash requirements for imported food stuffs, local taxes and school fees.

6. EVALUATION

The system provides almost all the food and immediate cash requirements of the household and involves practically no external inputs. However, it is vulnerable to any changes which bring about a shortening of the fallow period to the point where a grass fallow replaces a tree fallow. Robusta coffee, a new tree crop in the locality, has been very quickly and successfully adapted to the system. But there is, at present, a serious gap in the knowledge on the requirements of the individual crops, relationships between the fallow vegetation communities, and soil conditions so that sound advice cannot be given on methods of avoiding degradation of the tree cover in areas where the fallow period is being shortened, and on other aspects of management of the system. The PNG shifting cultivators have a deep knowledge of the fallow succession characteristics, and they are willing to accept innovations if enough incentives and motivations are provided.

This strength of the farmer is a major aspect which should be built upon in any attempt to improve the system.

Similar systems exist in many parts of lowland and mid-altitude PNG, and results and experience of one system could, within limits, be extrapolated to others. Critical site factors influencing the stability of the system are rainfall and, to some extent, altitude, which determine the rate of growth of successional tree species and thus the vulnerability of the systems to degradation.

It is essential that research is undertaken urgently with a view to providing appropriate guidance to improve the system and enable the farmers to attain optimal productivity on a sustained basis. Some studies that have been carried out in the mid-altitude localities of the country (9, 3) are of significance in this context. Similarly, in the immediate area of the system described here, land evaluation studies have been undertaken by CSIRO of Australia (6, 8). Some other studies on a country-wide basis are also underway (10). Areas on which research needs to be intensified on a priority basis include:

- pattern and dynamics of grass and tree succession following cultivation;
- conditions which each succession provides for the development of the following succession;
- relationship between the succession communities and soil fertility;
- effect of intervention in natural succession (through shortening of fallow cycles, introduction of new species, and so on) on the sustainability of the system;

- agronomic requirements of individual crops for optimal production in the system.

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LIST OF FIGURES

Table 1. <u>CULTIVATED AND NON-CULTIVATED FOOD CROPS IN THE MIXED CROP GARDENS</u>

FAMILY	BOTANICAL NAME	
Acanthaceae	*Graptophyllum pictim*	
Amaranthaceae	*Amaranthus hybridus*	
	Amaranthus tricolor	
	Deeringia polysperma	
Anacardiaceae	*Mangifera indica* #	
Araceae	*Alocasia sp.* #	
	Cococasia esculenta	(11 cultivars)
	*Xanthosoma saggitifolia**	
Bromeliaceae	*Ananas comosus**	(2 cvs)
Bursuraceae	*Cannarium sp.*	
Caricaceae	*Carica papaya**	
Convulvulaceae	*Ipomea batatas**	
Cruciferae	*Brassica chinensis**	
	Nastertium homalospermum	(2 cvs)
Cucurbitaceae	*Citrullus vulgaris**	
	Cucumis sativus	
	*Cucurbita moschata**	
	Lagenaria sp.	
	Trichosanthes anguina	
Dioscoreaceae	*Dioscorea alata*	(22 cvs)
	D. bulbifera	
	D. esculenta	(43 cvs)
Euphorbiae	*Manihot esculenta**	
Gnetaceae	*Gnetum gnemon*	(2 cvs)
Gramineae	*Saccharum edule*	(14 cvs)
	Saccharum officianale	(9 cvs)
	*Zea mays**	
Leguminosae	*Arachis hypogeae**	
	*Phaseolus vulgaris**	
	Psophocarpus tetragonolobus	(2 cvs)
Liliceae	*Allium odorum**	
Malvaceae	*Abelmoschus manihot*	
	Abelmoschus moschatus	(2 cvs)

Moraceae	*Artocarpus altilis* *Ficus copiosa*	(3 cvs)
Musaceae	*Musa spp*	(26 cvs)
Myrtaceae	*Eugenia malaccensis**	
Oxalicaceae	*Averrhoa carambola**	
Palmeae	*Areca catechu** *Cocos nucifera* *Metroxylon sagu*	(2 cvs) (2 cvs)
Piperaceae	*Piper nigrum*	
Rutaceae	*Citrus sinensis**	
Sapindaceae	*Pometia pinnata*	(2 cvs)
Solanaceae	*Capsicum frutescens** *Lycopersicum esculentum**	

