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PROGRESS REPORT NO. 8

July-September, 1984

USAID/ICRAF COOPERATIVE AGREEMENT

NO. DAN-5545-A-00-2075-00

PROJECT NO. 936-5545

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1. INTRODUCTORY NOTES

This is the 8th report of the USAID/ICRAF Cooperative Agreement. Project No. 936-5545, for the period July-September, 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 a Methodology Development, and
- Agroforestr Inventory

Progress reports for the three projects for the period, prepared by the respective project leaders, are attached. The third ICRAF/USAID Agroforestry Course was held this quarter in Malaysia and preparations are underway for the 4th Course to be held in Peru in June, 1985. In the D&D project, work continued on the development of the methodology at the Kenyan activity sites as well as at a site in the Himalayas of India, and new materials were written to assist in disseminating the methodology. The data evaluation phase of the Systems Inventory Project commenced in earnest during this quarter and computer coding is now in progress.

The financial statement for the period is included, following the individual progress reports.

2. AGROFORESTRY TRAINING (E. Zulberti)

The main activities of the July-September period focused on the organization and programme coordination of the Third ICRAF/USAID Agroforestry Course held in Sedang, Selangor, Malaysia from 1 to 19 October 1984. Hosted by the University Pertanian Malaysia (UPM), the course was jointly organised by the Forestry Faculty at UPM and ICRAF.

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

Follow-up activities continued during this quarter with the aim of gathering feedback information on the extent to which the agroforestry knowledge/methods presented during the November course are being put into use by participants. To that effect, a follow-up questionnaire was designed (see previous quarterly report) and mailed to participants on April '84. So far, twelve questionnaires (out of twenty two participants) have been completed and returned to ICRAF. A final report on the follow-up actions is to be prepared in late 1984-early 1985.

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

A course Report is under final editing. The report contains a description of the programme of activities followed during the three week course, the list of participants and their addresses, results of the evaluation procedures and a list of the training materials used. Follow-up activities were initiated in August '84 with a communication sent by the ICRAF Training Unit to all course participants (see Annex 1).

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

An in-house seminar was held at ICRAF on 11 September to review the general planning and organizational details of the Malaysia course programme. At this time, E. Zulberti briefed the senior

ICRAF staff present on the multidisciplinary country teams nominated by national institutions in Thailand, Indonesia, Malaysia, Philippines and India to attend the course (see Annex 2). The procedures for course announcement and selection of sponsored participants were explained in the previous quarterly report (see page 5). Out of the twenty-two participants expected to attend this event, three positions were requested by USAID to nominate candidates from the ASEAN region.

The course programme of activities remained largely as discussed by E. Zulberti and Dr. Kamis Awang from UPM in Malaysia last May '84 (see Annex 3). Training materials were prepared by ICRAF in Nairobi and sent to UPM on 19 September via DHL.

2.4. Fourth ICRAF/USAID Agroforestry Course, Peru, June 1985

Programme coordination activities are making steady progress towards the organization of the fourth agroforestry course under the ICRAF/USAID agreement for June '85. The course will take place in Yurimaguas, Peru. It will be jointly organized by a collaborating institution - INIPA (Instituto Nacional de Investicacion y Promocion Agropecuaria) - and ICRAF. Multidisciplinary country teams have already been invited to nominate candidates, mainly from the Amazon region (Bolivia, Brazil, Peru, Colombia, Venezuela and Ecuador) (see Annex 4). Regional institutions expected to participate are REDINAA (Red de Investigacion Agro-ecologica para la Amazonia), IICA (Instituto Interamericano de Cooperacion Agricola), CIAT (Centro de Investigaciones en Agricultura Tropical), CATIE (Centro Agronomico Tropical de Investigacion y Ensenanza). The Programme Coordinator of the ICRAF Collaborative and Special Projects Programme (COSPRO) - Dr. Filemon Torres - is to undertake a mission to Latin America to start discussions with national institutions potentially interested in becoming involved in the regional REDINAA network. The Land Use Systems approach is the conceptual framework under which the Peruvian course programme in agroforestry research will be developed. Dr. E. Zulberti will follow this up when she undertakes a mission to Peru in early '85 to coordinate technical as well as administrative aspects of the programme. Issues to be

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discussed are: the preparation of country reports on land-use systems in the Amazon region to be presented by course participants and discussed by the course group as a whole; the definition of expected inputs from national/regional organizations in the course programme (presentations, practical exercises, lectures, etc.); the translation of training materials into Spanish (IICA's support will be sought); the accommodation facilities at Yurimaguas (INIPA is constructing a training centre); exploration of different mobilization alternatives within the project site area, specially for the field exercises; and others.

2.5. Major Activities Planned for the Next Quarter

- Coordination of the Third ICRAF/USAID Agroforestry Course in Malaysia, 1-19 October 1985;
- Printing and distribution of Second ICRAF/USAID Agroforestry Course Report;
- Preparation of Third ICRAF/USAID Agroforestry Course Report;
- Follow-up activities/communications with participants of first, second and third courses.

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

3.1. Dissemination of the Methodology

In preparation for the external review, a compilation was made of countries and types of institutions/individuals from which requests for the D&D draft manuals have been recieved (see Annex 5).

Case study No. 4 in the series on Case Studies in Agroforestry Diagnosis and Design was printed and published as ICRAF Working Paper No. 11: D. Rocheleau and A. van den Hoek, "The Application of Ecosystems and Landscape Analysis in Agroforestry Diagnosis and Design: A Case Study from Kathama Sublocation, Machakos District, Kenya" (see Annex 6).

A brief introductory paper on D&D, emphasizing its role in the

design of AF systems, was written for a workshop in India: J.B. Raintree, "Designing Agroforestry Systems for Rural Development: ICRAF's D&D Approach" (see Annex 7).

Two training modules were prepared for the 3rd Agroforestry for Rural Development Course, on aspects of D&D: D. Rocheleau "Application of the D&D Methodology at varying Scales of Analysis" and J.B. Raintree, "Human Factors in Agroforestry" (see Annexes 8 and 9).

As part of the programme of the GERDAT sponsored "Agroforestry Days" meeting at Montpellier, September 13-14, an overview of the D&D methodology was presented by D. Depommier for discussoin and comparision with related French methodologies. Similarities in the logic of the procedures were noted, along with differences in the detail and length of time of the respective types of analysis.

3.2. Further development of the methodology

Work continued in the Kenyan activity sites, adding to the overall experience with D&D applications at different scales of analysis and with community organizational aspects. As a result of ICRAF teamwork in the COSPRO D&D exercise at the Bhaintan watershed in the outer Himalaya of India, more detailed methods for treatment of technology design and research considerations within the D&D framework have been developed. These are described in P.A. Huxley and P.J. Wood, "Technology and Research Considerations in ICRAF's Diagnosis and Design Procedures," ICRAF Working Paper No. 26. (see Annex 10). These and other additions and amendments will be reviewed and synthesized for inclusion in the revised manuals next year.

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

4.1. Data Collection

- More reports were received from the Regional Coordinator for American Tropics (CATIE - Dr. Budowski).
- More reports and system descriptions from the RC for South Asia (Dr. Tejwani).

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- P.K. Nair undertook travels in the Pacific Region and organized data collection from the Region (see Section 4.5).

4.2. Data Evaluation

Mr. S.P. Carruthers, a colleague of Dr. C.R.W. Spedding (AFSI data evaluator) visited ICRAF from 26th June to 8th July 1984 for discussions and consultations with ICRAF staff on various aspects of Systems Inventory data evaluation.

The returns from the various co-ordinators were examined jointly with ICRAF staff and the following important points emerged:

- The data sheets provided by the co-ordinators varied considerably in the number of systems identified and the quantity and quality of data for each system described.
- As a result of the above, more time and effort than originally anticipated would be required to convert the raw data sheets to a manageable format before the evaluation, computerization and classification phases can be embarked on.

In the light of the above, as well as experience of abstracting some co-ordinator data sheets, it became abvious that the originally structured data format (Quarterly Report March-June 1984) was too ambitious and needed refining. An example of the refined secondary data format filled in for the "Chagga Homegarden System" is appended to this report (Annex 11). Abstraction of all co-ordinator returns according to this format is now in progress at ICRAF and the University of Reading. These abstracted data sheets are being stored on an IBM-PC microcomputer.

4.3. Data Base

In addition to the systems data base mentioned above, another computerized data base is presently operational. It contains data obtained by literature reviews and systems inventory descriptions on "Multipurpose woody species with agroforestry potential" for about ninety different species. It allows rapid identification of promising

species for environmental and/or use criteria. This data base is presently answering an average of two enquiries per week.

4.4. Systems Description Series

Most of the system descriptions listed in the previous quarterly reports are now in the galley proof stage for the AFS journal. They will start appearing in print from the October 1984 issue of the journal. A few other system descriptions have also been received and they are being processed.

4.5. Collaboration with the East-West Centre, Honolulu and the United Nations University, Tokyo for AF Systems Inventory in the Pacific Region

During the period under report, P.K. Nair was based at the Environment and Policy Institute, East-West Centre, Honolulu, Hawaii as a Fellow (Professor), where one of this assignments was to organize the inventory of AF Systems in the Pacific region. He undertook travels to Papua New Guinea and Solomon Islands, and studied the promising and prominent systems in those countries, which include the Casuarina + coffee + food crops system in the highlands of PNG and cattle grazing under coconuts and forestry plantations in the Solomons.

The East-West Centre has just initiated a project with support from the United Nations University to impart training in AF to officials from the countries of the Region, and to undertake a detailed inventory of AF systems in the Region as a part of this training programme. This inventory will be done according to ICRAF's AFSI format and in close liaison with ICRAF. It will supplement the general reconnaissance of systems in the Region that has been prepared by the project. Dr. Nair's presence at the East-West during the formative stages of the project was helpful not only in finalizing the plan of action, but also in clearing doubts and offering clarifications to the United Nations University to enable it to take a final positive decision on the matter.

4.6. Other ouputs

- P.K. Nair prepared a working paper "Fruit Trees in Agroforestry" while at the East-West Centre, in which some of the results of AFSI have been included. The paper will soon be published by the EWC.
- P.K. Nair gave a seminar "Agroforestry: Existing Systems and Experimental Approaches" at the East-West Centre, Honolulu on 5 September 1984. It was well-attended by staff and students of faculties of the University of Hawaii, staff of EWC institutions, Hawaii State Government's forestry officials and several other AF enthusiasts.
- Erick Fernandes along with John Raintree contributed to an in-country training course organized by the International Maize and Wheat Improvement Centre (CIMMYT) at Kakamega, Western Kenya, from 28th May to June 9th. In addition, the International Livestock Centre for Africa (ILCA) also collaborated in the course dealing with the diagnostic aspects of On-Farm Research.
- Erick Fernandes participated at the invitation of CIMMYT in a regional workshop dealing with On-Farm experimental aspects, held at the University of Zimbabwe, Harare from the 3rd to 14th September and attended by participants from Burundi, Ethiopia, Kenya' Lesotho, Malawi, Sudan, Swaziland, Tanzania, Uganda and Zimbabwe. He presented a paper on "Special considerations in the planning, implementation and evaluation of on-farm experimentation in agroforestry farming systems".

4.7. Major Items of Work Planned for Next Quarter

- Continuation of data evaluation
- Continual up-dating of data bases
- Publication of more system descriptions in the AFS journal.

PROJECT FINANCIAL IMPLEMENTATION REPORT

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

PROJECT: 936-5545
COOPERATIVE AGREEMENT NO. DAN 5545-A-00-2076-00
AS OF SEPTEMBER 30, 1984

APPROVED BUDGET LINE ITEM	AMOUNT	BUDGETED	DISBURSEMENTS (US$)			
	1	2	3	4	5	6
	US$	KSHS	Prior Cumulative US$	This Period US$	Cumulative Thro' US$	Estimate Next 90 days US$
1. Salaries	444,525	-	368,905	22,525	391,430	12,350
2. Consultants	104,000	-	95,313	-	95,313	3,000
3. Travel and Transportation	103,500	-	48,385	6,332	54,717	10,000
4. Equipment, materials & supplies	107,240	-	71,169	18,903	90,072	11,000
5. Participant training	63,400	-	56,030	-	56,030	7,370
6. Overhead	162,335	-	127,056	9,551	136,607	8,745
7. Evaluation	15,000	-	12,568	-	12,568	-
Total	1,000,000	-	779,426	57,311	836,737	52,465

Estimated disbursements thru (columns 5 & 6) December 31, 1984	US$889,202
Less cash advances received thru/disbursements to 30/9/84	US$820,526
Cash advance/requested	US$ 68,676

I certify that records and supporting payment documents (eg. 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: Gatamah

Name: Karugor Gatamah
Title: Secretary/Treasurer
Date: October 10, 1984

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

PUBLIC VOUCHER FOR PURCHASES AND SERVICES OTHER THAN PERSONAL

VOUCHER NO.

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

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

DATE VOUCHER PREPARED: 10th October, 1984

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

REQUISITION NUMBER AND DATE: September 14, 1982 and amend No. 1 dd January 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 October to 31st December, 1984 (see attached signed project implementation report).				US$68,676

(Use continuation sheet(s) if necessary) **(Payee must NOT use the space below)** TOTAL US$68,676

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

APPROVED FOR = $

EXCHANGE RATE = $1.00

DIFFERENCES

BY [3]

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)

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ANNEX 3

CASE STUDIES IN AGROFORESTRY DIAGNOSIS AND DESIGN NO. 4

WORKING PAPER

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THE APPLICATION OF ECOSYSTEMS AND LANDSCAPE ANALYSIS IN AGROFORESTRY DIAGNOSIS AND DESIGN: A CASE STUDY FROM KATHAMA SUB-LOCATION, MACHAKOS DISTRICT, KENYA

BY

Dianne Rocheleau and

Annet van den Hoek

1984

INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY

MARCH, 1984

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F O R E W O R D

This fourth case in the ICRAF series on Case Studies in Agroforestry Diagnosis and Design is the result of one phase of a series of collaborative activites undertaken by ICRAF and Wageningen Agricultural University of the Netherlands at the Kathama field research site in Machakos District, Kenya. This collaboration, which was instrumental in the early development and testing of the D&D methodology, began in 1980 with the work of two Wageningen sutdents, Hans Gielen who conducted a survey of the role of trees in local farming systems and Els Fliervoet who made a botanical inventory of local trees and shrubs and their uses. These studies were jointly supervised by Cor Veer of the Department of Forest Management at Wageningen and Peter Huxley of ICRAF.

The next phase in the collaboration, which began in 1981, consisted of a two year study involving an application of the evolving D&D methodology by Remko Vonk, an M.Sc. student at Wageningen who was resident at the Kathama site for the duration of the study. Jointly supervised by J.B. Raintree of ICRAF and Cor Veer of Wageningen, the study began with a rapid appraisal diagnostic survey to identify potential roles for specific agroforestry interventions in removing farm-level production constraints which prevented the local farming systems from achieving their full potential in terms of the farmers' objectives. Following the design exercise based on the findings of the diagnostic survey, farm trials of promising experimental agroforestry systems and component technologies were initiated.

Concurrently with the on-farm trials of the initial prototype agroforestry designs, a third phase of the collaboration was initiated with the objective of refining the initial rapid appraisal diagnosis by giving greater quantitative specification to critical problems and by making a more detailed assessment of potentials for general land use improvements. Beginning in 1982 four additional Wageningen graduate students were phased into the Kathama site research activities to conduct "special studies", each of six months duration, under the general supervision of J.B. Raintree with technical supervisory inputs from other ICRAF staff members (P. von Carlowitz on forestry aspects, A. Young on soils and land evaluation, P. Huxley and P.K.R. Nair, on agronomic aspects, and D. Rocheleau on landscape analysis and watershed management) Academic supervision of the students' work from the Wageningen side was undertaken by Cor Veer (Dept. of Forest Management), Jan Boerboom (Dept. of Tropical Silviculture), Gerard de Bruijn (Dept. of Tropical Crop Science), Ingrid Duchhart (Dept. of Landscape planning) and J. B. Jansson, (Dept. of Plant Nutrition).

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At the conclusion of this third phase of collaboration in late 1983, a total of eight interrelated studies had been completed by the Wageningen Students on the following topics: Role of Trees in Local Farming Systems (Hans Gielen), Botanical Survey of Local Trees and Shrubs (Els Flier voet), Farm Level D&D Results and On-farm Trials (Remko Vonk), Evaluation of Tree Species Trials (Remko Vonk), Preliminary Mulch Farming Experiment (Remko Vonk), Potential Role of Local Voluntary Organizations in Group Agroforestry Activities (Jessica van Wijngaarden), Nutrient Balance in the Predominant Local Cropping system (Odile Nyssen), Measurements of Stickwood Increment in the Grazing Lands (Eduard Boer) and Watershed Scale Diagnosis and Landscape Design Study (Annet van den Hoek). Results of these studies exist in various stages of documentation at present and will be made available through various ICRAF publications in due course.

The work at the Kathama research site is being continued through the activities of ICRAF staff members. Methodological guidelines on the monitoring of on-farm agroforestry trials are currently being developed and tested at Kathama, now that the experimental technologies are becoming functional. Another major focus of current methodology development work is the elaboration of D&D procedures for larger-than-farm and intra-household diagnosis and design. The present case study, which builds on work undertaken with one of the students, is the first of several planned publications on techniques of variable scale Diagnosis and Design.

J. B. Raintree
Case Studies Series Editor

INTRODUCTION

What has Landscape got to do with Agroforestry?

Landscape is the visible expression of the interaction of land and people and their cumulative mutual influence. It is a kind of signature in spatial terms but is not static. Landscape often reflects the influence of the past, whether of a long association between one people and the land, or of a series of different inhabitants each in turn leaving their mark, as described by Sauer (1941). The present landscape can also provide us with a point of departure for improvement of existing land use systems or for design of entirely new systems. Landscape is the drawing-board for integrated agroforestry diagnosis and design beyond the single plot or the individual farm.

The science of agroforestry, like that of ornamental horticulture, hinges on the combined manipulation of the geometry of landscape and the spatial relations among diverse plant components and between plants and their environment. While ornamental horticulture focuses on an aesthetic product, agroforestry exploits the logic of spatial relationships and ecological and economic interactions to provide subsistence and/or commercial benefits for people. One emerging field of agroforestry (AF) science and practice is the incorporation of AF Systems into the design of sustainable landscapes to serve rural people (Hoek, 1983). This involves a fusion of agroforestry technical skills, landscape analysis and design, ecosystem analysis and planning, and social analysis and organizational skills. Such an approach can serve a wide range of research and development interests including farming systems, watershed management, social forestry, agroforestry systems, and soil and water conservation programs.

The general perspective is not new, and is partially developed in the works of geographers (Sauer, 1941; Moss, 1981, Brookfield, 1983 landscape architects (McHarg, 1969; Duchhart & Heetman, 1979) anthropologists (Geertz, 1972; Brokensha et. al 1983), ecologists (Odum and Odum, 1976), agroecologists (Hart, 1980, 1982), and agroforesters (Lundgren, 1982; Budowski, 1982; Raintree, 1983). Several disciplines can provide theoretical and practical background for such an approach to agroforestry. The geographer sees regions, component landscapes and functional relationships in place between land and people (Harvey, 1969). The landscape architect sees pattern, visual form, physical and symbolic stability, comfort, compatibility of form and function; objects of study include roads and drainage networks, buildings, topography, boundaries, meeting places and vegetation of all kinds, whether in a region, town, neighbourhood or village. Anthropologists and social ecologists see decision makers (individuals, households, communities, polities) affecting the land and being affected by it, shaping cultural landscapes and distinct human ecosystems (Harris 1966). Systems ecologists see interactions of organisms with their environments in terms of material cycles and flows of energy in nested hierarchies of systems (Odum, 1982). Common to all of these disciplines is the study of the human use of the land over a sliding scale of observation, although each focuses on different processes and objects of interest through their telescopic lens.

Agroforesters are no exception. We see trees, crops and livestock combined in space and time and managed by people to produce cash or subsistence. The level of resolution (e.g. the scale at which we can focus clearly on those combinations)

is not limited to farmstead or plot (Huxley, 1982) Interaction between components may require studies of micro-biology, while feasibility analysis of a new AF system for rural development may require community or regional level studies. It is the larger-than-farm community or village scale which is of concern in this case since this is the level at which analysis and design of landscape can be of greatest use and in which the greatest gap exists between separate farm forestry, social forestry and conservation approaches. Much of the research and development work in agroforestry systems has focused on farm or forest plots, and more recently on farming systems. However, the agroforestry diagnosis and design (D&D) methodology developed at ICRAF for farm level application is readily expanded to accomodate communities, watersheds and administrative units.

Why the need for a special approach?

There are several practical reasons to design for larger-than-farm units. Rural development programs need to reach a wider group than a particular farming system (Weber and Hoskins, 1984); they may need to include landless people, town dwellers and part-time farmers. The latter three groups are often dependent on public lands, and /or on other people's land for subsistence or cash income.

Technology alone will not fuel the rural development process (Woods, 1983) and it is critical to consider the distribution of benefits both between households (Berry, 1983; Chambers, 1983;) and within households (Hoskins, 1983; Fortmann and Rocheleau, 1984; Jones 1984; Peters 1984). This requires the mental ability to jump fences, while acknowledging their existence, and it requires technology designs that help to

open doors (but not kick them down) for those with limited access to land, water and other factors of production beyond their own labor

Land tenure, tree tenure, water rights, and use rights of all three are critical considerations (Fortmann, 1983; Riddell, 1983). Simple public-land solutions are often not viable (Foley and Bernard, 1983) and do not guarantee fair distribution of costs and benefits whether between communities (Noronha, 1982) between households (Mahiti Team, 1983) or within households (Sharma, 1981; Joshi, 1982). The incorporation of women in AF is one example where landscape units can provide a practical focus for defining opportunities for improved production. By classifying landscape niches on or off-farm that are accessible to, and/or controlled by women we can arrive at more realistic designs to serve them (especially for production of fuelwood and other products now gathered as free goods). Landscape often reflects division of ownership, control and decision-making, and is an expression of existing opportunities for AF interventions. As such landscape analysis with ecological and social inputs can provide the framework for combined farm and community-level designs.

Another issue in agroforestry is the role of traditional and semi-traditional associations that own and/or manage land as groups. Their land management and agricultural production activities are often integrated into a single group management unit. However, in many places such associations are based on reciprocal exchange of commodities, services and rights to land-based resources among separate households (Dove, 1983). Traditional and more formalized women's mutual aid groups are substantial forces contributing to rural development and natural resource management (March and Taqqu, 1982). Throughout africa, Asia and Latin America, there are examples of women's self-help associations participating in soil conservation (Wiff, 1977), crop production (Barnes, 1980), forest protection (Bhatt, 1980) afforestation(Hoskins, 1982, 1983) and fuelwood management (Wijngaarden, 1983). Farmer's associations

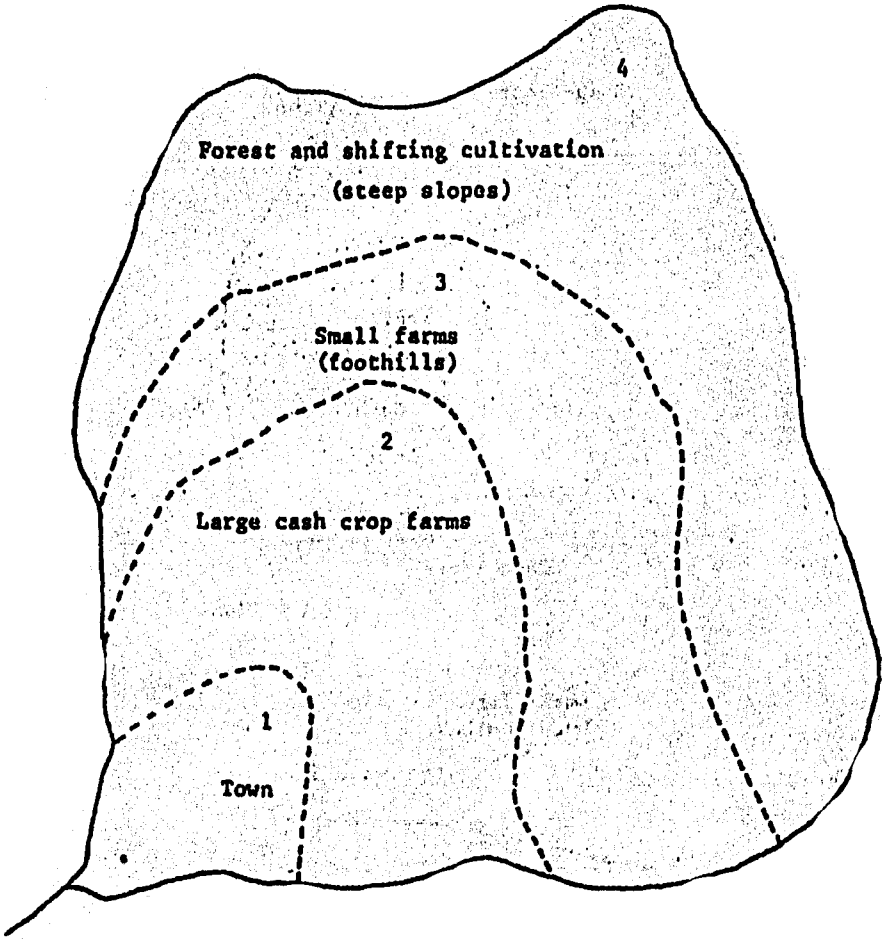
and mixed men's and women's self-help and cooperative groups are similarly widespread (Sawadogo, 1983). Where these groups exist it is important to consider the whole group(s) and their combined control and use of resources.(Fortmann, 1983).