* Introduced since c1900 #Cultivated outside of gardens

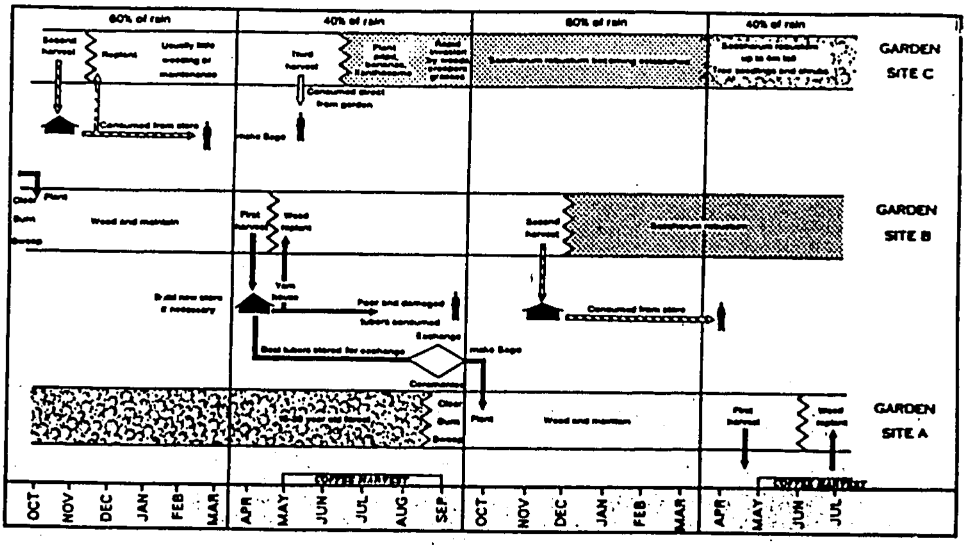

Figure 1: The sequence of garden site clearing, planting and harvesting, and natural regrowth.

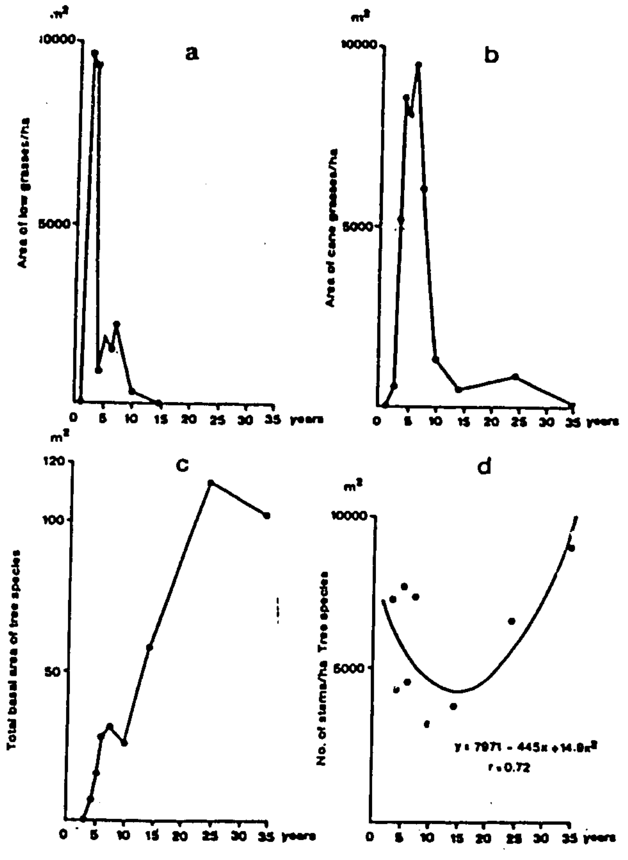

Figure 2: The pattern of regrowth of fallow garden sites: (a) area of low grasses (mainly Imperata) per ha; (b) area of cane grasses (mainly Saccharum) per ha; (c) total basal area of tree species per ha; (d) number of stems of tree species per ha. The horizontal axis in each figure represents the number of years since clearing.