Even where groups do not exist there is often a need to deal with the "hollow middle" (Roe and Fortmann, 1982), that scale of natural resource management that falls outside both the individual farm, and political jurisdiction (government services), yet impinges on both. This applies to a wide range of natural resources and services critical to farm families and rural populations in general. Physical infrastracture that could affect agroforestry potentials in rural areas includes: roads; paths; boundaries; drains; irrigation works; soil conservation works; water supply, storage and distribution facilities. These infrastructural components of landscape can provide sites (land) or services (water, drainage, protection) for AF interventions and AF in turn can help to stabilize and define the infrastructural network while providing subsistence or commercial products for residents. Both in cases of larger-than-farm infrastructural networks and off-farm shared source areas for fuel, fodder, etc., tenure and rights of usufruct are key factors to be considered in AF design. Natural resources from off-farm sources often include such indispensible items as water, fuelwood, timber, fodder, medicinal herbs, raw materials for crafts and other products of forest, rangeland, fallow and boundary lands (Hoskins, 1983) many of which are managed by women or may be informally managed by groups (Muzaale, 1982).

Irregardless of the type of management unit, often there are both biophysically and socially determined opportunities in specialization already exhibited in the landscape. Farm level studies focus on self sufficiency for subsistence, or trade with large commercial centres. However, rural people often have

developed integrated trade (in cash or in kind) for specialized products and services between farms, between areas or between distinct groups. Two examples of land use stratification are given in Figures 1 and 2. .The functional links between land use systems may present constraints or opportunities. A landscape level design could help to reinforce existing exchanges of grazing rights for plowing services, or fuelwood gathering rights for food crops, between people who control land resources of very different production capabilites. Designs at larger-than-farm scale can also help to project community capacity for improved production with a more optimal use of the diverse natural resource base, if there is enough social cohesion to support fair and sustained local trade or if there are secure enough markets for commercial specialization.

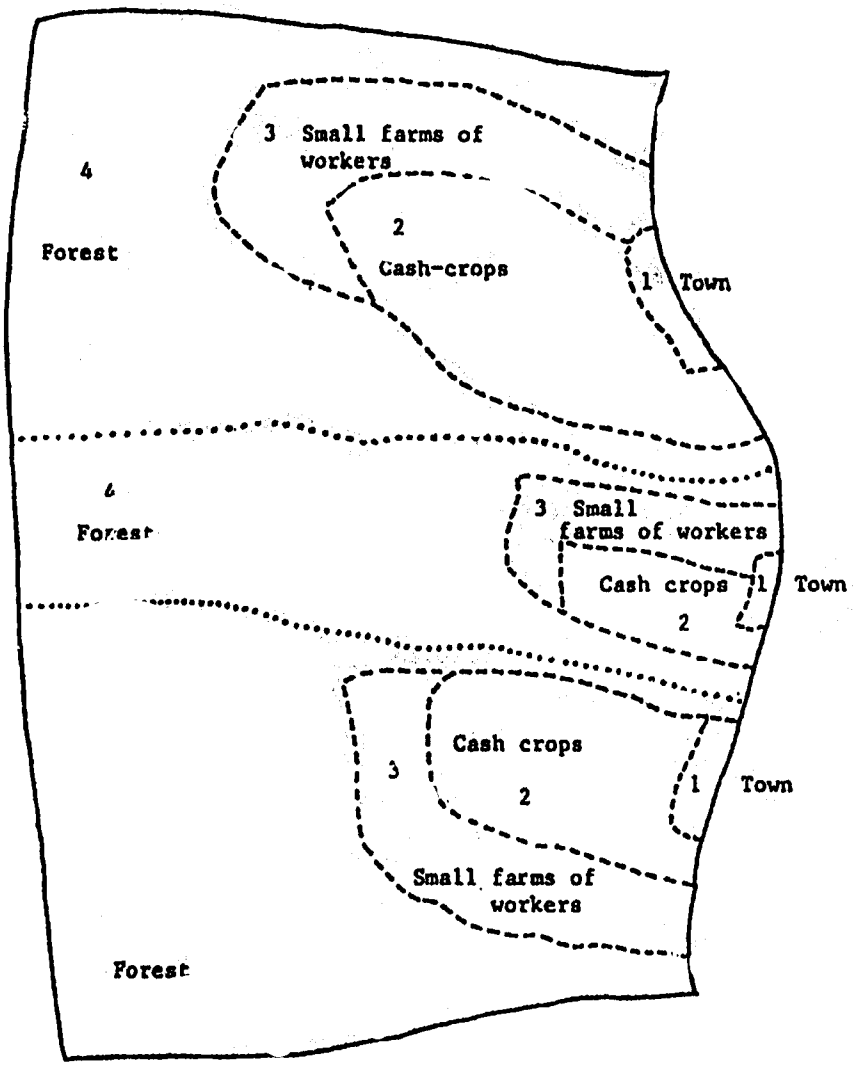
The management of tropical upland watersheds and other fragile environments also requires a larger-than-farm approach with emphasis on watershed or other ecosystem units,(Hamilton, 1983; Pereira, 1981; Russel, 1981; Antonini et al. 1975). Agroforestry diagnosis and design for reclamation and/or sustained production in such areas requires an integrated systems analysis of nested hierarchies of watershed and land use units. For example some erosion and runoff studies have combined small plot and watershed scale analyses,(Edwards, 1977; Edwards and Blackie, 1981; Thomas et al, 1981; Rocheleau, 1984; Rapp, Berry and Temple (eds) 1982; Stromquist, 1981), and some land use plans incorporating agroforestry systems have used nested watershed studies of soil and water loss under varying composition, density and management of land cover (Tejwani, 1981). The net results of larger scale land use analysis and watershed measurements may sometimes contradict simplistic direct extrapolations from small scale plot studies because of the functional relationships between certain infrastructural elements of landscape and specific land uses, or between seemingly disparate land uses (Bajrachrya, 1980; Johnson et al. 1979;



Watershed boundary

Sub-unit boundary

FIG. 1: GEOGRAPHICAL STRATIFICATION



Administrative Boundary (bounded by river, roads)

Sub-unit Boundaries (Land Use)

Property line - estates

FIG. 2: STRATIFICATION BY FUNCTIONAL CRITERIA

Rocheleau, 1984). The need to combine these scales of observation and design and to combine structural conservation measures with improvement of the production system, including grazing and woodlands (Pereira, 1981), can be addressed by a landscape ecology focus (Johnson et al. 1979) within AF diagnosis and design.

The actual geometry of the existing landscape plays a significant part in AF potentials. The degree and pattern of land subdivision (whether by property lines or by physical boundaries within property) will determine the relative importance of boundary lands and linear features vs. whole area treatments (Johnson, 1983). The potential role of living fences and fenceposts in fuelwood (Poulsen, 1981) and fodder (Baggio, 1982) production has been estimated at ≥ 20% of total production potential for farmlands. In fact the amount and relative proportion of production from such linear features depends heavily on size and shape of plots, as illustrated in Figures 3 and 4 and Table 1. This is particularly important in the case of smallholders with plots ≤ 1 ha. In the case of India (Johnson, 1983) estimates show the potential of boundary tree-planting on bunds to meet 100% current fuelwood demands by smallholder households with ≤ 1 ha. Choice and priority of AF designs for different types of landscape niches strongly affects the distribution of benefits within household and rate of adoption between households. In many cases boundary plantings on private or public land (with secure use rights) will more directly benefit women and smallholder households in general. In systems where they do not control croplands women may be better able to get access to such boundary zones for partial replacement of dwindling off-farm fuel and fodder resources. This would reduce time and labor spent on collection at distant sites and would provide better security of supply. This emphasis will also have a proportionately greater effect on smallholder families and as such provides a leverage point for reaching the poorest first.

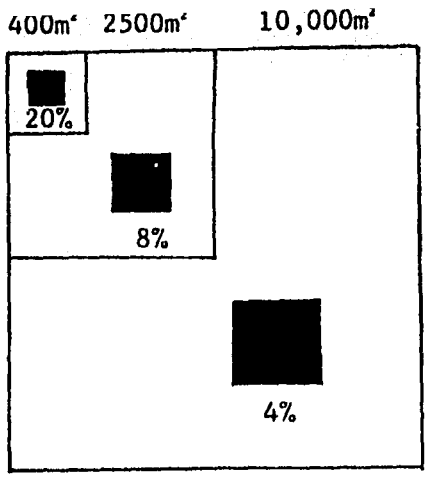


Fig. 3A: Square Sub-Divisions

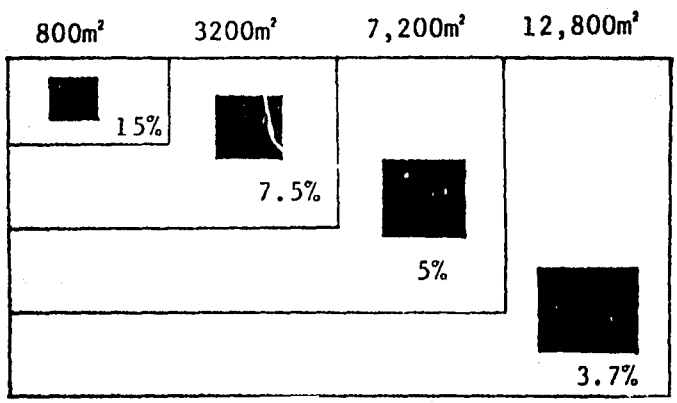


Fig. 3B: 1 x 2 Rectangles

FIG. 3: EQUAL-AREA BLOCKS REPRESENTING TOTAL BOUNDARY AREA FOR PLOTS OF DIFFERENT SIZE

Table 1 Relation of Boundary Area to Total Area

Shape	Total Area (m^2)	Boundary Area (m^2, at 1m width)	Boundary Area % Total
Square	400m²	80m²	20.0%
"	2500m²,	200m²	8.0%
"	10000 m² (1 ha)	400m²	4.7%
"	20000 m² (2 ha)	560m²	2.8%
1x2 Rectangle	400m²	84m²	21.0%
	2500m²	210m²	8.4%
	10000 m² (1 ha)	426 m²	4.3%
	20000m² (2 ha)	600 m²	3.0%

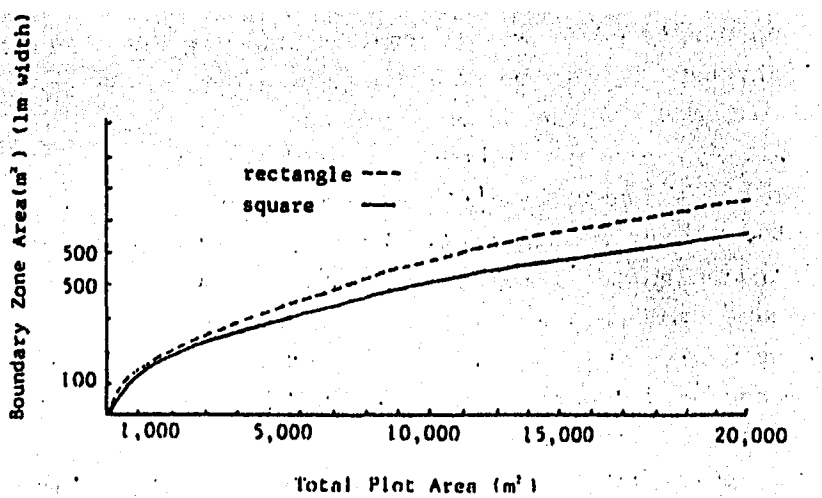


FIG. 4 GRAPH RELATING BOUNDARY AREA TO TOTAL AREA FOR SQUARES AND 1 × 2 RECTANGLES

Aside from initial AF design, evaluation of AF technologies can also benefit from an expansion to the community or ecosystem level. "Externalities" in single farm and single-watershed studies appear as real costs and benefits in nested hierarchical analyses. Differences between households, classes of people (sex, age, status), geographical areas, land facets or land uses can be included in analyses of current situations and projected effects of AF designs. This approach can account for distribution of local vs. regional effects of runoff, erosion, and sedimentation. Likewise, the cumulative effects of widespread adoption of new technology on the community's economic input-output and on local and regional marketing conditions may be critical to the longterm success of many projects. Even short-term sucess may depend on marketing or other constraints at the next higher level (Hufschmidt et al. 1983).

The extrapolation of tentative design and production estimates onto the framework of existing landscape (at whatever scale) helps keep realism and honesty in feasibility analyses and in after-the-fact evaluations. Opportunity cost of other vegetation displaced or of alternative uses is often visible in the landscape or can be deduced from juxtaposition of land use with units of landscape on maps.

For example, is your dream hedgerow replacing someone's only source of sisal for handicrafts? A quick look at dimensions, spacing and extent of live sisal-fencing on aerial photos or in landscape sketches may provide a quick answer or suggest a compromise design without loss of sisal production. Or, conversely, one may find that units of land with similar appearance may serve quite distinct purposes (Murray 1981), hence the need to overlay type, intensity and timing of landuse on the visible landscape. All other things being equal, an emergency (reserve) grazing area that serves 10 families once every 2 - 3 years will not be as difficult a site for new fodder tree planting as one

that is continually grazed by a small number of animals from one household. By the same token a pasture that is part of a private scattered landholding, 2 km distance from the home, has almost no potential for a farm-level cut-and-carry system, wheareas a more degraded site close to the home may have a much higher potential for conversion to a cut-and-carry lot, given the farm households's constraints.

All of the points cited indicate the advantages of combining landscape and systems analysis to maintain a balance of form and function in AF design and evaluation criteria. The importance of social and ecological questions for AF are widely accepted, and the ability to address both is a major asset of this approach. It remains to describe and demonstrate how this can apply to research and development projects.

Who would apply this method?

As in the AF diagnosis and design for farming systems(ICRAF, 1983) the landscape diagnosis and design is best carried out by an interdisciplinary team of variable composition, depending on the type of project and the system itself. The team might vary from landscape architect, forester, sociologist, and agronomist to watershed management specialist, anthropologist, farming system specialist, tree crop expert. The initial analysis relies heavily on maps and aerial photographs with good potential for use of remote sensing imagery (where available) to choose sample sites for rapid appraisal, subsequent surveys and implementation. From rapid appraisal through implementation both qualitative and quantitative techniques are used, the balance being determined by project needs, team abilites, and available resources. The level of training among team members may also vary, ranging from 2 years technical or college training to wide international experience, depending upon the available resouces and the requirements of the task at hand.

The implementation of such an approach, ideally, should take place under dramatically different circumstances in rural extension, education and development services (Woods, 1983) but within the current framework in most countries an integrated plan can be implemented in small areas by project teams drawn from existing research and extension institutions (Torres, 1983). Such projects can then serve as models for local and regional teams from extension services, non-government organisations, and/or informal networks of self-help and cooperative associations (Idsert, 1984).

How do you systematically apply such an approach?

The best reply to this question is a case study example to illustrate the need for this approach, its scope for development, and how it works. The methodology is still tentative and the procedures followed so far reflect a search by interdisciplinary researchers. This includes trial and error and an experiental, informal approach to the social aspects of implementation, supplemented by cartographic analysis, erosion, runoff and yield estimates, and a socially conditioned time and labour estimate. We expect that the earlier stages of diagnosis and design will become more systematized with future applications of the approach and we welcome suggestions to that end.

CASE STUDY EXAMPLE: KATHAMA RESEARCH SITE

This study began as an extension of the Kathama Agroforestry Project[1] a field test of the agroforestry systems diagnostic and design (D&D) methodology. Landscape analysis and design were introduced to extend the D&D procedures to development of productive, adoptable agroforestry (AF) technologies for public, semi-public and boundary lands managed by small groups or individual households. The landscape study focused on roadsides, property lines, gullies, and degraded hillslope grazing lands (Hoek, 1983). A systems approach combining aspects of landscape, land use, ecosystems and community (social) analysis related the findings and activities of farm and larger-scale studies.

The larger-than-farm D & D follows the same iterative cycle (Figs 5 and 6) as that described by Raintree (1983) with the added interplay between different scales of analysis (in this case farm, watershed, community). The landscape systems D & D for Kathama followed a D&D exercise at the farming systems level and two years of on-farm trials, all of which provided an usually rich source of baseline information. The details of the D&D approach (ICRAF, 1983), the research area (Vonk, 1983; Gielen, 1981) and the on-farm trials (Vonk, 1983) have been described elsewhere.

Land.

The Kathama study site (~ 30 km^2) is in Kathama sub-Location, Mbiuni Location, Northern Division of Machakos District, Kenya (Fig. 7). The Kathama market place is approximately 100 km east of Nairobi, within the watershed of the Athi River (Fig.8), situated between the Kanzalu Range and the Yatta Plateau

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1. A joint research project of ICRAF, Nariobi and the Department of Forest Management, Wageningen University from 1980 to 1983,followed up (1984) through the Diagnosis and Design Project, Systems Program, ICRAF.

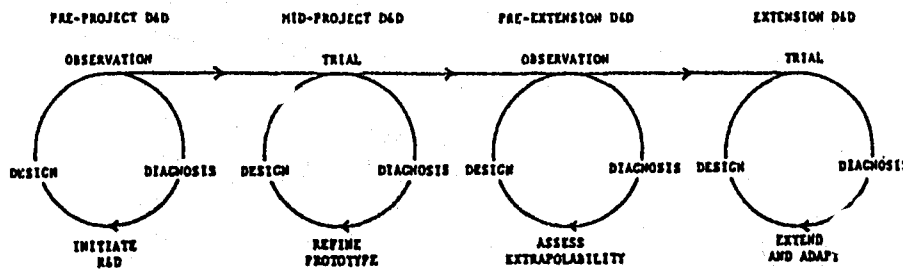

FIG. 5: D&D AS AN ITERATIVE PROCESS IN THE PROJECT CYCLE
(Source: Raintree, 1983; ICRAF, 1983)

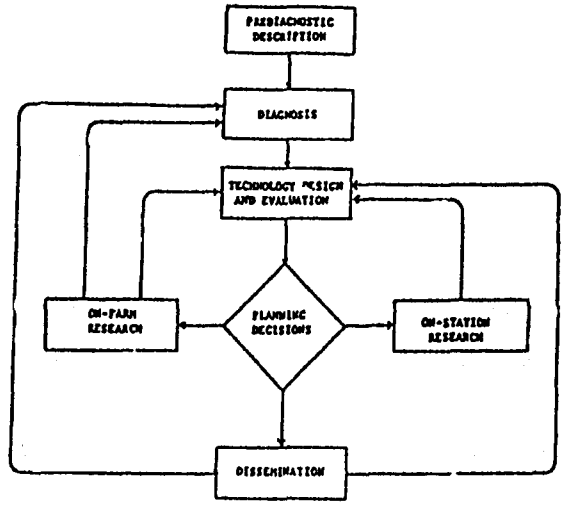

FIG. 6: DIAGNOSIS AND DESIGN (D&D) PROCESS
(Source: Raintree, 1983; ICRAF, 1983)

D&D is an iterative process which continues throughout the life of a project as part of its internal guidance system. Note feedback linkages.

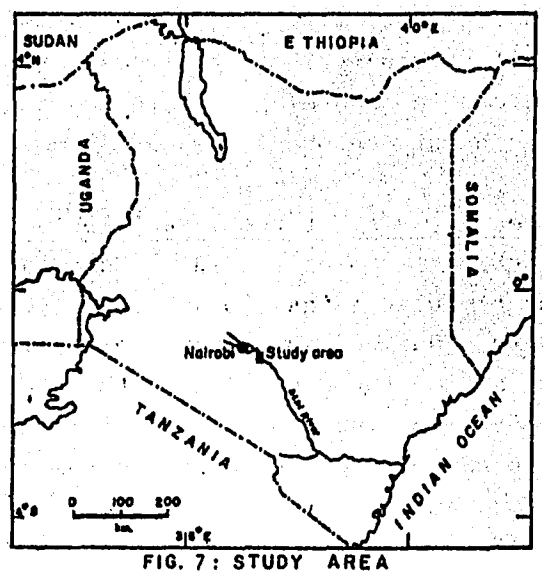

FIG. 7 : STUDY AREA

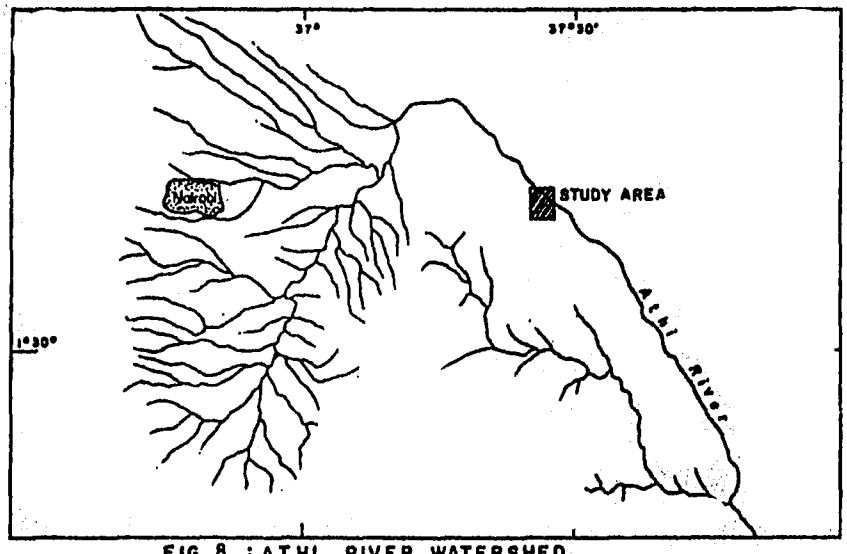

FIG 8 : ATHI RIVER WATERSHED

(Figs. 9 and 10). The river traverses the site following the edge of the Yatta Plateau (Fig. 9). The climate is transitional from sub-humid to semi-arid, with a mean annnual (bimodal) rainfall of 850 mm (Fig. 11), and a mean annual temperature of 21°C (range 13° - 27°C). Rainfall is extremely unpredictable both within years and between years; seasonal rainfall can vary between 140 and 730 mm (Vonk, 1983).

Slopes are gentle over most of the area (≈ 5%), however, the upper slopes of the escarpment exceed 50% and farmers cultivate slopes in excess of 30%. (Figs. 10 and 12). The lower slopes are densely populated and intensively cultivated relative to the rest of the area, making this land unit important beyond it's proportional share of the total study site. Overall the slopes of the Kanzalu range and the slopes to the Athi River both warrant extra emphasis because of proximity to permanent water sources (springs and Athi River, respectively). The same is true for the slight depression at the foot of the Kanzalu range where temporary wells are made in the dry river beds and permanent shallow (open) wells can be found on farmlands (Figs 12 and 13). (Hoek, 1983).

Most of the soils are alfisols (sandy loams over sandy clay loams to sandy clay), (Collinson, 1979) with some ultisols (deep well-drained sandy clay loams) along the upper footslopes of the Kanzalu Range, and along the Athi River (Vonk, 1983). A strip of pellic vertisols runs through the center of the area (Figs. 9 and 13). All of the soils in the area show some signs of erosion or degradation (Fig. 12). Along the upper slopes of the Kanzalu range rockslides and landslips occur, as well as sheet erosion. The mid-to-lower slopes show the effects of both gully and sheet erosion, varying from moderate to severe, depending on slope and land use history. The undulating uplands are characterized by slight to moderate sheet and rill erosion, while the vertisols in the central depression are both compacted (grazing lands)

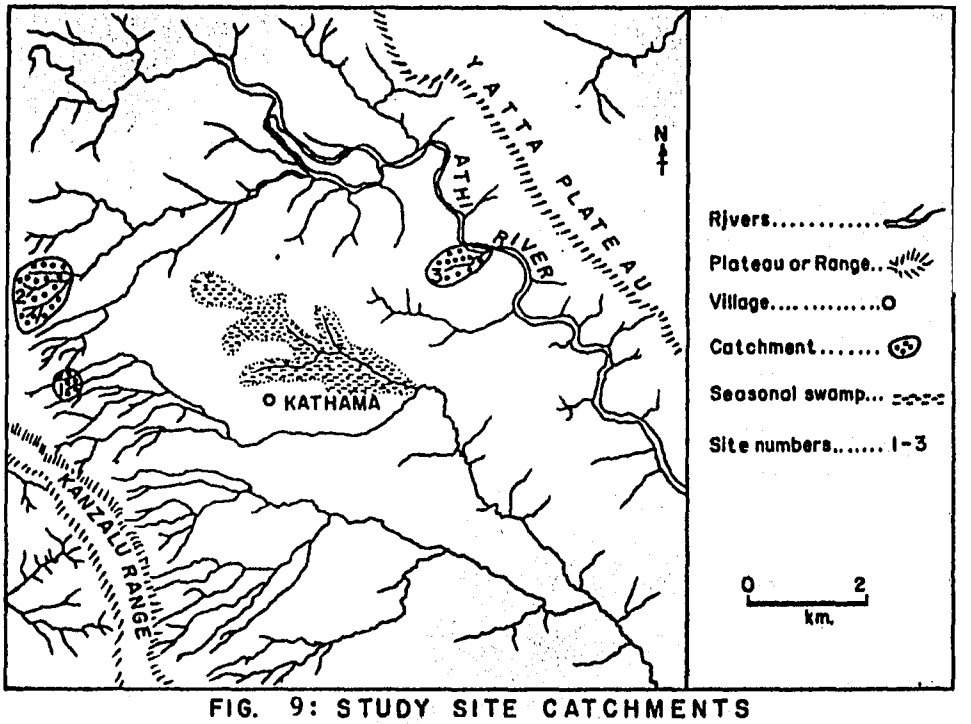

FIG. 9: STUDY SITE CATCHMENTS

(Hoek, 1983)

LAND UNIT	RELIEF	SLOPE
A. KANZALU RANGE	A1. ridge	A1.4. flat to very gentle
	A2. dissected hilly slopes	
	A3. steep slopes with rocks	A3.1. steeply sloping
	A4. rolling footslopes	A4.1. moderately sloping
B. UNDULATING UPLAND	B1. undulating uplands	B1.1. flat to very gentle
		B1.2. gently sloping
		B1.3. moderately sloping
	B2. flat/almost flat depression	B2.1. flat to very gentle
		B2.2. gently sloping
	B3. rolling slopes	B3.1. flat to very gentle
		B3.2. moderately sloping
C. ATHI RIVER LANDSCAPE	C1. river island	
	C2. floodplains	
	C3. riverbed	
D. YATTA PLATEAU	D1. plateau	
	D2. slopes	

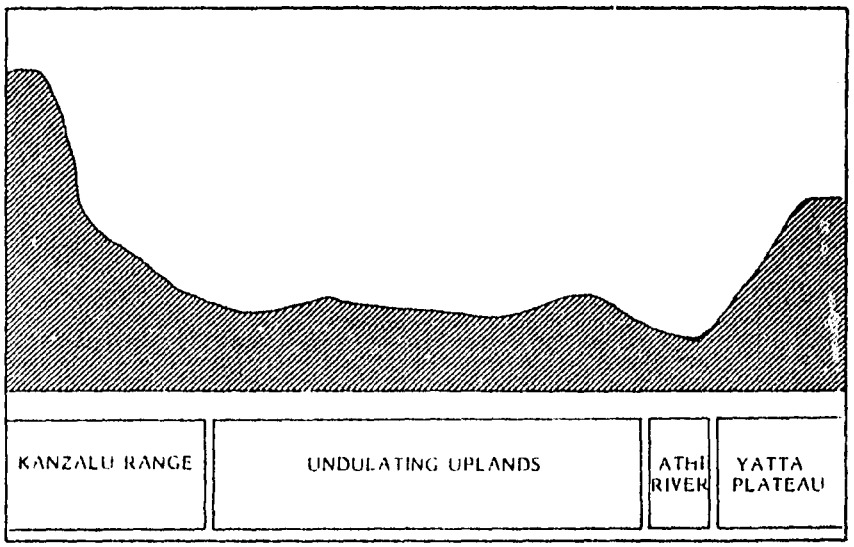

FIG. 10: TOPOGRAPHIC PROFILE WITH LAND UNITS
(Hoek, 1983)

KATHAMA

Location 1° 12' S
37° 23' E
alt: 1240 m

mean annual rainfall 850 mm 1)
" " pot. evapotr. 1965 mm E_o 2)
agro ecological zone LM 1 / 1 M - 3)

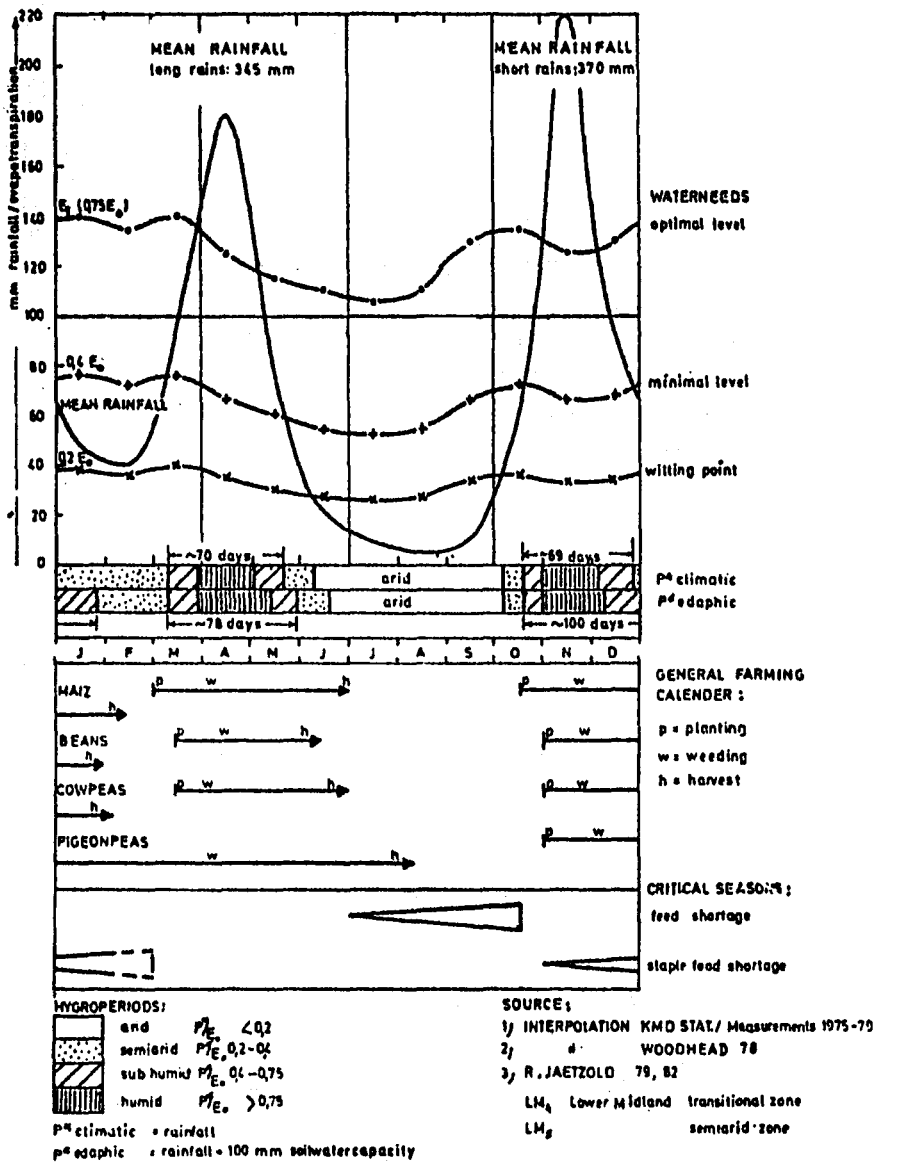

FIG. 11: CLIMATE SUMMARY FOR KATHAMA

(Darnhofer, ICRAF)

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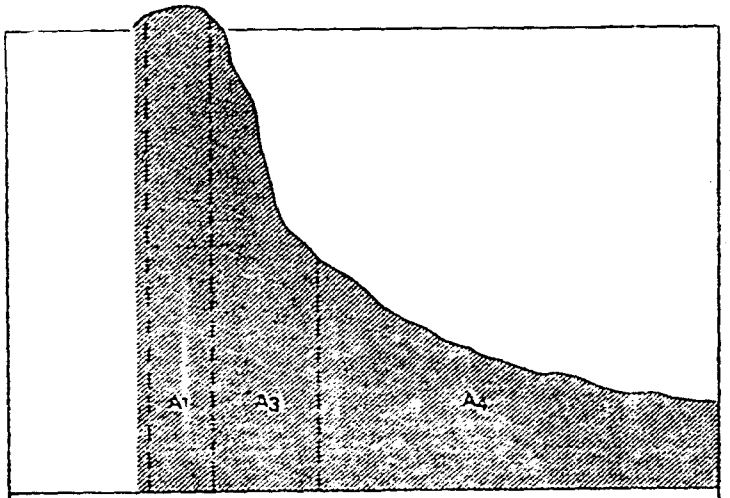
FIG. 12A: LAND UNIT DESCRIPTION

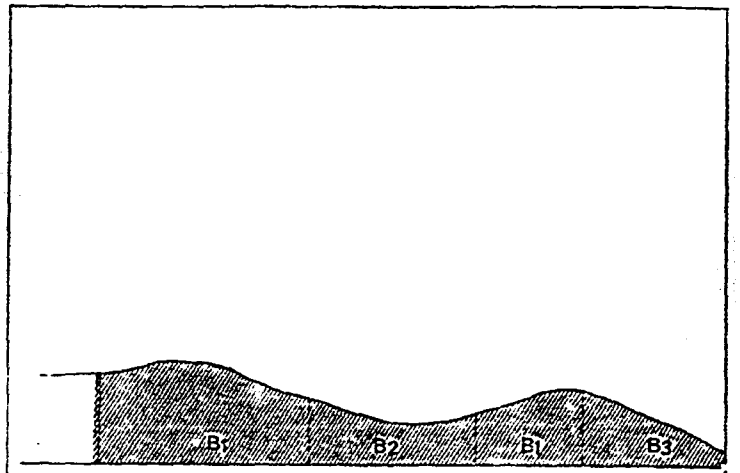


	ridge	Steep slopes with rock outdrops	Rolling footslopes
Slopes	A1.1 flat to very gentle	A3.1. steeply sloping	A4.1. moderately sloping
Drainage	well drained	well drained	in places imperfectly drained
Soils		shallow stony soils	reddish brown clay ultisols
Landuse	road + shambas[1]	bushland used for grazing and fuelwood	- mainly shambas with subsistence crops fruittrees - grazing in and along gullies - high density of households
Vegetation	bush-land	bushland in gullies mod. density	Combretum / Acacia woodland
Erosion	land slides	land slides sheet erosion (severe)	severe gully erosion high runoff. badlands

(Hoek, 1983)

1. "Shamba" farm

FIG. 12B: LAND UNIT DESCRIPTION



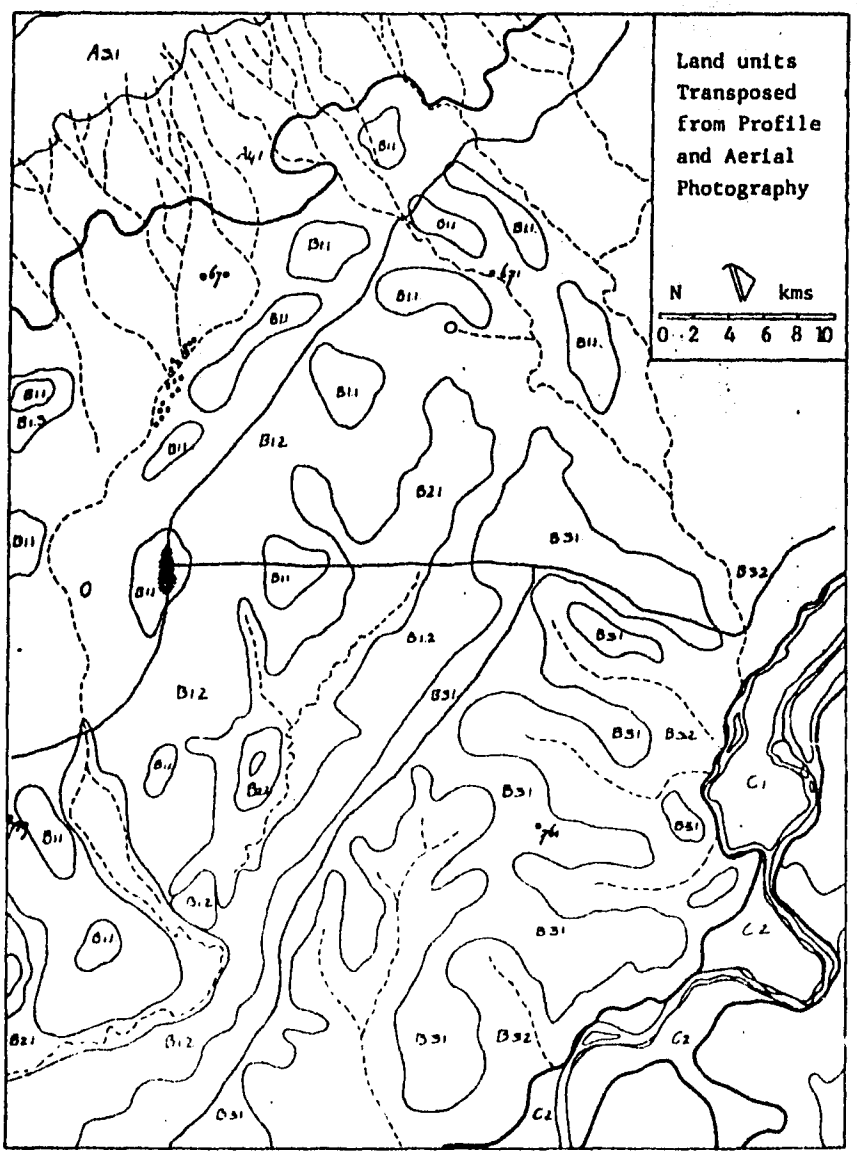
	undulating uplands	flat/almost flat depression	rolling slopes
Slopes	B1.1. flat to very gentle B1.2. gently sloping B1.3. moderately sloping	B2.1. flat to very gentle	B3.1. flat to very gentle B3.2. moderately sloping
Drainage	well drained	badly drained seasonal water-logging	well drained
Soils	red compact sandy loam to sandy clay alfisols	Black cotton pellic vertisols	mod. deep to deep dark red clay ultisols
Landuse	shambas with subsistence crops and grazing land	wet grazing land on edges: maize on higher parts shambas - housholds	mainly grazing land. On ridges: households and roads
Vegetation	Combretum/Acacia woodland mod. density	shrubland low density	Acacia woodland mod. density
Erosion	low erosion rate rill erosion	gully erosion	severe rill and sheet erosion bare compacted land

(Hoek, 1983)

LEGEND TO LAND UNIT DESCRIPTION

LAND UNIT	RELIEF	SLOPE
A. KANZALU RANGE	A1. ridge	A1.4. flat to very gentle
	A2. dissected hilly slopes	
	A3. steep slopes with rocks	A3.1. steeply sloping
	A4. rolling footslopes	A4.1. moderately sloping
B. UNDULATING UPLAND	B1. undulating uplands	B1.1. flat to very gentle
		B1.2. gently sloping
		B1.3. moderately sloping
	B2. flat/almost flat depression	B2.1. flat to very gentle
		B2.2. gently sloping
	B3. rolling slopes	B3.1. flat to very gentle
		B3.2. moderately sloping
C. ATHI RIVER LANDSCAPE	C1. river island	
	C2. floodplains	
	C3. riverbed	
D. YATTA PLATEAU	D1. plateau	
	D2. slopes	

FIG. 13: PLAN VIEW OF LAND UNITS*



*See legend p.23

and eroded (gullies along paths). The soils along the slopes to the Athi River show the effects of both continuos cultivation (sheet and rill erosion) and overgrazing (compaction, sparse cover) (Hoek, 1983).

The natural vegetation on the site is described by Fliervoet (1982) as Acacia-Combretum woodland. The dominant species are Acacia tortilis, Combretum Zeyheri, Terminalia brownii and Lantana camara. Large mature trees are rare, particularly in the case of Acacia tortilis which has been felled extensively for charcoal-making.

Wildlife includes hares, small antelope, several species of birds, squirrels and some lizards and snakes. Termites are widespread, and along with the hare and antelope, impose constraints on the species selection and/or management practices for agroforestry systems.

People.

The Akamba people have occupied this region (Machakos and Kitui Districts) for several generations, and although the oral history varies with respect to the area of origin there is a concensus as to migration from another region (possibly the coast). The group as a whole is in a transition from pastoralism with some agriculture to permanent cultivation with some animal production (mixed farming).

Within the region occupied by the Akamba, Kathama presents a relatively densely populated site with 172 persons Km^2 (Table 2.) The access to water along the Kanzalu Range and the Athi River probably accounts for the relative population concentration. Population pressure has already caused some families to leave the area for the more sparsely populated Yatta Plateau. Others have moved into more marginal areas within the study site: upslope on the range or out onto the valley and away from the water sources.

Table 2: Population and Land use Distribution for Machakos District, Mbiuni Location and the Research area

		District[1]	Agroecological Zone 5 Machakos[1]	Agroecological Zone 4 Machakos[1]	Mbiuni Location[1]	Kathama res. area[2]
Total Area	Km^2	14,245	998,000	156,000	144	14
Population	Pers	1,019,200	456,000	376,000	19,900	2,415
Population density	Pers /km^2	72	47	147	69	172
Cropland	%	6	14	19	14	27
Cropland/ household	ha	1.3	1.9	0.4	1.1	1.1
Grazing-land	%	80	71	59	72	52
Grazing-land/ household	ha	6.7	9.1	2.4	3.1	2.1
Animal units[4]/ha grazingland	AU/ha	-	-	-	-	3.3
Animal units/ household	AU/hsld	-	-	-	-	6.9

Excerpted from Vonk, 1983

1a) Data on Machakos District ecological zones 4 & 5 and Mbiuni from Ecosystems Ltd. (1981).

1b) An agro climatological zone defined by the rainfall potential evapotranspiration ratio; zone 2: PP:PE 67%; zone 3: 52% - 67%; zone 4: 37% - 52%; zone 5: 22% - 37% (Braun, 1981).

2) Data on Kathama research area from H. Gielen (1982).

3. A household is assumed to be comprised of six (6) members (Hoekstra, 1983), except for the Kathama area, where it is 7 persons (Gielen, 1982).

4. Most households have 10 goats, up to7 cattle; 1 animal unit = 5 goats; 1 adult cattle; 2 cattle < 1 year; 1.3 cattle 1 - 3 years (Rukandema, et al. 1981).

The people at the study site are almost all farmers (participating members of farm households) with relatively few people ($\approx$ 25) engaged in trades or small businesses. Both men and women engage in cultivation with women responsible for most tasks other than plowing. Most women make sisal baskets and rope for cash income and many people (men and women) burn bricks or charcoal for home use and sale (Wijngaarden, 1983; Kantor, Personal communication). However, for most households the main source of income other than farming is remittance income from people employed off-farm (usually men, residing in cities). Nearly half of the households in the Location (Mbiuni) earn incomes below the poverty level (Kshs. 1,500/= Yr^{-1} including farm products (Wallis and Waning, 1976; Vonk, 1983).

The natural rate of increase in Kathama is 4% (Ginneken, 1981) but the population growth rate is only 3%, due to the high rate of emigration. Those who leave are mostly men from 20 to 50 years of age seeking employment in Nairobi or large towns. Large numbers of men have left during drought years (Ginneken, 1981; Gielen, 1982; Vonk, 1983). Crop failure due to drought is common (at least one season in five) and periodic famines are offset by food relief.

The high rate of natural increase and the emigration of young men has resulted in a high proportion of women-headed households with a very high ratio of dependents to "producers" (children* to adults). The women of the area are, therefore, under double and often conflicting pressures to produce more crops than before with less adult labor than was previously available. The average household size is 7 persons, with a wide variation in available labor force depending on family composition.

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* While children do participate in herding, gathering and other tasks, the small ones have limited capabilities and the older children are in school.

Land use.

The relatively advanced position of Kathama in the shift from agro-pastoralism to permanent intensified cultivation of food crops provides a glimpse of the future for the rest of Machakos District (Table 2). Over 25% of the area is in cropland and more than 50% is devoted to grazing. Of the remainder most is bush regrowth or woodland (including gully and ravine vegetation) that is at least occasionally subjected to grazing and browsing. The woodland serves as a source of fuelwood (usually cuttings, sometimes whole trees) and wood for charcoal and brick-burning (whole trees, usually larger hardwoods). The denser woodlands are concentrated in inacessible areas or on sites extremely unsuitable for cropping or grazing. These sites serve a number of households as sources of stickwood although most of the land is privately owned. The same is true to a lesser extent of the more open grazed woodlands in the valley.

The farming system in the area is fairly uniform; the ratio of cropland to grazing land and the relative importance of the two enterprises vary along a continuum limited to mixed farming. Most farmers raise two crops per year of intercropped maize, beans, cowpea and pigeon peas, for subsistence. Some fruit crops (citrus, mango, banana, papaya, guava) are also grown around the home compound or interspersed with annuals on the cropland. Small quantities of fruit, as well as sunflower seeds and cotton, are sold as cash crops; mango and papaya are the most widespread as small-scale cash crops [1] (Vonk, 1983).

Labour, manure and seed are the major inputs with very little use of chemical fertilizer (cost limits use) or other agrochemicals. Almost all of the cropland is terraced, even in slightly undulating topography. Most farmers use draft animals for plowing, usually just after the onset of the rains. The cropping calendar shows peak labor demands at planting and weeding times (April/May; Oct./Nov.) and at harvests (Dec./Jan; June/July). Each household plows and plants concurrently on

1. Charcoal is widely used during the rainy season and is a minor but strategically timed source of cash at the end of the dry season. It also assumes more importance as a "cash crop" when crops fail.

their respective plots, but self-help groups (rotating labour exchange) often help with weeding, terrace construction and repair, tree crop planting and fencing on farms of group members.