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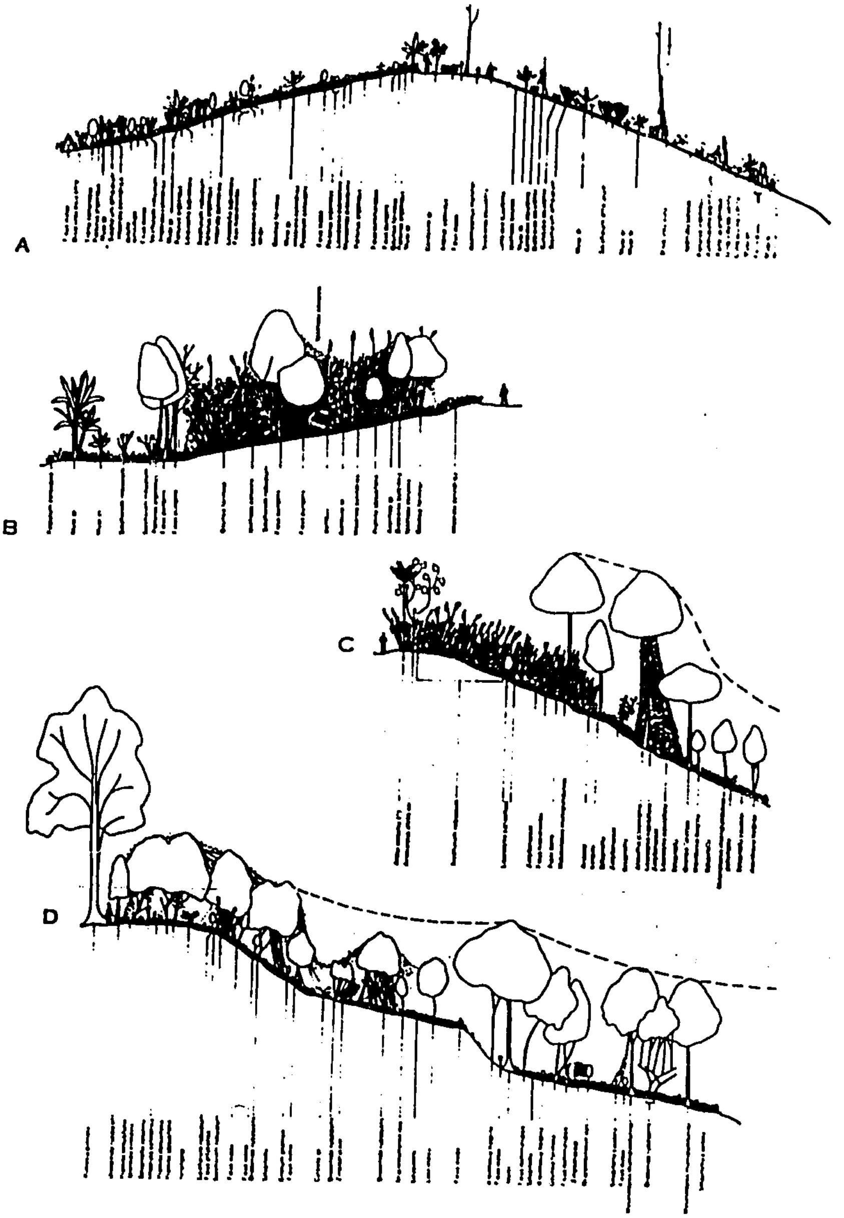

Figure 3: Cross-sectional transects through fallows of different ages: (a) 1 year after clearing and planting - the righthand slope has been weeded and replanted for a third time, the left has been allowed to go back into fallow; (b) a 5 year old fallow - tall cane grass and fast growing softwood tree species dominate, but some food crops still remain; (c) 10 year old fallow - on the lower, moister slope tree species have shaded out the cane grass, which remain dominant on the upper slope; (d) 25 year old fallow - all cane grass has now been shaded out and the first tree species are being succeeded by slower growing trees. The large Pommetia has been planted during some previous cultivation. This side is ready for re-cultivation.

Figure 4: Large bundles of dry Pommetia leaves are collected together and carried to the new yam gardens by woman, to be used by their husbands in planting the yam crop. Bundles commonly weight over 40 kg.

Figure 5: A newly cleared yam garden during planting. Seed tubers have been laid out near holes prepared for them and bundles of Pommetia are ready for use. The trees which previously covered the site have been pollarded and killed by burning, but are not felled. The surface of the garden has been swept of ash and debris but otherwise is undisturbed.