Cattle and goats are the most important domestic animals in this system (Table 2). Oxen serve as draft animals and also as an investment. Goats are investments and a periodic source of ready cash and provide milk and occasionally meat for the farm household. Both cattle and goats are confined in corrals at night; farmers collect the manure and apply it to one bench terrace per season, in rotation (Nijssen, 1983; Vonk, 1983). Management of grazing and browsing varies from tethering to careful herding to almost free range, depending on landholding. Social pressure to control grazing is strongest when grain crops are vulnerable to attack but "social fences" fade during the dry season. Animals are driven long distances to water holes or to the Athi River. Off-farm fodder sources play an important role during this period. Roadside and gully sites provide grass, shrubs and high protein pods to supplement on-farm fodder. Many larger land holders also grant grazing and browsing rights to several other households based on kinship or other social ties or in exchange for cash or services.

Land Tenure, Use Rights and Water Rights

Most of the land in the study site was adjudicated over ten years ago, with the exception of the woodlands just across the Athi River on the Yatta Plateau and a very limited area of government land on the Kanzalu Ridge. However, exclusive use by one household is applied only to cropland (permanent, terraced), home compounds and small grazing plots. Woodlands and large holdings of wooded grazing land are controlled by single households but are perceived as conditionally available to the larger community or to sub-groups thereof.

In general all but the largest landholders rely to some degree on off-farm[1] fuel and fodder sources, sometimes only seasonally. Moreover, some smallholders now occupy property that has been subdivided and reduced to little more than the minimum area required for subsistence production of food crops. These households depend almost completely on off-farm sources of fuel, fodder, timber, thorn-fencing and minor forest products. Access to this discretionary common use of private land is unevenly distributed between households and also varies with seasonal and periodic events such as prolonged drought, the latter being an emergency and considered just cause for granting broader privileges than usual. Forms of payment vary as well. Grazing rights may be rented, exchanged for services (for example, plowing) or may be simply granted on the basis of family or social ties. Rentals may apply to individuals or to groups; one group in Kathama has banded together to rent a large parcel of supplementary grazing land on the Yatta Plateau along the river (Wijngaarden, 1983).

Gathering rights for fuelwood are seldom compensated although some farmers report buying felled trees from neighbors for charcoal or fuelwood. More commonly the practice is referred to as "borrowing" but the indebtedness one incurs has to do with social status and deference to the donor. The usual understanding is that "borrowers" take dead wood, small stickwood and the least desirable species. Some gathering without permission also occurs in the denser more remote woodlands (Kantor, personal communication). While fodder and fuelwood are almost free goods, fencing material, timber (building poles) and charcoal trees are perceived as commodities to be purchased directly. In some cases charcoal makers may rent access to land for tree harvesting and burning (Hoek, 1983).

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1. "Off-farm" in this case refers to areas outside their own farms, including public and boundary lands as well as other people's private farm property.

The same plots now available for restricted common use are the main sources of land for conversion to cropland, subject to exclusive use by the owners. Since the demand for food is less elastic than the demand for grazing, cropland parcels tend to preserve the same size from one generation to the next while the grazing land dwindles.

Water rights in the area range from private ownership and exlusive use of open shallow wells on-farm, to free public access to hillside springs and flowing rivers, to temporary shallow wells in dry river beds dug and fenced by small ad hoc groups that may also share water collection and stock-watering trips. Access to water is a major determinant of location preference and is reflected in the location of the largest and or most prosperous landholders. The latter are concentrated along the base of the Kanzalu Range (Fig.12) where permanent shallow open wells are easy to establish and maintain. These are usually reserved for exclusive use by the owner's household and are considered to be property held and controlled by the head-of household. Proximity to the Athi River is also advantageous, as is proximity to the springs on the upper slopes of the range. Both of these are considered public domain with ease of access influenced by location of owned property.

The complex and ambiguous mix of land tenure, use rights and water rights has strong implications for the development of agroforestry technologies and their integration into the larger system. Control of the factors of production for agroforestry systems (land, water, labor, capital, information) will determine in large part the distribution of costs and benefits from new technologies. The design of agroforestry systems should take into account the variability in amount and type of resources available to different groups. One approach would be to include agroforestry options scaled to each level of access; a second approach would be to creatively integrate complementary resources at a larger-than-farm scale.

Government Services and Organization.

The chief of the location (Mbiuni) represents the government in the area. He exercises his authority through direct contact and decision making and through delegation of authority to the sub-chief (Kathama sub-location) and village headmen (recognized elders with local government ties). The self help (Mwethya) groups at the study site answer directly to the sub-chief but are considered to be non-government associations registered with government and answerable to local authorities. In Kathama the group members are mostly women (80 - 100%) and the organizations are based on traditional labor exchange groups. Leaders may be men or women and span a broad range of income or status. Speaking ability, integrity and natural leadership qualities are major criteria, and often one leader (of two) will be a large landholder. These mutual aid societies have been actively encouraged and registered (formalized) since 1981 throughout Kenya. The groups in Kathama range from very traditional older women's agricultural groups to mixed men's and women's public works groups, to women's crafts and marketing associations. All of these are designated as self-help groups and in Kathama most of these engage in public works (road and gully repair) one morning per week during the dry season. Some groups work as often as 3 days per week and a few are limited almost exlusively to sisal rope production and sales and to farm-level work.

Church groups are a strong focus of community organization and service. However, the influence of the churches is often mediated through the self-help groups rather than into separate direct-action projects. The churches sometimes channel food aid and construction materials for self-help projects and the self-help groups often have some religious afiliation in common among members.

The University of Nairobi operates a weekly medical clinic for mothers and young children (infant and mother health care and family planning). Most residents travel to Kabaa (10 km) or Kangundo (> 10 km) for both routine and emergency health care.

The district level grain storage and agricultural supply centers are not widely used by Kathama residents. Marketing depends heavily on individual connections with middlemen and haulers, and on informal networks among producers within Kathama sub-location. Market place facilities are limited to collection points for charcoal, a small area for vegetable, fruit and grain sales, a maize mill and storage building, a hide tannery, a tailor's shop, a few small tea shops and two shops with a limited selection of household goods.

DIAGNOSIS AND DESIGN

Farming Systems Problems and Potentials.

The farm level D & D was carried out earlier and as such formed the basis for the later expanded D & D for the community and surrounding watershed. The rapid appraisal (diagnosis) of farming system problems and potentials in the area (Table 3) identified two key points limiting cash income and food production. The dry season fodder gap limits animal production, which is a major source of ready cash (especially when food stores are depleted) and functions as a bank for savings/investment (Fig. 14). Soil fertility, soil moisture and soil erosion problems limit production on cropland, causing both food and cash shortages (Fig. 15).

Several technologies (AF and non-AF) were evaluated for overall feasibility and problem-solving potential. The designs chosen for farm trials included: alley cropping

TABLE 3 SUMMARY OF FARM LEVEL DIAGNOSTIC AND DESIGN INDICATIONS FOR A TYPICAL FARM (3.5 ha) AT THE KATHAMA RESEARCH SITE. (From Vonk 1983, Raintree 1983)

KATHAMA
MACHAKOS DISTRICT
KENYA

SITE SUMMARY OF AGROFORESTRY DIAGNOSIS AND DESIGN INDICATIONS ON A REPRESENTATIVE FARM

SYSTEM DESCRIPTION	LAND USE SYSTEM DIAGNOSIS		AGROFORESTRY POTENTIALS
	HOUSEHOLD SUPPLY PROBLEMS	PRODUCTION CONSTRAINTS	
Climate Semi arid-sub-humid **Soils** Sandy loams over sandy clay loam to sandy clay; imperfectly drained in places **Farming System** Mixed farming **Crops** Maize, beans, pigeon peas, cowpeas **Livestock** Zebu cattle, goats and sheep **Economy** Subsistence farming **Population Density** 172/Km^2 **Growth Rate** 3.4%	**Problems in Basic Needs Supply Sub-Systems** FOOD - Seasonal staple food shortages normal, must purchase; drought related crop failure on avg. of once in every five years; low milk and meat production due to dry season feed shortage for livestock FUEL - Insufficient production from own land, must purchase fuelwood for household and cottage industry uses; lack of large trees for brick burning. SHELTER - Lack of construction quality timber and poles, must purchase; lack of large tree for brick burning; lack of fencing and shade trees. RAW MATERIALS FOR HOUSEHOLD INDUSTRY Must purchase fuelwood for brick making. CASH - Low net household income due in part to cash outflow for staple foods, fuelwood, and construction wood; savings and earning potential of livestock enterprise limited by dry season feed shortage **CONSERVATION PROBLEMS** Erosion Declining Soil Fertility Degradation of grazing land vegetation	**Antecedent Causal Factors** **Crop Land** 1. Low fertility and declining yields 2. Lack of manure 3. Low available moisture 4. Oxen too weak for dry season ploughing/planting; hence inefficient use of limited soil moisture. 5. Soil erosion and water loss due to heavy runoff. 6. Waterlogging on low spots 7. Labour bottleneck at ploughing and weeding time. 8. Insect pests. **Grazing Land** 1. Small grazing area 2. Insufficient dry season feed production. 3. Insufficient production of fuelwood **DESIGN CONSTRAINTS** Low capital Low available labour Long dry season, frquent droughts Termites & other pests	**Specific Problem-Solving Agroforestry Potentials** 1. Elimination of dry season feed gap by planting of multipurpose fodder trees in grazing areas and as hedgerow in cropland with concomitant erosion control effects and fuelwood and mulch coproduction possibilities; improved feed situation should allow dry season ploughing/planting. 2. Cut-and-carry fodder trees for increased pen feeding and usable manure production. 3. Alley cropping/mulch farming with leguminous and other trees to control erosion, increase water infiltration, conserve soil moisture, improve soil fertility and structure, reduce the need for tillage and lessen the labour requirement for weeding, insect repellence 4. Hedgerows and living fences of high-yielding fuelwood species and fruit producing thorn bushes (as a hedge against famine in bad years, for supplementary livestock feed in average years). 5 Multistorey fruit trees with undersown grass-legume pasture.

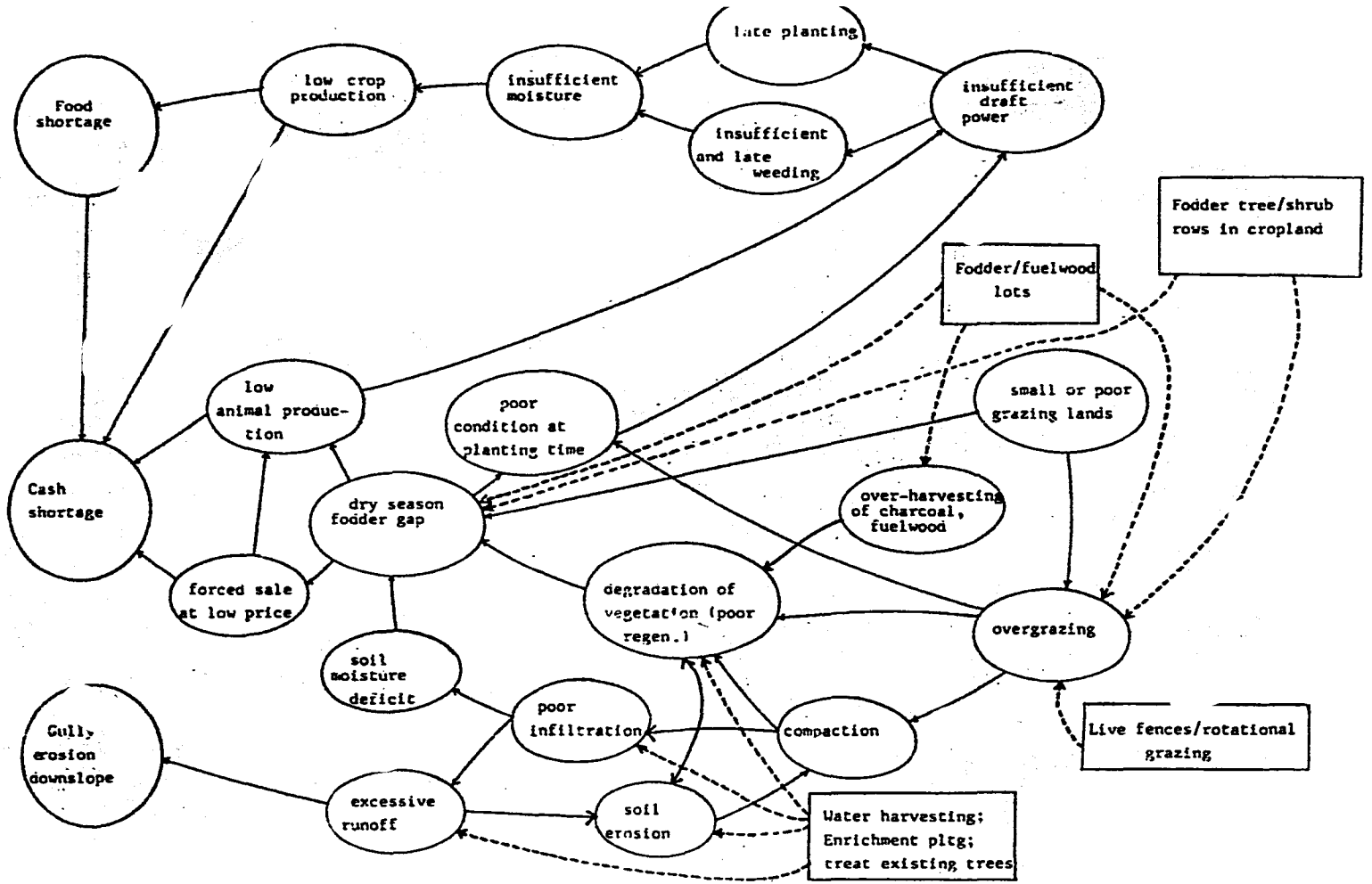
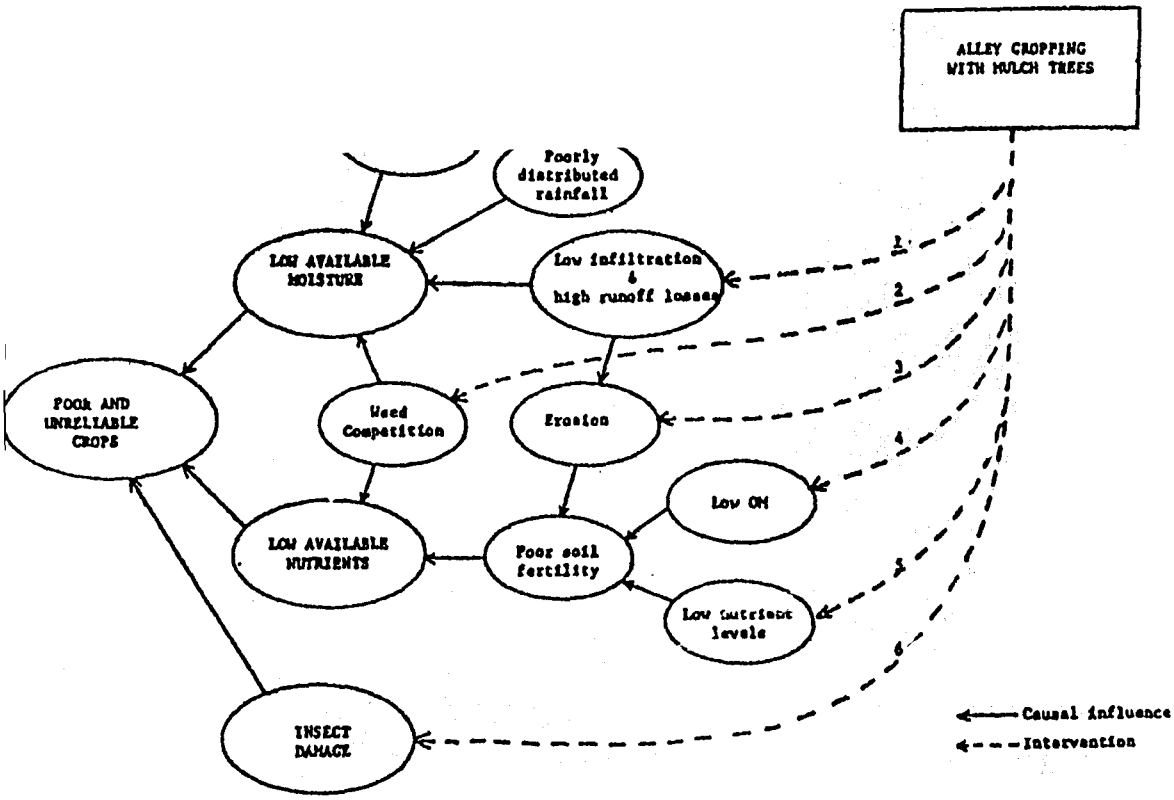


FIG. 14: CAUSAL DIAGRAM OF ANIMAL PRODUCTION PROBLEMS AFFECTING FOOD AND CASH SHORTAGES.

(Adapted/updated from Vonk, 1985)



Potential Mulch Trees

N-fixing	Insect-repellent
Leucaena leucocephala	*Adhatoda vasica*
Mimosa scabrella	*Azadirachta indica*
Sesbania bispinosa	*Derris indica*

Potential Interventions

1. Improved infiltration, reduced runoff
2. Weed control with reduced labour
3. Reduced splash and runoff erosion
4. Increased organic matter
5. N-fixation and nutrient pump action of deep penetrating roots
6. Use of insect-repellent mulch species.

FIG. 15. DIAGNOSIS AND DESIGN - CAUSAL DIAGRAM

The partial causal diagram depicts causes of food problems in the mixed farming system of Kathama, with suggested technological interventions. (Source: Raintree, 1983).

(hedgerow intercropping) with woody perennials in food crop plots (Figs. 15 and 16); enrichment planting and treatment of existing vegetation (and site) in small plots of degraded grazing land; establishment of small fodder lots on protected cropland, fallow or grazing plots; and establishment of living fences for fuelwood and/or fodder. The purpose of these trials was to implement the technologies derived from the D & D survey and to follow some on-farm trials through the full cycle of iterative D & D procedures so as to test, refine, and demonstrate the methodology. The specific technologies tested were useful by-products of the study, applicable to the larger scale D & D study and to the agricultural development of the area.

Preliminary results from the grazing land species trials by Vonk (1983) (Table 4) indicate a need for improved methods of direct-seeding and other low-imput methods of plant propagation and establishment. Where nursery seedlings were successfully established there was a need for low-input pest control technologies and/or more rigorous selection of pest-resistant species. Termites were a major problem at these sites. Better protection and/or preventive design against browsing are also necessary, given the damage sustained in many of the trials (Vonk, 1983). The alley cropping trials were also established with seedlings (after direct seeding failures) using Leucaena leucocephala (Var. Peru) and Cassia siamea hedgerows[1], superimposed on a plot of intercropped maize (Zea mays) and pigeon pea (Cajanas cajan) (Vonk, 1983). The hedgerows have been coppiced for two seasons at 30 and 60 cm heights (in respective segments throught the field.) The mulch has not yet had a major effect but both stickwood and mulch have been harvested twice and the hedgerows have exhibited vigorous growth within the dryland context. Some variations on the design

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1. Hedgerows are composed of alternate Leucaena leucocephala and Cassia siamea plants at 0.5 m in row spacing and 3 m between -row spacing.

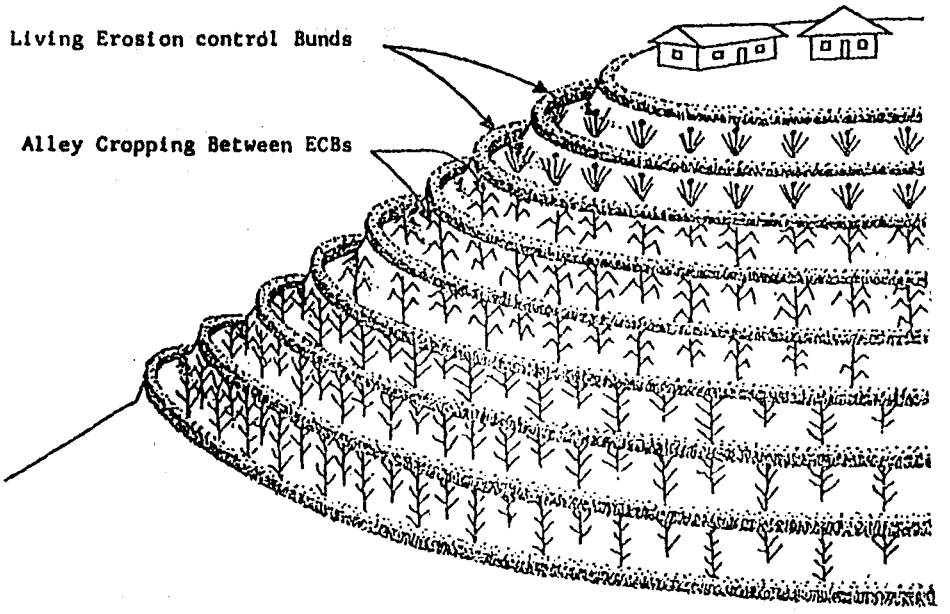

FIG. 16 A HILLSIDE ALLEY CROPPING SYSTEM

(Source: Raintree, 1983;
ICRAF, 1983)

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1. As an alternative to bunds, rows of Guatemal grass (Tripsacum laxum) on the contour may help to control erosion and produce fodder (S. Chinnamani, personal communication, 28-6-1984).

	firewood	coppicing	pollard/poles	fodder	leaves	animal feed	food/fodder	shade/food	honey	water and soil conservation	windbreak	hedge	living fence	living fence	mulch	shade/mulch	shade	agroforestry	resistance to drought	agroforestry	resistance to disease	erosion control	living fence	living fence	living fence	living fence	living fence	living fence	living fence	living fence	windbreak
Leucaena leucocephala																															
'K8'	x	x	x	x	x	x	x	x	x	x			x	x						x	x	x	x	x	x	x	x	x	x		
'K28'	x	x	x	x	x	x	x	x	x	x			x	x						x	x	x	x	x	x	x	x	x			
'Peru'	x	x	x	x	x	x	x	x	x	x			x	x				x	x		x	x	x	x	x	x	x	x			
Cassia siamea	x	x	x	x		x				x	x					x		x	x	x							x				
C. sturtii	x	x			x					x									x					x	x						
Atriplex nummularia	x	x			x			x	x	x								x						x	x						
Sesbania grandiflora	x	x			x	x	x			x			x	x										x	x						
S. bispinosa	x				x		x			x				x				x						x	x						
S. sesban	x	x			x		x			x				x										x	x						
Styloxanthus scabra		x			x					x			x					x							x						
Zizyphus mauritiana	x	x			x	x	x					x	x			x	x				x	x	x	x	x						
Prosopis chilensis	x	x	x		x	x	x	x	x					x				x						x	x						
P. juliflora	x	x	x			x	x	x	x			x	x	x				x						x	x						
P. nigra	x	x	x		x	x	x		x					x				x						x	x						
P. pallida	x	x	x		x	x	x		x					x										x	x						
Grevillea robusta	x	x	x	x				x	x							x								x		x					
Acacia albida	x	x	x		x	x	x	x	x			x		x				x							x			x			
A. tortilis	x	x			x		x	x	x			x					x	x						x							
A. holosericea	x	x			x			x						x				x	x					x							
Parkinsonia aculeata	x	x			x	x	x		x			x	x	x				x				x		x	x						
Croton megalocarpus	x	x	x	x									x					x				x									
Jacaranda mimosifolia	x	x	x																							x					
Tamarindus indica	x				x	x	x					x	x	x												x	x				
Azadirachta indica	x	x	x	x				x	x	x					x	x	x								x						
Melia azedarach	x	x	x	x				x	x	x						x	x								x						
Acrocarpus fraxinifolia	x			x										x										x	x						
Casuarina equisetifolia	x	x	x	x	x				x					x				x						x	x					x	
Balanites aegyptica	x	x	x		x	x	x	x	x			x				x	x								x						
Moringa oleifera						x										x															
Samanea saman	x	x	x	x	x	x	x	x	x				x	x		x	x							x	x	4					

TABLE 4: RECOMMENDED SPECIES LIST BASED ON FARM TRIALS AND OBSERVATIONS IN SIMILAR ENVIRONMENTS

Excerpted from Vonk, 1983.

References: Fernandes, 1983.
Getahun, 1983
Haller, 1981
Barrow, 1982
National Academy of Sciences, 1980
Buck and Teel, 1983

have been suggested by other farmers in the area during visits to the farm trials. Several farmers would place single or double rows of M.P.T.'s* for mulch-and-fuelwood or mulch-and-fodder on or along the bench risers of their terraced cropland. Others expressed an interest in blocks of mulch-fuelwood and polewood (small timber) trees. Some farmers with hedgerow trials have also begun to use the Leucaena as a dry season fodder bank to supplement the maize stover and pigeon pea leaves that farmers normally allow cattle and goats to browse/graze in September (Rocheleau, 1984). In addition to the farm trials, team members observed the performance of indigenous and exotic trees and shrubs under normal conditions, as well as their response to prunning and water-harvesting treatments. (Vonk, 1983). Published data and reports from trials at similar sites (A. Getahun, personal communication) also provided indications for modification and expansion of AF trials at the site (Vonk, 1983; Teel, 1984). Several promising indigenous and exotic species were identified for further application in AF designs for Kathama (Table 4) within the continuing D & D cycle in the farm trials.

D & D Larger- than-Farm Scale - 1st Cycle

The larger-than-farm D & D took the prior studies of self-help groups and the farm level results from cropland and small grazing plots as a point of departure. The purpose of this endeavor was two-fold:

1. to extend the D & D procedures to development of productive adoptable AF technologies for small group or farmer management of public, semi-public or boundary land (including gullies, degraded hillslope woodlands and grazing lands, roadsides, and property lines);

2. to investigate methods of coordinating watershed management objectives with on-farm management of soil and water resources and use of productive agroforestry technologies.

*Multipurpose trees.

The environmental field reconnaissance, map interpretation, aerial photographic interpretation, and landscape analysis study identified soil erosion and excessive runoff as major landscape problems (Figs. 12 and 13; Table 5). The drainage network emerged as the predominant structural landscape feature in need of stabilization; it formed the basis for further stratification and detailed study at the Kathama site. A more detailed qualitative analysis including informal interviews, cartographic analyses and detailed field observation was conducted in two small catchment sub-units (Fig 9 sites 1 and 3). The diagnostic maps for sample sites in catchments 1 and 3 show the land cover, sources of excessive overland flow, points of runoff concentration, and active sites of channel and gully erosion (Figs. 17 and 18).

The site along the Athi River (fig. 17) shows a close association of degraded compacted grazing land (b on map) with active gully erosion. In this case the grazing land and cattle paths to water were the major immediate causes of gully erosion. However, the same plots had been previously cultivated, exhausted and subjected to severe sheet erosion (loss of topsoil, exposure of subsoil over much of the area(b)). The owner of one of the larger degraded plots reported that productivity was so low he was considering leaving the grazed plot fallow to recover. He indicated other recovered plots nearby, the time taken to reestablish vegetation and the variability of results based on soil type/condition. He was less concerned about gully erosion since it was not well developed enough on his own land to directly threaten farm production or use of major footpaths.

The hillslope site on the Kanzalu Range (Fig. 18) also illustrates the role of compacted grazed woodland and degraded grazing lands as sources of excessive runoff and causal agents of gully erosion on croplands and paths downslope. In this more densely populated catchment the improperly constructed bench terraces,

Table: 5: SUMMARY OF AGROFORESTRY DIAGNOSIS AND DESIGN FOR THE COMMUNITY AND SURROUNDING WATERSHED

SUPPLY PROBLEMS	SUSTAINABILITY PROBLEMS	CONTRIBUTING FACTORS	AGROFORESTRY POTENTIALS OF COMMUNITY LEVEL
FOOD - Low grain yields throughout sub-location; dependence on imports from other districts, food relief in drought years.	Declining yields predicted on existing crop land; poor yields and land degradation anticipated for newly opened marginal lands.	High cost of fertilizers, inadequate supply of manure, and low soil fertility; inadequate labor for weeding at peak demand periods; introduction of grain crops inappropriate to ecological zone; expansion of grain crops onto marginal sites (steep, dry, gullied).	Promote fruit and nut trees to supplement diet through group nursery projects. Mix group vegetable gardens with tree nurseries Promote mulch (green manure) strategy through group participation in farm trials to determine best species, management.
WATER - Inadequate supplies for domestic and agricultural use; uneven distribution of access by wealth, relative location; inadequate development of municipal sources.	Existing water sources subject to deterioration by siltation, flooding lowered water table.	Excessive runoff on grazed lands upslope reduces infiltration and groundwater recharge; floods and siltation plague impoundments, dry river-bed wells.	Use group contacts to locate nuseries, veg. gardens at permanent waterholes on group member's property. Combine water-harvesting with AF experiments using available materials, soil conservation groups; use MPT's and grasses to protect impoundments.
FUEL - Charcoal and brick-burning trees scarce throughout sub-location; high expenditure of time and labor to procure fire-wood; uneven distribution of quality, quantity by land facets, farm size.	Browsing keeps trees at shrub size; Degradation of source areas (soil compaction) is preventing regeneration of favored species.	Overgrazing hillslope woodlands and small plots downslope by all households on slope.	Promote zonation of fuelwood production on upper slope, trade for food; convert selected gullies to ravine woodlots (fodder lots if controlled access). Increase fuelwood production in boundary lands of finely sub-divided landscape.
INFRASTRUCTURE - Drainage roads inadequate to service sub-location; lack of integration within each network and between networks.	Existing roads, drains, crossings threatened by gully erosion, siltation individual (piecemeal) decisions to modify drainage and paths.	Frequent movement of cattle upslope causes severe gullies in midslope woodlands; flash floods remove even trees in gullies; use of sledges for water carts erodes roads, disrupts drainage.	Divert drainage from selected drainage channels to croplands and/or fodder lots. Use vegetation (MPT's, grasses) to define and stabilize permanent drainage and road network, while producing poles, fuel.
RAW MATERIALS - Commercial charcoal and brick-burning tree sources depleted throughout sub-location; shortage of construction poles - purchased from other locations.	Degradation of source areas in over-grazed over-harvested woodlands is preventing regeneration of pole wood species; degradation will hamper future efforts to re-establish favoured species.	Lack of training and infrastructure (physical and organizational) to propagate desired species within the sub-location.	Plant polewood trees on internal farm paths and along roads. Integrate charcoal and brick-burning trees into ravine woodlots, fencerows Develop nurseries, seed collection with self-help groups.
CASH - Reliance on charcoal as cash crop by poor small-holders; almost no off-farm employment; marketing disadvantage relative to nearby towns; remittance income from absentee men sporadic.	Remittance income dwindles, becomes less dependable with time away, and rising urban unemployment; charcoal stock being depleted in adjacent source areas - enterprise not sustainable as is.	Land cannot accommodate new full-sized holdings of young families, food crops given priority; promoted cash crops high risk for zone (cotton), market for other cash crops unreliable.	Integrate fruit (citrus, guava) and nut (macademia, cashew) trees into terraced cropland, with concurrent organization of market channels already used by a few farmers. Incegrate training into group trials, nursery work.
SAVINGS/INVESTMENT - Dry season fodder gap forces untimely sale of goats, sale or loss of cattle; land prices prohibitive - shortage of arable plots.	Degradation and subdivision of grazingland; widespread conversion of grazing areas to cropland preclude maintenance of herd size under current practice.	Best dry season fodder trees (pod trees) have been harvested for charcoal; animals allowed to range freely during long dry season; land conversion to crops.	Use MPT's to sub-divide larger grazing lands for rotation. Use N-fixing species planted in strips or microcatchments to reclaim degraded grazing areas; Plant pole trees for cash on farm and along roads, with tree rights assured (group, individual, through chief)

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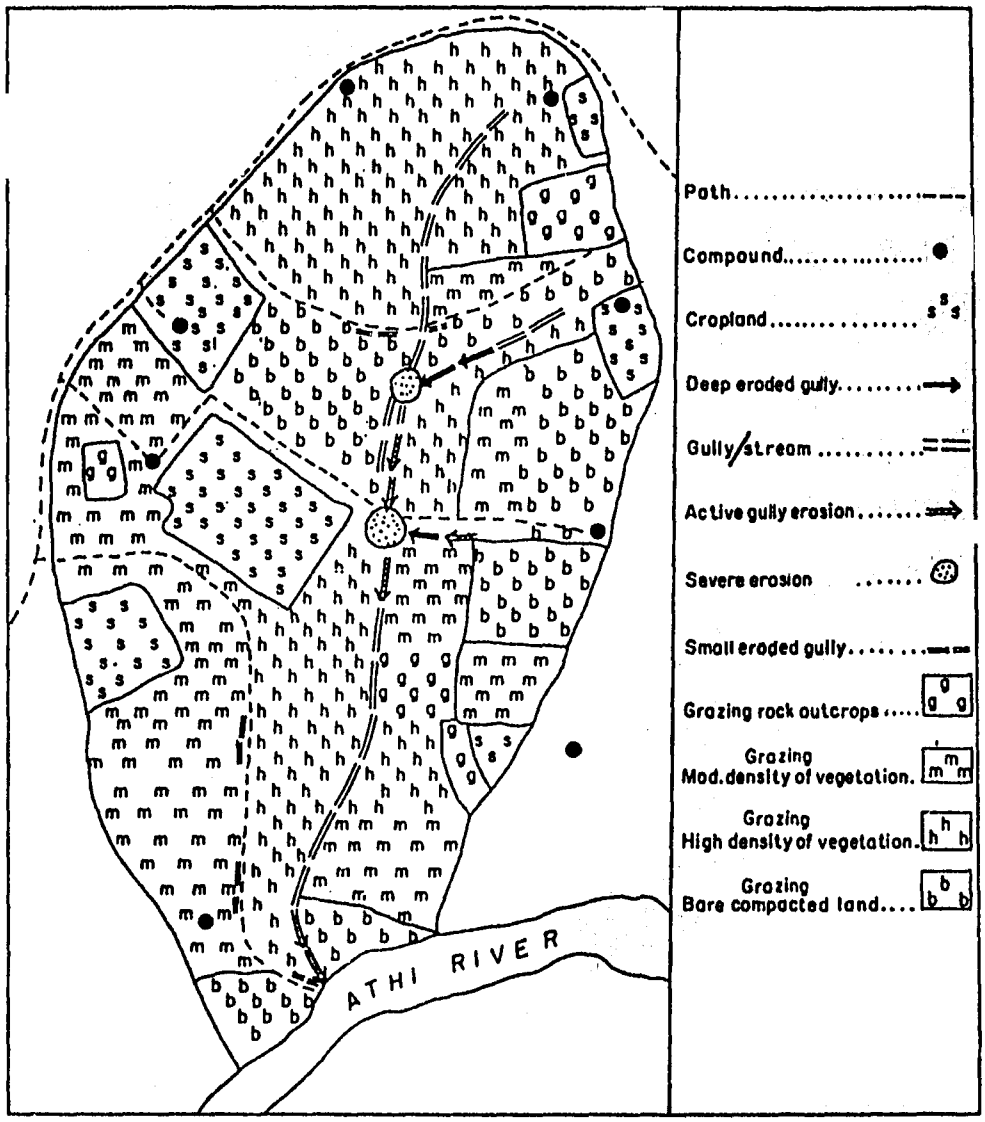


FIG. 17 ULAANI CATCHMENT (3) DRAINAGE AND LAND COVER (Hoek, 1983)

* See Fig. 9 for Location

** Sketch, not to scale

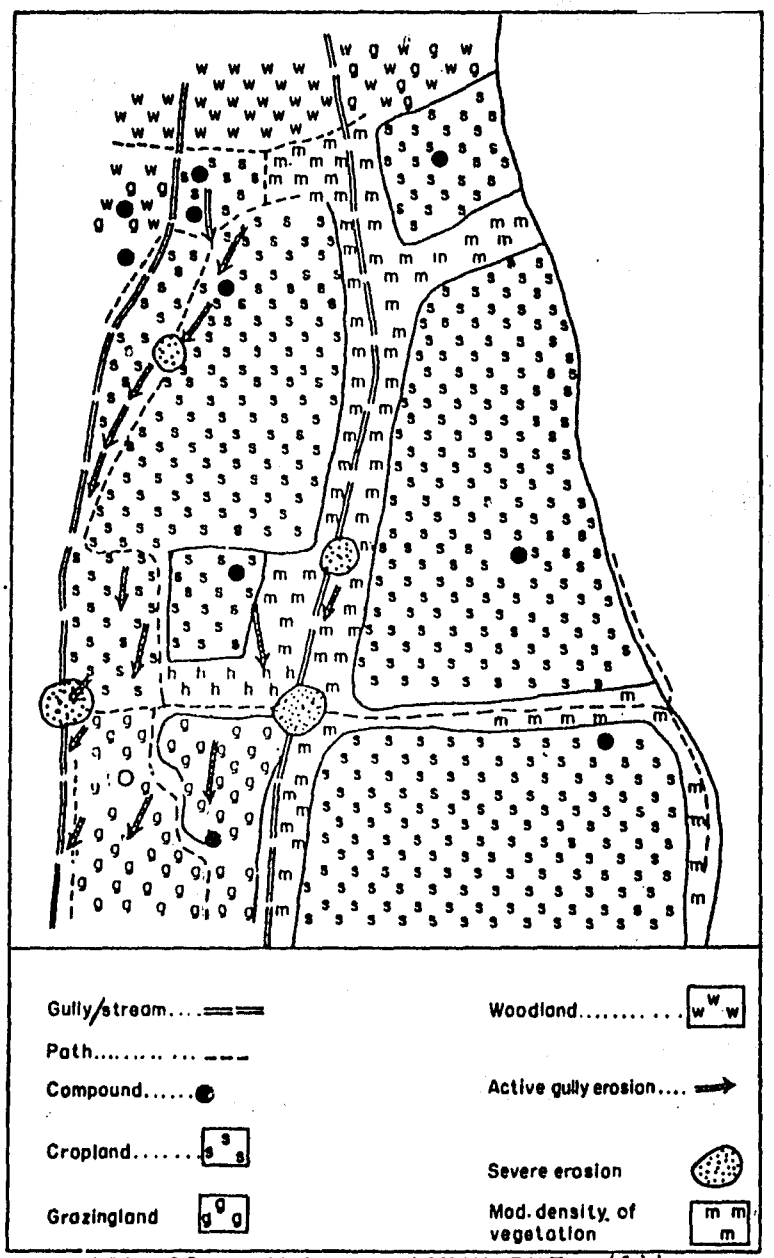


FIG. 18 : KALAMA CATCHMENT (1)*
DRAINAGE AND LAND COVER

* See Fig. 9 for Location

** Sketch, not to scale

60

home compound drainage and paths all serve as points of concentration for runoff, and compound the problems of soil moisture loss upslope and gully erosion on the mid to lower slopes. The drainage network is ad hoc and represnts the cumulative (and often unanticipated) effect of many separate decisions and actions by individual landowners upslope on private and public land and water resources immediately downslope. The drainage network also shows evidence of reactions to downstream effects, in the form of spot treatments by individuals on private lands and by groups on public and boundary lands. Small check-dams in gullies and numerous cut-off drains attest to the interest taken by some residents in some consequences of the disrupted hydrologic cycle in the catchment.

In general interviews about farming practice and land management, some people revealed a high degree of awareness and comprehension vis-a-vis increased runoff from overgrazed and barren areas upslope, and new home and terrace construction. The addition of new drains from these sources was frequently cited as a cause and/or aggravation of gully erosion on downslope farms and public paths. One woman attributed the formation and/or dramatic growth of several nearby gullies to the establishment of parallel roads (e.g. drains) running downslope. Land adjudication was followed by a land survey (ca. 1972) which placed roads between all of the landholdings on the slope, leading to re-alignment of home compound and bench terrace drainage along the new linear network of roads and paths. This same phenomenon has since been observed in many other areas of the slope of the Kanzalu Range as a major contributing cause of gully erosion features. This process had a multiplier effect when coupled with the degradation of upslope grazing land and the poor design of terraces and farm drainage on the fragile hillslopes.

Given the results of the first cycle of diagnostic surveys the team concluded that:-

1. there exists a high potential for direct action on watershed management problems at the Kathama site; and
2. agroforestry can address these problems in part coupled with improved planning of structure placement, choice of techniques and construction.

The first point is supported by the fact that people are aware of the problem, that individuals and self-help groups are already engaged in remedial work at present, and that they acknowledge difficulties with placement of treatment, choice of technology and maintenance/stabilization of more permanent structures. The team also saw a need to supplement or replace temporary structures with vegetation and to increase the productivity of land and labor at such sites vis-a-vis fodder, fuel timber and/or food production.

The applicability of agroforestry technologies was supported by the results of the farm level D & D exercise, both in terms of fodder, fencing and timber problems on-farm and in terms of the success of some species and AF designs tested on-farm. The watershed level D & D exercise indicated additional needs for multipurpose trees aside from the soil and water conservation aspects. Discussions with individuals and women's groups about fuelwood and fodder availability and management revealed that smallholders rely very heavily on off-farm fuelwood and fodder sources and many consider fuelwood supply a problem. The current role of gully sites as off-farm grazing lands and fuel wood sources for many households, further strenthens the case for maintaining these productive functions at such sites under a sustainable system.

Gully reclamation,coupled with more intensive management and increased fuel/fodder production emerged as a priority for exploratory trials, given the existing involvement of self-help groups in gully reclamation. Other "leverage points" for application of AF or combined AF/soil and water conservation technologies included: the degraded hillslope grazing lands (sources of excessive runoff and sources of fuelwood and fodder for many households); the roadsides and boundaries (often points of concentration and channels for runoff); soil conservation structures on croplands (often unstable and/or unproductive); and home compounds (points of concentration for runoff, convenient for closer management/ protection of plants).

The development of AF designs for these niches focused on the Kalama catchment (Fig.9 Site 1) because of the higher activity of self-help groups, the higher population density and the diversity of problems and potential solutions concentrated in one site (Fig. 18). The landscape design for the sites as a whole emphasized structures (Fig. 19) along linear features such as gullies (Fig. 20) and several types of planting on areas and on linear features (Fig. 21). Designs for treatment of grazing lands (Figs. 20 and 21) included enrichment planting (grasses, shrubs, trees) combined with microcatchments (Fig. 22), pitting (Figs. 23 and 24) cut off drains (Fig.25) contour wattling (Fig. 26) and contour planting in furrows (Fig. 27). Designs for improved vegetation on existing structures and features ranged from alley cropping (Fig.16) or planting on bench risers in cropland (Fig. 28) to planting of more productive tree, shrub or grass combinations on boundaries and around home compounds (Fig. 29). "Filler" planting along and in gullies was also suggested, as well as border plantings on roadsides (especially in/around drains). All of the structural interventions will of course require site-specific design calculations based on rainfall intensity, slope and runoff.

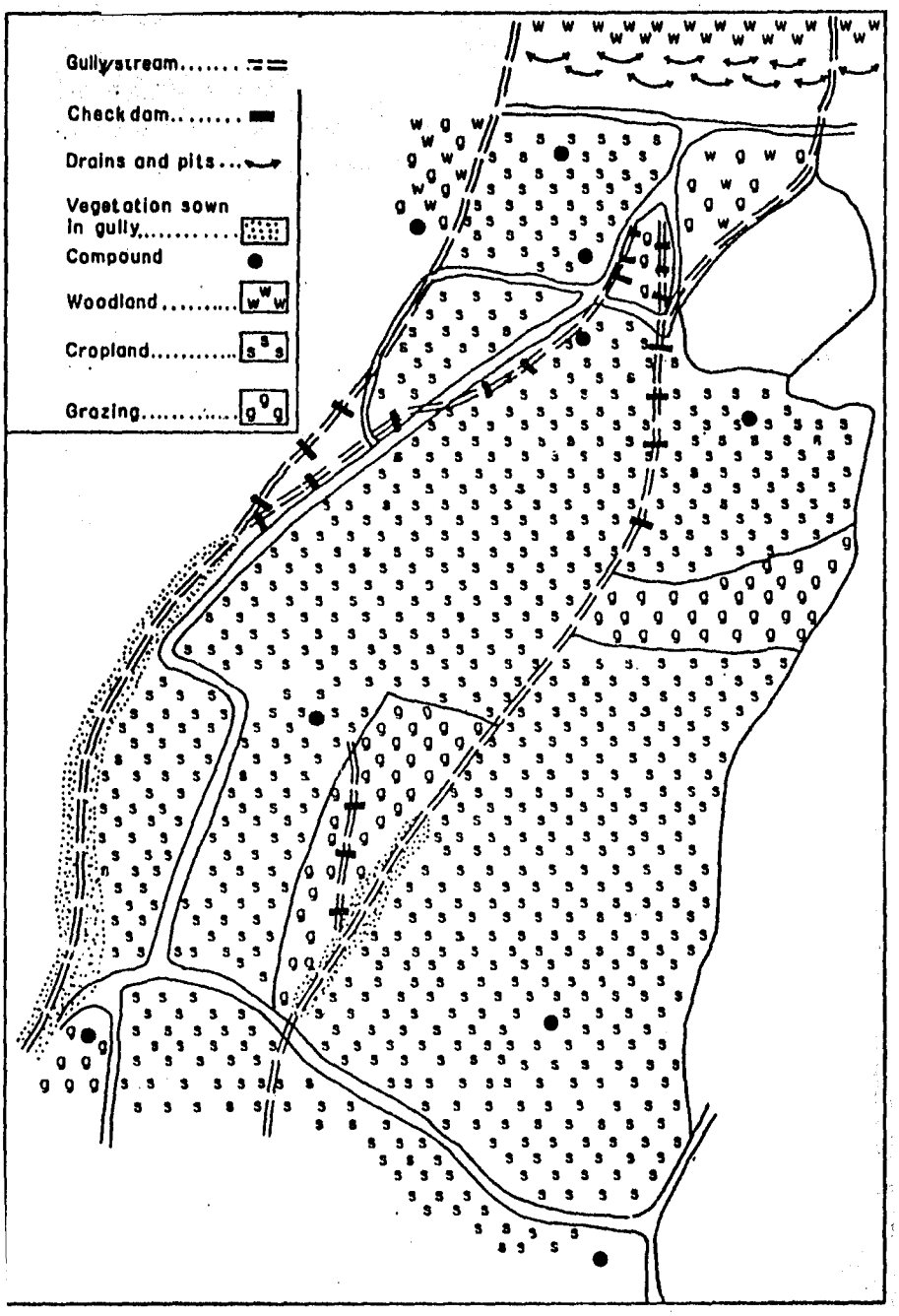
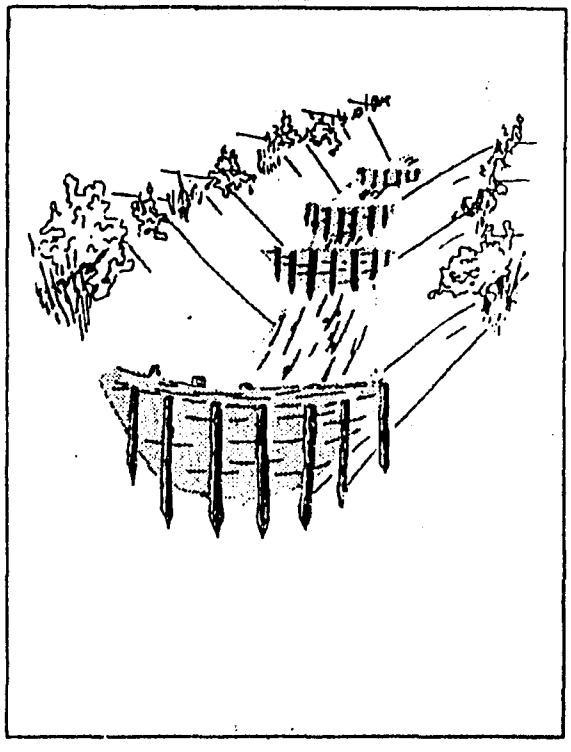


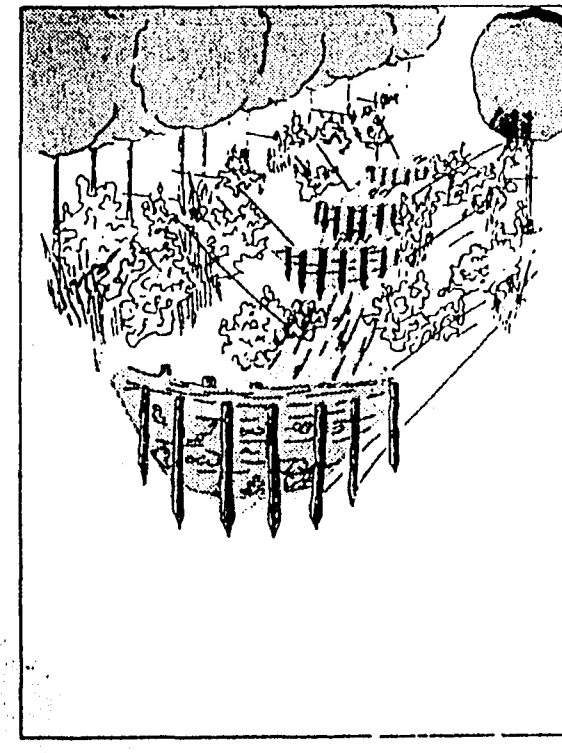
FIG.19:DESIGN CATCHMENT KALAMA I

(Hoek, 1983)

FIG.20: PRODUCTIVE GULLY RECLAMATION DESIGN



Stage 1.
Wooden checkdams and a bed of stones, brush, and grasses are placed in the gully.
(1 to 2 seasons)



Stage 2
Recovery of natural vegetation is supplemented by tree, shrub and grass planting, around, in, and along the gully.

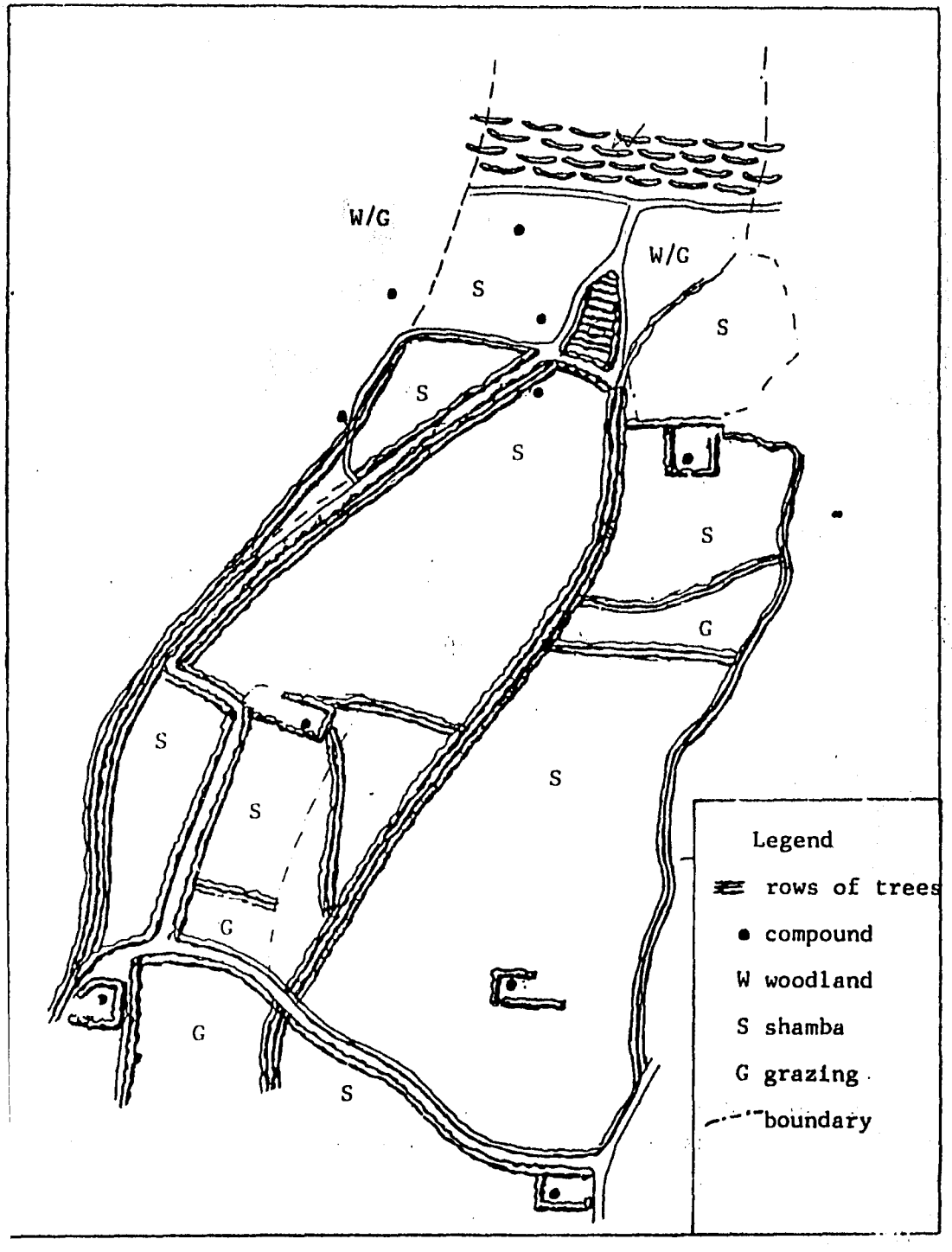


FIG. 21 DESIGN FOR PLANTING, KALAMA CATCHMENT

(Hoek, 1983)

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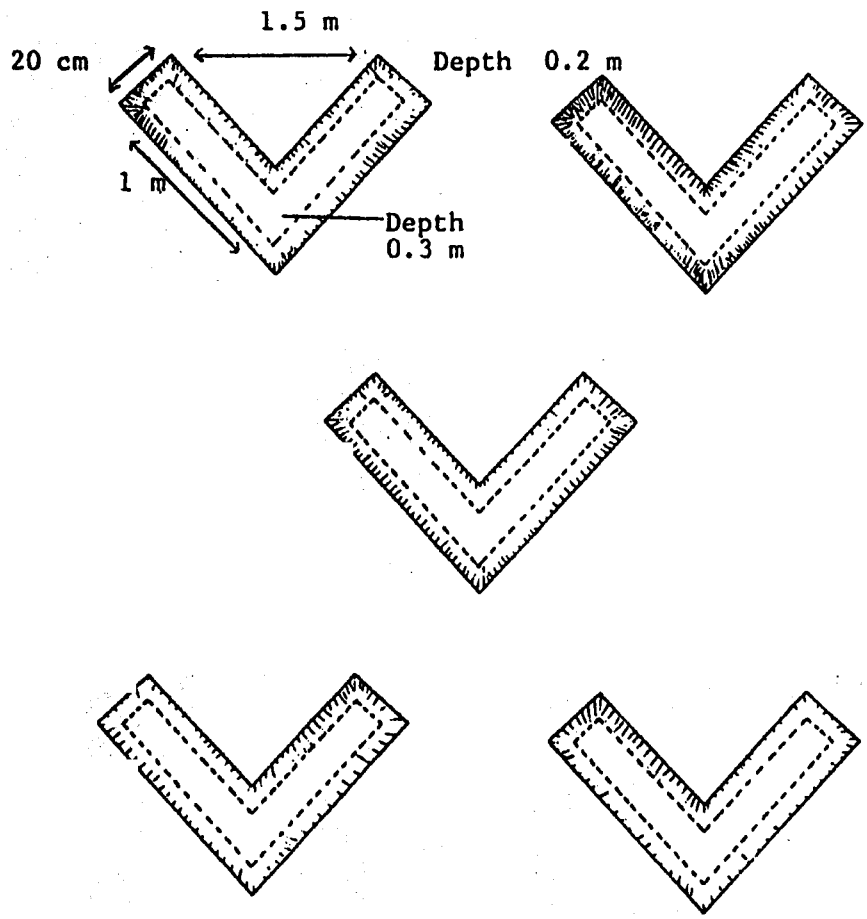
FIG. 22: ARRANGEMENT OF MICROCATCHMENTS FOR WATER HARVESTING AND ENRICHMENT PLANTING.

Approximate dimensions suitable under conditions in Kalama catchment:



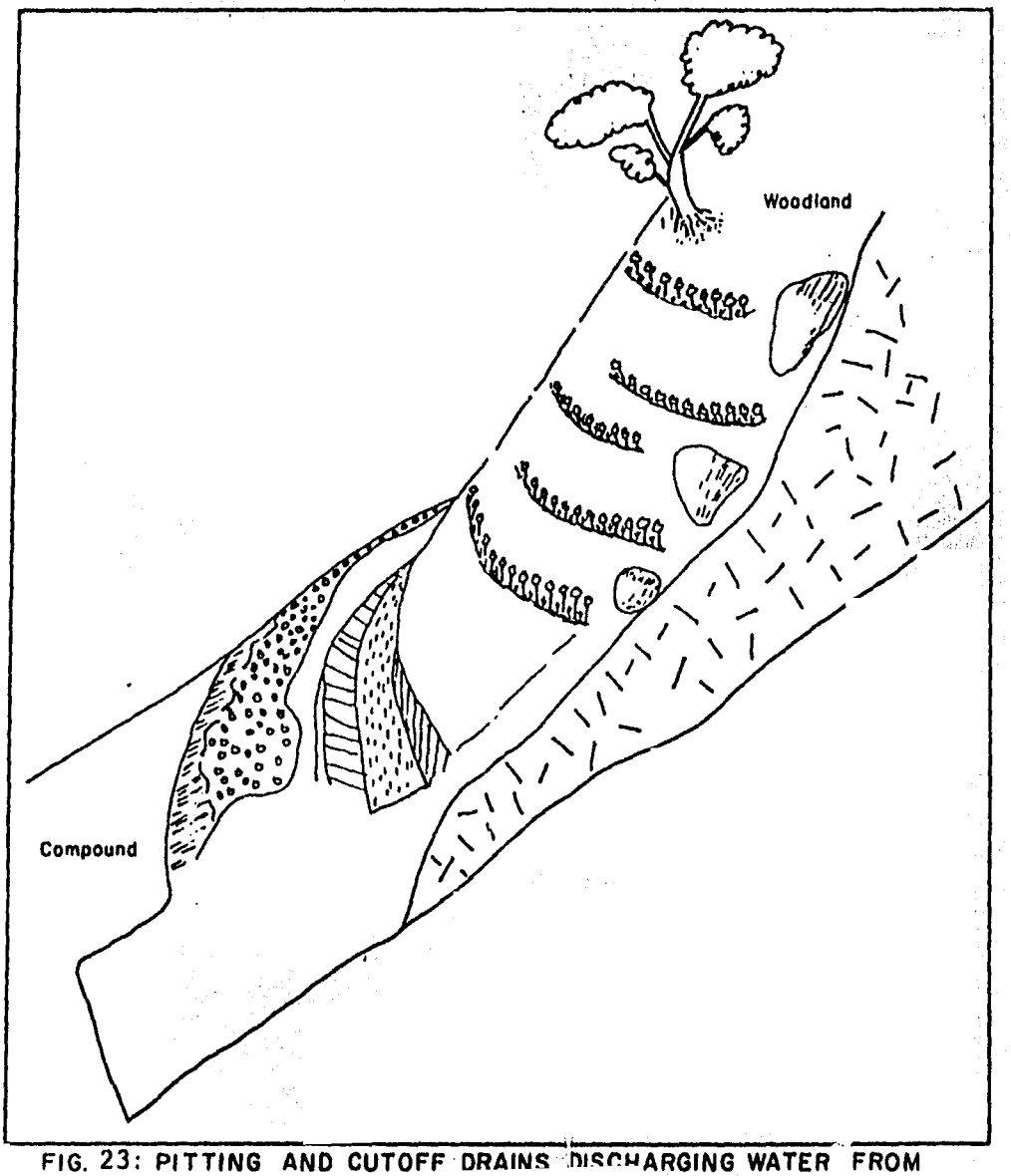
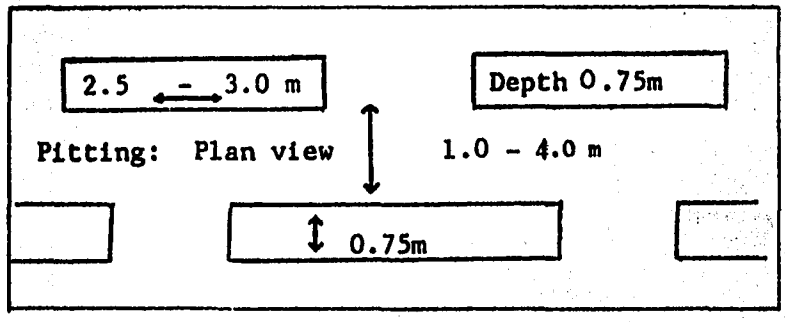


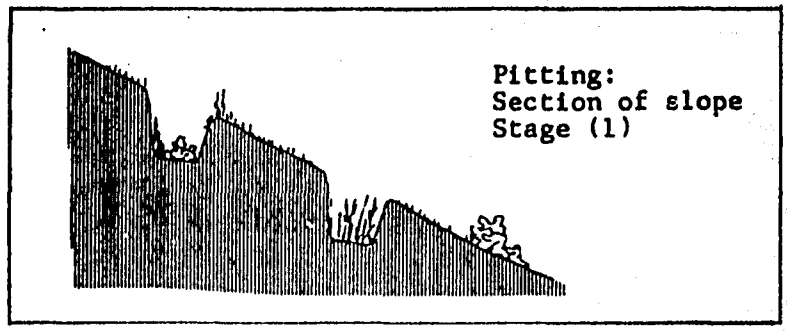
FIG. 23: PITTING AND CUTOFF DRAINS DISCHARGING WATER FROM HILL SLOPE

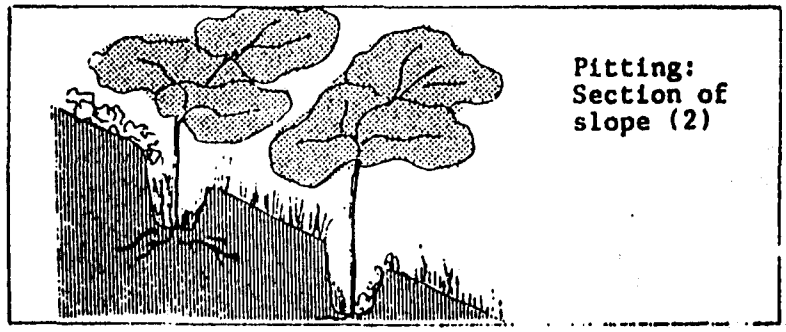
(Hoek, 1983; Wenner, 1980)

FIG: 24: DETAIL

PITTING FOR WATER HARVESTING,
INCREASED PRODUCTION ON SLOPES





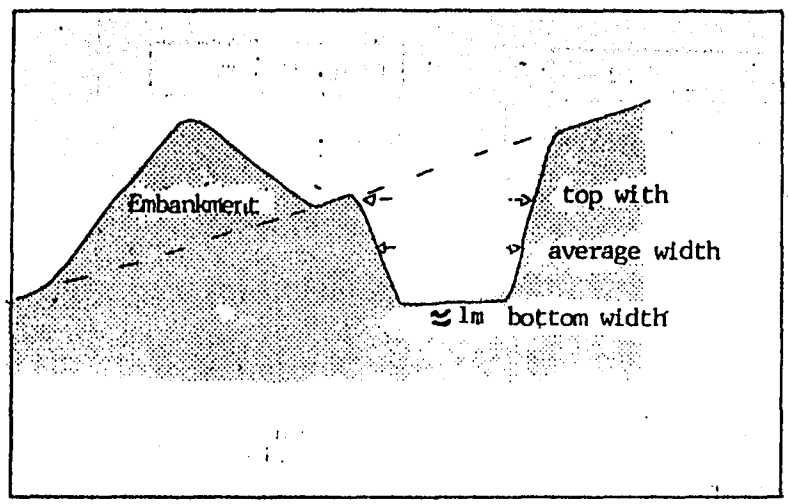


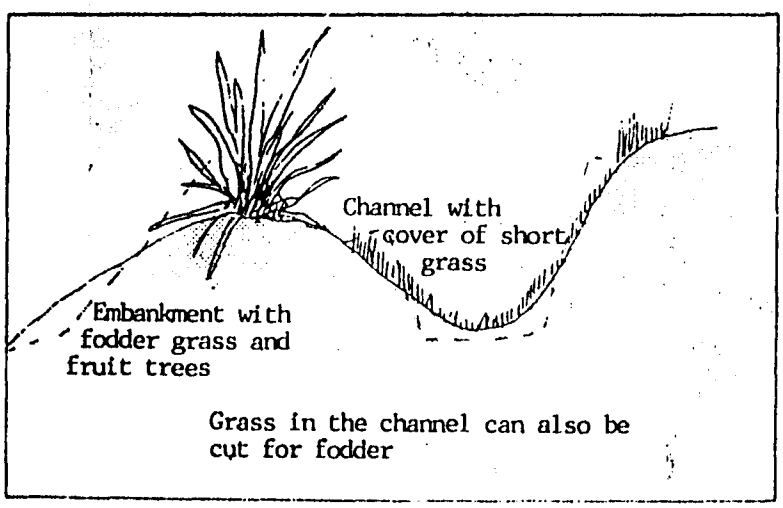
(Hoek, 1983)

FIG. 25: DETAIL: CUT-OFF DRAIN

Stage 1. Structure

Stage 2. Planting





(Hoek, 1983: Wenner, 1980)

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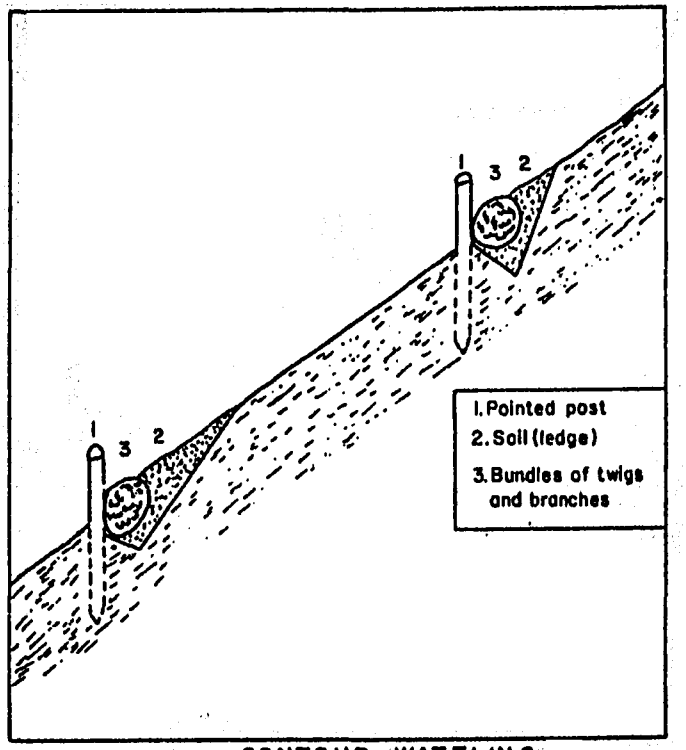


FIG. 26 CONTOUR WATTLING

(Hoek, 1983)

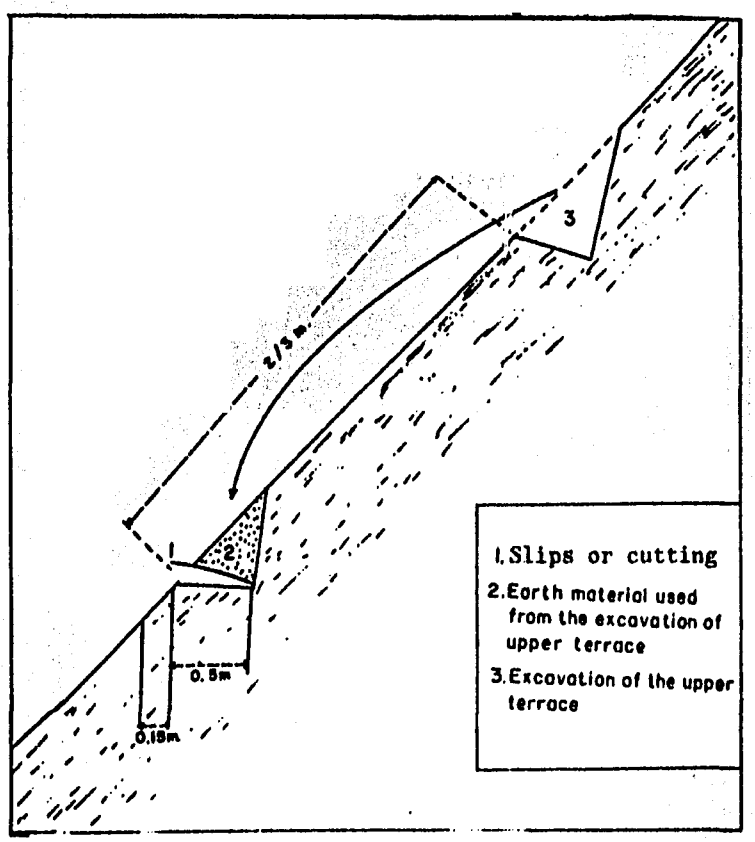
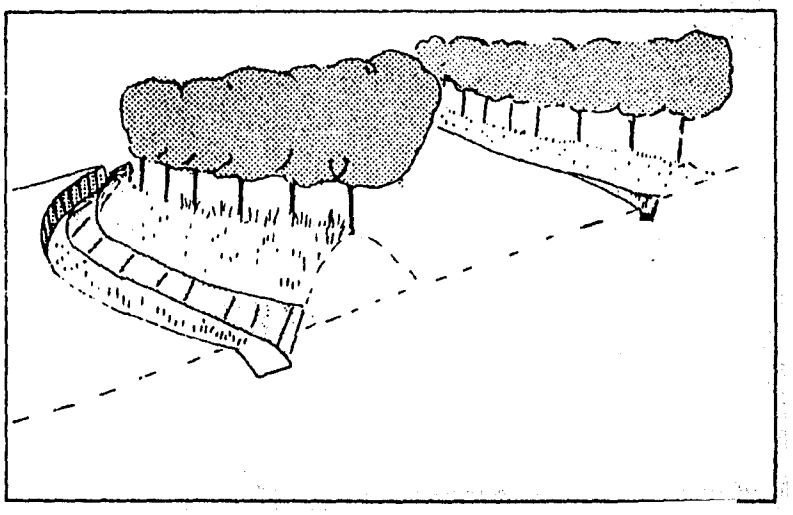


FIG. 27 : CONTOUR PLANTI
(Hoek, 1983)

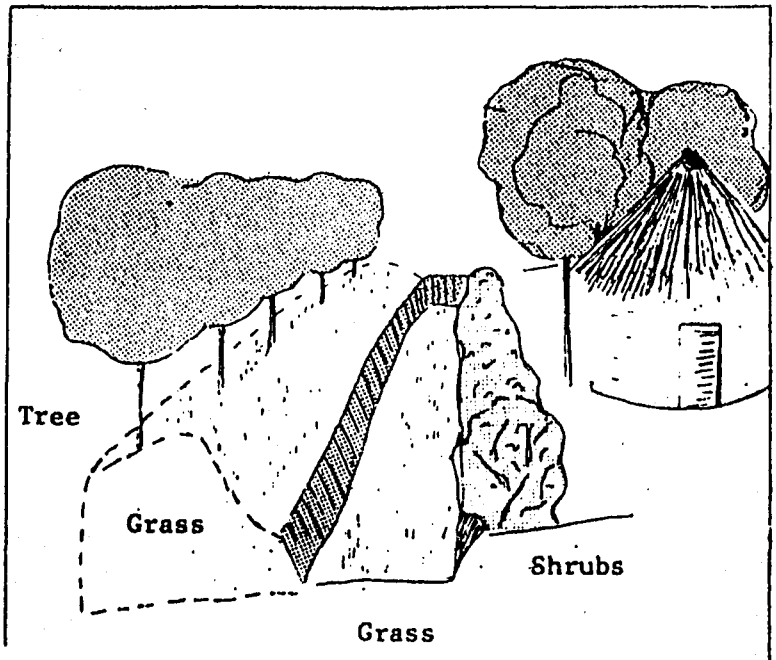
FIG.28: FANYA JUU TERRACING



Grass and trees on the benches, grass in drains

Hoek, 1983)

72



Use of internal boundaries for soil conservation, water harvesting, drainage and production.

FIG. 29: DRAINAGE AND PLANTING AROUND HOME COMPOUND FOR FUELWOOD AND FRUIT PRODUCTION

(Hoek, 1983)

The resulting integrated landscape design in cross section view (Fig. 30) shows the fit of these technologies into a productive sustainable agricultural landscape (Fig. 31). The before-and-after oblique view design sketches (Figs. 32 and 33) show the extrapolation to the larger study site along the Kanzalu Range. The current condition and the ideal implementation of the design are juxtaposed to illustrate the scope of potential effects.

In order to better evaluate the feasibility and probable effects of the proposed design, a parallel ecological and spatial analysis was conducted to quantify some of the existing conditions and potential changes. A representative small watershed(1) was chosen on the Kanzalu Range (Fig. 34) including the Kalama catchment. Results included areas of different land use and land cover categories (Figs. 35, Table 6,) the total length and area of various linear landscape features (Table 7) and the relationship of various land use and land cover types (including linear features) to runoff, erosion and production problems and potentials (Table 8)(2) The analysis also extended to the functional relationships between various land uses and the relation of structure and function in the landscape.

In this landscape linear features can play a major role in production (Table 7) as well as in soil and water conservation. The most prominent linear features are the drainage and transportation networks (Fig. 36). Interpretation of aerial photo graphs(3) revealed the importance of property and internal plot

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(1) Choice of the small research sites and the representative watershed were based on a knowledge of the area, and on interpretation of aerial photographs. However, methods could be devised for choosing sets of sample watersheds from satellite imagery, aerial photographs, or maps.

(2) Areas and lengths measured, runoff and erosion rates estimated.

(3) Aerial photographs; 1980; black and white; 1:20,000; property of Machakos Integrated Development Project, Machakos.

FIG. 30: INTEGRATED AGROFORESTRY SOLUTIONS NESTED IN THE LANDSCAPE

Tree, shrub and grass combinations

on the farm

on boundaries, in gullies and along roads

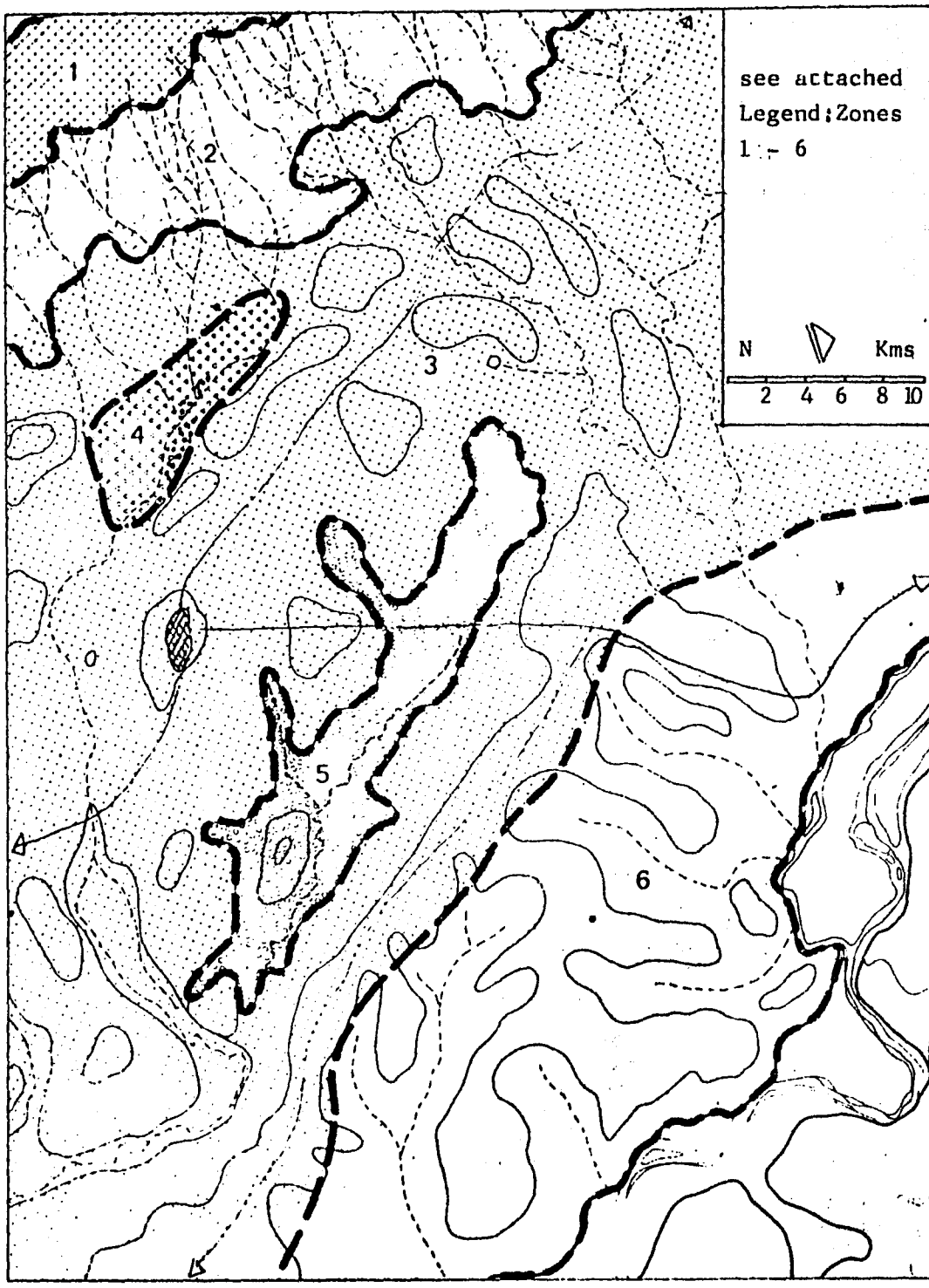
Landscape Niche Affected:

Gully and grazing lands		Cropland	Home compound	Internal boundary zone	Cropland	Road
erosion control in gully and grazing land for: Improvement of the drainage condition by -checkdams and natural vegetation - control of grazing and improvement of grass, fodder and fuelwood production	Living fences	grass and fruit trees on the benches of the terraces for: -erosion control -improvement of fruit, fodder, wood and grass production	trees around the home and boma (corral) for: fodder production, shade, shelter and decoration	grass for: erosion control, production of fodder	hedgerow system: trees are planted in rows between the crops to: -provide mulch, fodder and wood -control erosion, improve drainage condition	trees along the road or path for: shade and decoration, improvement of drainage condition

(Hoek, 1983)

15

FIG. 31 GENERAL SPECIFICATIONS FOR LAND AND WATER DEVELOPMENT BY LAND UNITS



(Hoek, 1983)

LEGEND, FIG. 31

1. Woodland Kanzalu Range, Upslope:

   - slow down and divert the runoff
   - direct runoff to stable or permanent drains
   - improve the infiltration capacity of the soil

2. Gullied Mid and Lower slopes:

   - improve the drainage condition (see 1)
   - stabilise the gullies with soil conservation structures and improved vegetation

3. Undulating Uplands:

   - changes upslope, as mentioned in (1) and (2) will improve the drainage condition and the channel stability in this zone.

4. Depressional Area:

   - optimize the use of this relatively wet area
   - protect the existing dams against erosion

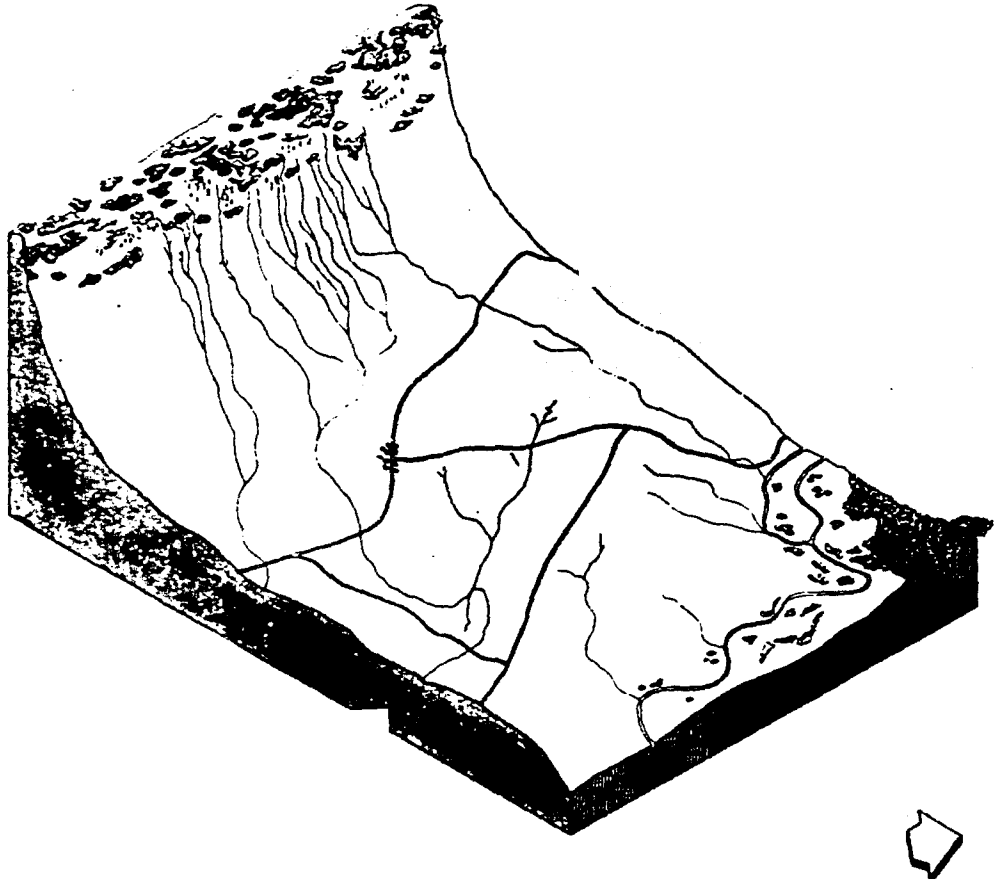
5. Black Cotton Soils, (vertisols):

   - improve the management and control grazing to allow recovery of natural vegetation.
   - promote growth of useful shrubs and trees adapted to this soil.

6. Slopes to the Athi River:

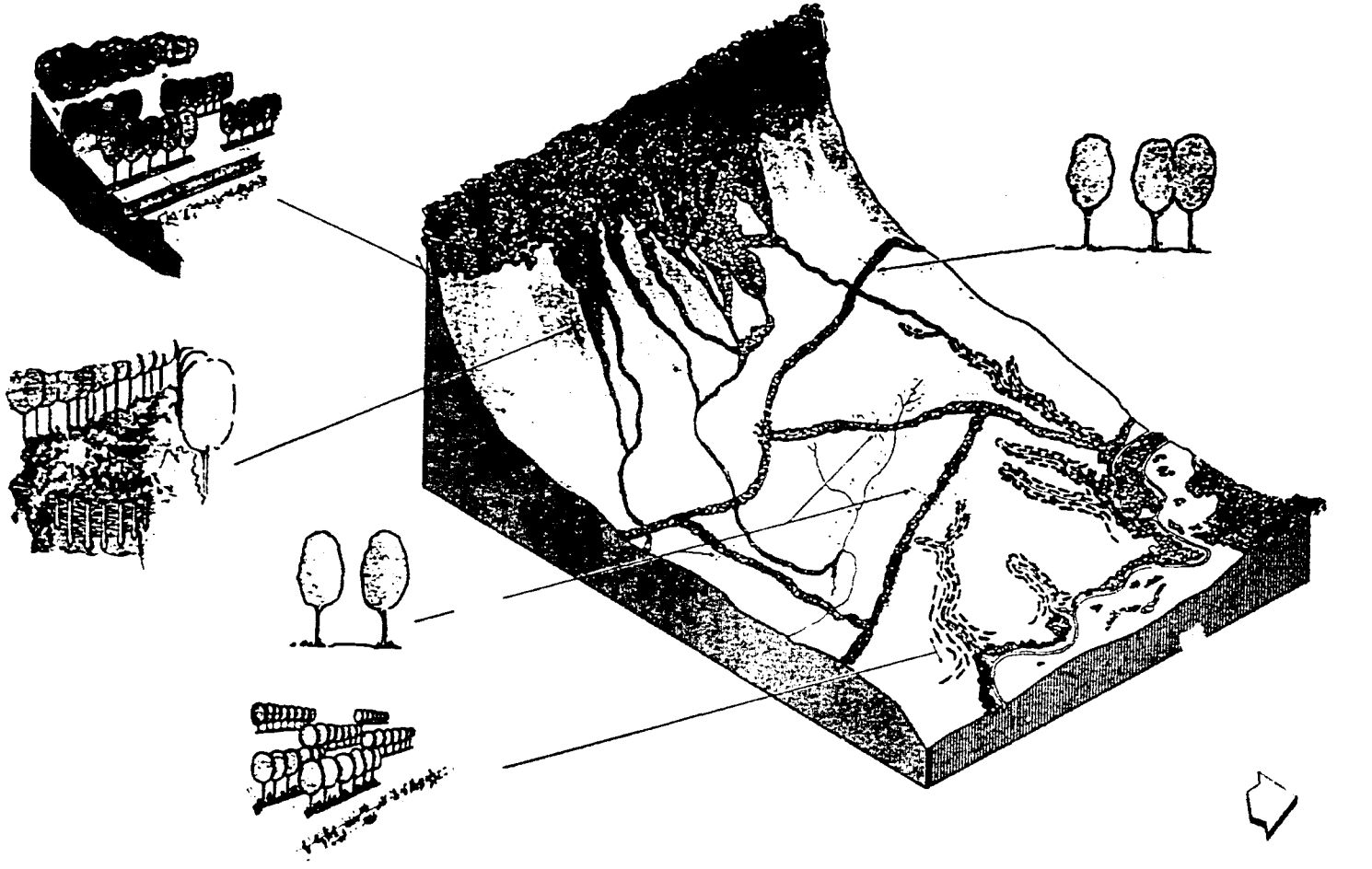
   - improve the drainage condition of the grazing land by closer control of herds
   - combine soil conservation structures with the planting of grass and trees.

Fig. 32



PRESENT SITUATION

Fig. 33: Landscape Design Sketch



(Hoek, 1983)

FIG. 34: STUDY AREA FOR DETAILED LANDSCAPE ANALYSIS AND GROUP WORK

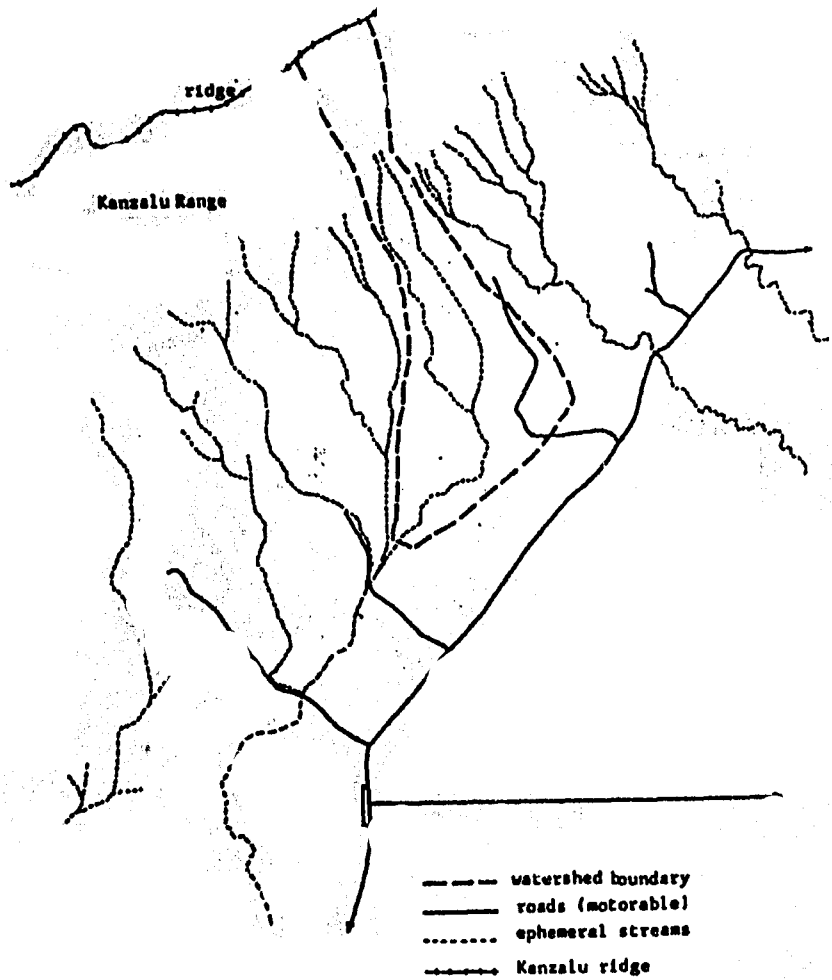


FIG. 35: LAND USE IN THE WATERSHED

1. Woodlands - some grazing
2. Pasture - sustainable
3. Degraded grazing lands
4. Cropland
5. Public land, sparse cover

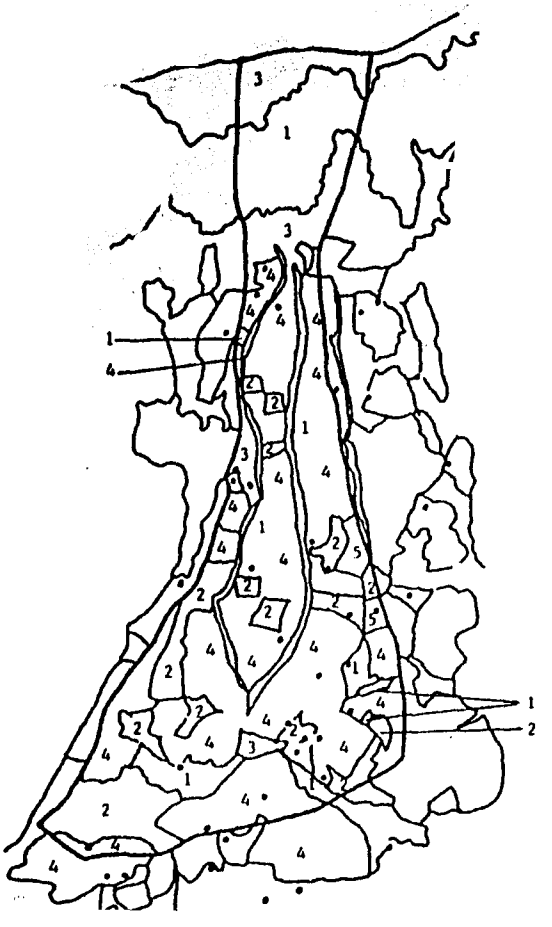


Table 6: Land use in the Watershed Aggregated by Category

	Wooded Ravines	Grazed Woodland	Sustainable Pastures	Degraded Grazingland	Cropland	Public Lands	Total
ha	5.6	17.3	18.0	11.6	52.8	1.0	106.5ha
% of total	5%	16%	17%	11%	50%	1%	100%

Table 7: Production Potential* Estimates From Length and Area of Linear Features and Boundaries

	Roads and Paths		Gullies and Channels		Property and Internal Boundaries		Total
	Major	Minor	Major	Minor	Existing	Bench Risers or Rows	
Length m	2,600	2,400	4,200	3,200	8,340	15,000(3)	35,740 m
Width m	2	1	3	2	1	1	
Area m^2	5,200	2,400	12,600	6,400	8,340	15,000	49,940 (5.0ha)
Potential fuel production kg yr^{-1}	10,400	4,800	25,200	12,800	16,680	30,000	84,880(84.9t) – 100,000kg (100t)
% of demand in watershed	7%	3%	17%	9%	11%	20%	67%
Potential fodder production trees kg yr^{-1}	10,400	4,800	25,200	12,400	16,680	15,000	84,880 kg yr
grass kg yr^{-1}	4,576	2,112	12,600	6,400	6,458	6,600(riser only)	38,746 Kg yr
Combined kg yr^{-1}	13,420	5,856(4)	16,632(2)	8,448(2)	20,943(4)	19,356	84,655 kg yr
Assume 5 kg A.U. day	6%	3%	8%	4%	6%	6%	39%

1. Estimated assuming 1 lopped tree per m^2 producing 2kg DM leaf and 2kg DM wood $tree^{-1}$ and .55kg m^{-2} yr^{-1} grass (1.44kg m^{-2} $season^{-1}$) and 1kg m^{-1} of Napier grass in gullies (based on rapid appraisal and data from Otarola and Ugaldi, 1983; Baggio, 1982).

2. $\frac{2}{3}$ area in grass strips, with $\frac{1}{3}$ area in fodder trees

3. Assume only 500m per farm 30 farms

4. Grass production reduced by $\frac{1}{3}$ to account for weeding near trees.

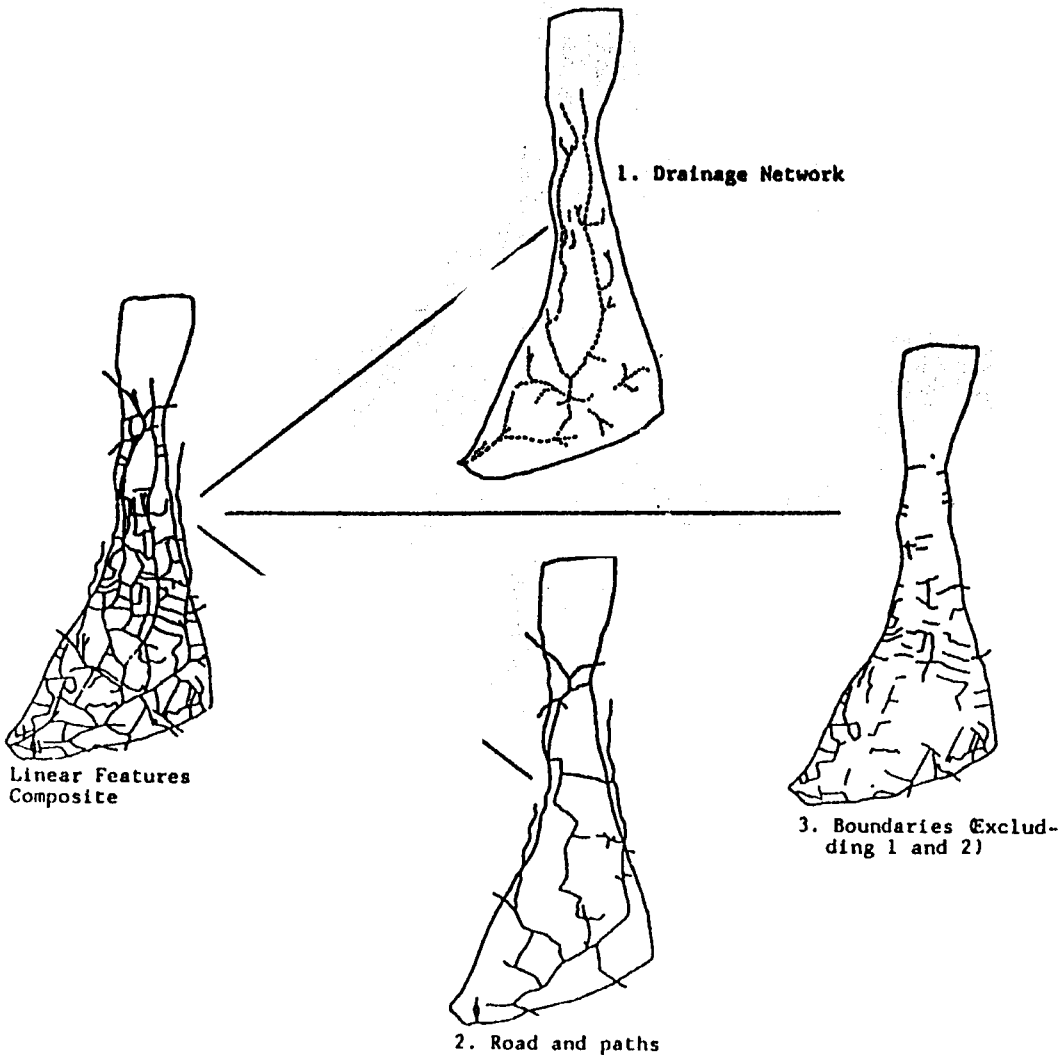


FIG. 36: LINEAR ELEMENTS OF LANDSCAPE WITHIN THE WATERSHED

Table 8. Estimated[1] Ideal Requirements for Structural Treatments and Plants Within the Watershed

Gully repair with related land treatment

Major channels	Minor channels	
4200m	3200m	
No. Check Dam Structures 250[2]	250[2]	
Length of Drains, Diversions	450m	
Volume of storage[3] in pits or micro-catchments in grazing-land upstream	4500m^3	45,000 structures of 0.1m^3 storage each
No. trees and shrubs[4]	25,000	
Napier grass (initial beds for seed, demo.	3,000 units (slips)	

1. Based on rapid appraisal and rough calculations
2. Assume direct treatment of 1,000m. at the upstream end, small structures every 4m
3. Assuming 5cm rainfall storage
4. Assuming grass to be seeded or naturally re-seeded.

boundaries as well (Fig. 36). Based on relative area occupied these features have a high potential as production sites; 1.8% of total area is in gully and stream borders, 0.7% in paths and roadsides and 2.3% in property and internal boundaries, which places 5% (nearly 5 ha) of the total area in linear features (Table 7). The greater availability of water in gully and stream channels and in roadside or boundary drains also represents a production advantage over many block planting sites, such as grazing lands. Moreover, internal boundaries in croplands and home compounds offer the benefits of existing fences and protection, plus ease of access for maintenance.

Conservative estimates for fodder and fuelwood production potential for drainage, transport and boundary features (Table 7,) indicate that more than 50% of current fuelwood and almost 40% of fodder needs can be met by planting trees, grass and shrub combinations along these ribbons and corridors of land. While this same production could be allocated to blocks, hedgerows or dispersed plantings in grazing and croplands (Table 6), the real or perceived opportunity cost of land utilised may be much higher in cropland and the real costs of establishment and maintenance would be much higher in most grazing lands. The need to protect fodder trees from early browsing may tip the decision in favor of small well-protected fodder lots in grazing plots close to the home compound, depending on available space, species used and proximity to wildlife habitats or cattle and goat trials.

In upslope plots the added incentives of reclamation, soil improvement or water harvesting would, however, often weight the decision in favor of some area treatments on grazing land (Table 8), in combination with carefully chosen placement of road, path, and farm drains planted to productive vegetation.

Compacted and degraded grazing lands may produce 10 to 20 times the runoff and soil loss of the original woodland vegetation (Thomas et al. 1981; Rocheleau, 1984; Greenland and Lal, 1977). In this case the steeper slope, shallower natural soil profile and areal extent of the upslope grazing lands, combined with current land use and soil condition to make these kinds of plots No. 2 and 3 Fig. 35) the major sources of rapid storm runoff on the Kanzalu Range. In terms of area treatments the upslope grazing lands warrant first priority for structural and vegetation improvements. Based on experimental results from similar environments and land use conditions (Thomas et al. (1981) it is reasonable to expect dramatic short term (1-2 year) decreases in runoff and erosion rates under controlled, reduced grazing combined with the proposed treatments. Further reductions can be expected over the long term. Less is known about the indirect impact on groundwater levels downstream due to slower seepage from upslope soils.

Sheet erosion at degraded sites over the last ten years was estimated at 130t $ha^{-1}yr^{-1}$, slightly less than gully erosion estimates (156t $ha^{-1}yr^{-1}$) at the same site. Gully erosion, however, represents the more active process at this time, and threatens more valuable croplands, home compounds and infrastructure downstream. The case for parallel treatment of both interrelated processes does not require detailed quantitative measurements for justification. Detailed planning can proceed on the basis of the available climatological data and the analyses of erosion processes. The estimated number of structures and plants required to fully implement the design is given in Table 8. However, the actual placement of treatments and choice of best site will depend on what is feasible in terms of time, material and labor allocations.

While the potential benefits were estimated during the first cycle D & D, several questions remained as to feasibility, cost and distribution of costs and benefits, given the existing conditions and practices in Kathama. These questions were left to the second cycle of D & D, on-site trials with self-help groups and selected households (to complement the continuation of the second cycle on the original 10 farm trials).

D & D Larger-than-Farm Scale 2nd Cycle

The team initiated a small pilot project within the Kalama catchment to further explore the research methods, technologies and organizational activities necessary to implement the landscape design within the D & D context. The excercise also provided a practical context in which to test and evaluate the method, the design and the component technologies for application in similar environments in Machakos District (ranges and hillslopes, Zone 4).

The specific objectives of the pilot project were:

1. to develop AF methods suitable for implementation, monitoring and evaluation of larger-than-farm scale group projects;
2. build rapport with the groups and assess their organizational and technical capabilities and potential;
3. modify AF designs/implementation plan to fit (2)
4. to integrate proven or promising AF technologies (for feed, timber, fodder and food production) into existing and planned soil and water conservation works on and off farm within the study area (in coordination with MIDP soil and water conservation efforts);
5. to assess the time, personnel and materials required for (4), and to modify AF designs/ implementation plan accordingly;
6. to identify both indigenous and exotic multi-purpose trees for future inclusion in landscape designs for soil and water conservation under similar conditions;
7. to test and/or monitor promising species and AF technologies and to promote proven species on private farm land through liaison with existing groups.

Initial discussions with Mwethya group leaders, the chief, the sub-chief and local extension agents showed a willingness to experiment with productive tree-shrub-grass combinations to supplement soil and water conservation measures. A specific

proposal was presented to one group ($\approx$20 members) to stabilize a small active gully and to plant fuel, timber and fodder species on the pre-selected site. Following a site visit and discussion the group agreed to work one morning per week with the ICRAF team and the affected property owners (who had previously agreed to implement the proposed design (Fig. 37).

On the third week the Kathama sub-chief directed several other groups to send some members to assist. The original group asked to be relieved of exclusive responsibility for work at the site because the affected property owners were non-members and the site was outside the group's mandate area (a small watershed selected as a focus for MIDP-Mwethya Groups soil conservation efforts). The ICRAF team agreed to move to the designated area after one more session to complete work at the first site.

After completion of three small check-dams in the gully (Fig. 37) work continued on the initial site in the form of an on-farm trial with the individual farmer most affected by the gully. He offered a small plot of grazing land ($\approx$100m^2; adjacent to and threatened by the gully) for a fuel-and-fodder-lot trial. The farmer, assisted by the ICRAF team, neighbors and family dug 60 micor-catchments for planting of grass and trees, and to promote growth of existing useful trees on the site. The micro-catchments and the improved vegetation were chosen to increase fodder production as well as to improve infiltration and disperse runoff.

Species planted at the site and successfully established after one season included:

1. Grazing land plot
   - Gliricidia sepium*
   - Leucaena leucocephala*
   - Acacia tortilis
   - Acacia holosericae*

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* unproven species to be planted and monitored as experimental introductions to this area.

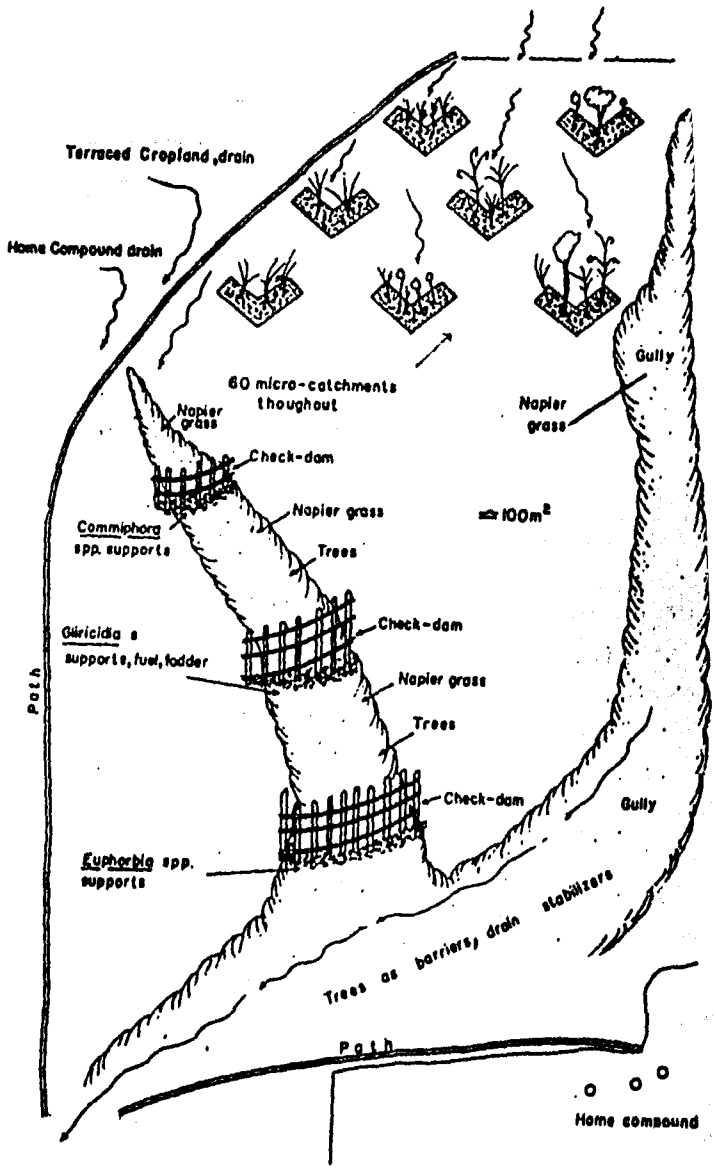


FIG. 37: DETAILED DESIGN FOR GROUP WORK SITE NO. 1

2. Gully

Commiphora africana	- for structural supports
Euphorbia terucalli	
Croton megalocarpus	- fuel
Eucalyptus spp	- poles/fuel
Gliricidia sepium* (cuttings)	- fuel, fodder
Albizzia amara (cuttings)	- fuel, soil stabilization
Sesbania sesban (cuttings)	- fodder, soil stabilization
Napier grass	- fodder, soil stabilization

Local extension agents and Mwethya group leaders arranged for work at the new group site to be shared among five groups, alternating two groups one week and three the next (approximately 30 people present at any given work session). The area to be treated was chosen by the Mwethya group leaders. ICRAF trainees and local extension personnel then chose the specific site and planned the soil and water conservation stuctures. The ICRAF team and the five groups worked one morning a week through most of the dry season (August to mid-November) to construct the required structures and to prepare the area for planting (Fig. 38).

At this site three small check dams and two cut-off drains were constructed. Fifty micro-catchments were also made both for tree and grass planting and for existing trees. Severe soil degradation made construction difficult under dry season conditions. Conditions for plant establishment were also quite harsh. Species planted at the site included:

1. Grazing land plot (micro catchments)

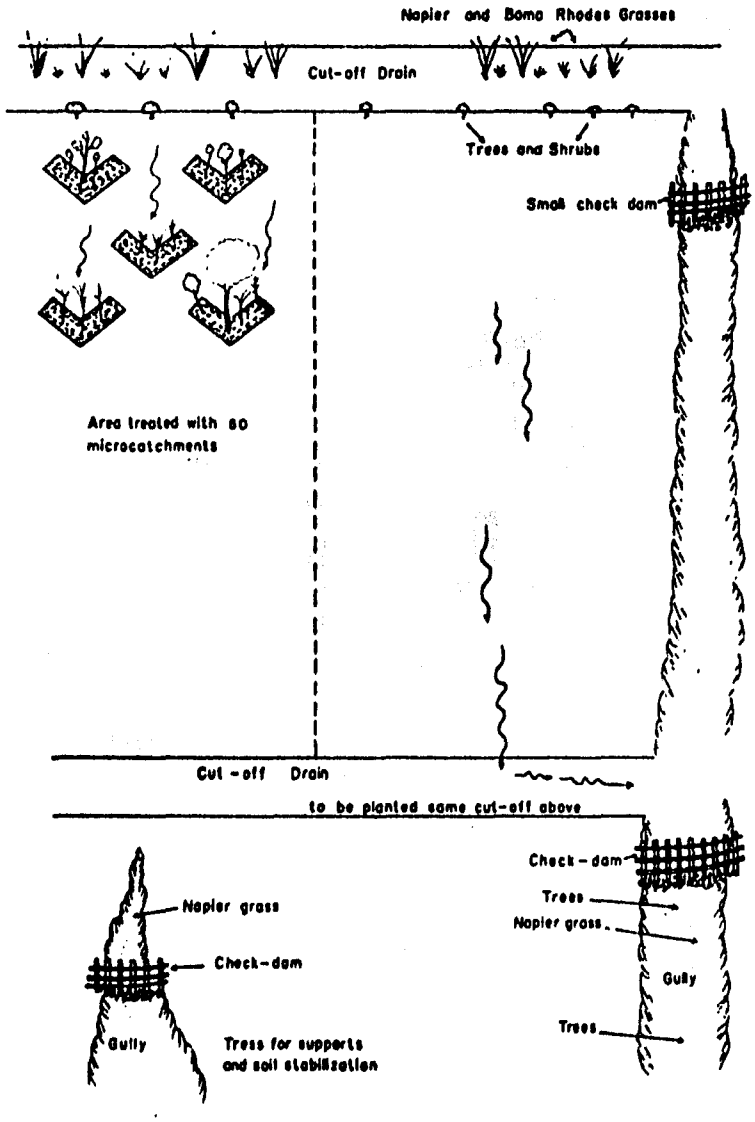
   Acacia holosericae*
   Azadirachta indica*
   Cassia siamea
   Melia azidirach*
   Napier grass

---

* unproven species to be planted and monitored as experimental introduction to this area.

** other species used for live checkdams in India have been suggested: Ipomea Cornea Vitex negando, Arundo donax, Agave americana and A.sisalana (S. Chinnamani, personal communication, 28-6-1984).

FIG. 38: DETAILED DESIGN FOR GROUP WORK SITE NO. 2.



2. Gullies and Drains

same as for gully at first site, plus Acacia albida

Throughout the group work sessions both formal and informal discussions were held to determine which end-uses and which species were of most interest to participants,both for group work sites and for their own farms. Members also tried some new techniques of land preparation (such as microcatchment construction) and compared them with existing practices. The extension and research personnel emphasized the utility of micro-catchments and small gully control structures as niches for useful trees, shrubs and grasses on farms and boundary lands. Time and labour estimates for group work are provided in Table 9.

During the course of these discussions the participants asked for seedlings to try out on their own farms. The ICRAF team provided seedlings[1] and cuttings to the participants

1. as an incentive for continued participation;
2. as an experiment in connecting community and farm scale trials; and
3. as an opportunity to observe variable species survival and farmer assessment of species on a large number of farms, informally.

Given that these groups are composed mainly of women (85%) this also provided a vehicle for initiating future farm trials of species or technologies of particular interest to women (e.g. fuelwood trees, sources of supplemental food and cash, fodder for milk animals).

For the on-farm participants, weekly contact through the Mwethya groups has been supplemented with home visits by local field

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[1] The plants for the first two seasons (for both group sites and farms) were provided on the basis of ad hoc (and generous) assistance by several national institutions. Seedlings and cuttings were provided by the Ministry of Energy and Agriculture nurseries at Kitui and Mutwapa. Grasses were provided by Katumani Dryland Research Station.

Table 9 Time-and-Labour Estimates for Self-Help Groups Working in Watershed Rehabilitation[1]

Task	No.	Time[2]
Small checkdam	2	1 session
Cut-off drain (narrow)	40m	1-2 session(s)
Pitting	40	1-2 session(s)
	1 ha	25+ sessions
Microcatchments	60	1-2 session(s)
Fencing site	400m or 200 trees	1-2 session(s)
Planting Holes	400	1 session
Tree-planting	500	1 session

Realistic Goal for Planning One Year's Work, 4 sites at or near origin of gully, each with "package" of treatments:

5 small check dams with necessary drains, diversions; 500m^2 treated microcatchments or pits with trees and shrub planting and appropriate fencing or tree protection.

1. Based on 2 groups operating in this area, with 20 working members each at every session, 32 sessions per year of public conservation work, each session spanning one morning, with 2 full hours physical labour per person.

2. Varies with dryness or wetness of soil, condition of site.

assistants and by informal training activities[1]. Prior to planting time group members were asked to prepare adequate holes or micro-catchments in their home compounds or cropland in order to guarantee some minimal protection of the seedlings and to ensure greater visibility of the plants and observation of their progress by family members. No other directions were given as to use or placement.

All participants were visited at least once prior to planting and most had prepared some holes or microcatchments before the on-set of the rains in early November. The plants were distributed in late November as part of the planting activities at the group work site.

Each of the regular members of the five participating groups (about 120 people) received a collection of thirteen plants. The species included:

Citrus spp (rough lemon: 1 budded[2], 1 plain	(2)
Anacardium occidentalis	(1)
Psidium guava	(1)
Cassia siamea	(2)
Carica papaya	(1)
Leucaena leucocephala	(2)
Acacia holosericae	(1)
Acacia albida	(1)
Azadirachta indica	(1)
Melia azidirach	(1)

All of the above had shown some promise in existing production systems or in previous farm trials in the area. In addition to the above selected species, some farmers agreed to plant rooted cuttings of Gliricidia sepium, Albizia amara and/or Sesbania sesban

(1) One group leader and three local assistants were trained by ICRAF on-the-job trainees in citrus budding (from collection of cuttings in Katham to budding procedures in Kitui). The resulting budded citrus were provided (one each) to the 120 group members, and the training session will be repeated in Kathama with group members during the coming seasons.

(2) with Washington navel orange.

to test ease of establishing and survival under farm conditions. All three are potential components of fuelwood/fodder production technologies for small farms in Kathama.

Following the onset of the November rains (1983) and distribution of the plants, group activities focussed on weeding and other tasks on members' farms, the normal practice for cropping seasons. During this period the team began monitoring and evaluation activites. All group work sites are monitored quarterly for plant survival and performance. The adequacy of the soil conservation structures for establishment of AF technologies is also being assessed (through qualitative observations of site stability, soil moisture and soil accumulation). Team members also solicited the observations and opinions of group members and property owners about plant performance and soil conservation treatments. Quarterly photographic records are maintained for both group sites and for selected farms.

Local assistants returned to the farms of 60 group members (chosen at random from the total of 120) to identify each plant and to observe and record the choice of planting sites, the management practice, and the condition of the plants. Interviews with these members focussed on choice of site, reactions to plant performance, questions about maintenance, and speculation as to more extensive planting in the future (location, end-use, species). At 30 of these farms (random sub-sample) individual plant growth is measured quarterly in addition to repeated observation and interviews. Year-end visits will yield survival records and farmers' reactions/suggestions from the larger sample group of 60. Results thus far indicate 60 to 80% survival depending on species and planting site, with browsing and termites as major problems.

Several tentative conclusions and new research priorities emerged from the first evaluation. The overall approach, research methods, AF technologies, and plant components were all subject to critical review. The conclusions are as follows:-

1. The general approach requires a stronger emphasis on local participation and incorporation of group/community decisions into the landscape design (or watershed management plan) at an earlier stage of development. Choice of work site should depend on the interests and priorities or existing work sites of the participants, with deviations made only as necessary to accommodate technical criteria.

2. In view of the vast discrepancy between ideal and real designs (Tab. 8 & 9) the group work should be designed for maximum physical, demonstration, and training effect. This can be accomplished by concentrating the work at the head of a few gullies and by successful (dramatic) improvement of water harvesting and fodder production on farmlands upslope of the treated gully. The training should aim to motivate and prepare the groups to repeat similar techniques and practices collectively or individually on their own farms. As such the methods used must be adoptable now under farm conditions and farmer experience. Moreover, research training and extension need to be integrated throughout the series of project activities. Participants need some initial training (however informal) in order to carry out their role in the research process, and the trainer/research managers can learn much from the "trainees" during the training sessions, about potential constraints of the technologies themselves and about likely directions for future extension programs. Many of the questions and suggestions from the self-help groups have been, essentially, requests for training. It is knowledge, not motivation, which limits the use and management of trees and shrubs to fill local needs. Traditiona knowledge applied to the forest and woodlands as a source of abundant and free goods; as such, skills in plant propagation, establishment and intensive management were not necessary. Most people recognize that conditions have changed and many are keenly aware of the need for new skills in land management and crop production.[1] While some training

1. Farmer suggestions for further research and training include low input pest control (Ahmed et al.,) "mulching" of manure supply in corrals, and low-cost plant propagation.

component is generally appropriate to such a project it is particularly important for people in transition from extensive to more intensive forms of land use (and tree use).

3. The issues of tree tenure, land use and water use rights need to be dealt with within the design of AF interventions. There seems to be scope for individual group members to request groups to prepare land or plant live fences, fodder lots, fodder trees/shrubs on cropland and other AF interventions. However, there is also the possibility of extending tree harvesting rights to group members, small informal groups or individuals who repair and plant gullies or degraded grazing land. The former has greater potential since the gullied areas are not subject to conversion to cropland and represent less risk and short-term opportunity cost to the land-owner. Based on experience to date at the first gully site the inclusion of quick yielding fodder plants such as Napier grass in gully reclamation provides a tangible incentive for the owner and/or users to reinforce the structures and protect the site as a high quality dry season fodder reserve. Small farmers downslope might well work out a mutually beneficial arrangement with largeholders upslope to reclaim gully sections in exchange for grassland or tree harvesting (coppicing) rights. The problem originates in largeholder grazing lands but it is the smallholder who would be enticed by small increments in available fodder to perform the necessary land preparation and planting work. This avenue is being explored for group work or farm trials over the next dry season.

Boundary planting on property and internal boundaries has been one of the most popular options for the on-farm use of seedlings by group members. This is the niche most often mentioned for timber and fuelwood trees and bench terrace risers could provide an internal boundary niche for fodder. Although it has received little attention within the context of the group AF/soil conservation trials, boundary planting

warrants greater emphasis for future group work. In view of its obvious merit for private farm production and demarcation this may be readily incorporated into individual farm rotations of group labour, rather than competing for the limited time allocated to public works/soil conservation. The relative benefits to poor smallholders and young women with small families (or widows) are especially high (labour savings).

The criteria for choice of representative study areas and sites require further elaboration. Landscape geometry (size and shape and sub-division of plots and networks) coupled with land cover and land use can provide a basis for classification of landscapes from aerial photographs and/or satellite imagery. This would be especially important for development or research projects where watershed plans and landscape designs would then apply to a large recommendation domain. It is an important step in the methodology to transcend the uniqueness of the landscape study site and to apply the analysis / design to a category of landscape (Young, 1984).

All of the above provide points of departure for the next year's research which will focus on the combination of research/ extension/training and on the extrapolation of results and experience from the project into a more standard institutional framework within Machakos District.1

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1. To be reported in a second working paper on the social, training, extension and planning aspects of the topic.

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DESIGNING AGROFORESTRY SYSTEMS FOR RURAL DEVELOPMENT: ICRAF'S D&D APPROACH

by

John B. Raintreee

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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

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Research is research and development is development. Although the two can be effectively combined in an integrated "research for development" approach, all too often the degree of integration is less than what is needed to meet the challenges of rural development in today's world. Recognizing the need to gear applied technological research more effectively to the needs and potentials of rural populations and land use systems, considerable progress has been made in recent years to develop workable interdisciplinary methodologies and institutional arrangements to achieve the goals of national development policies. Two such innovations developed in India, the "Operational Research" and "Lab to Land" programmes of the Indian Council for Agricultural Research are examples of the renewed emphasis on research for rural development.

Agroforestry, as an approach to integrated land management, is widely thought to have enormous potential as a source of technological solutions to problems of rural development. Although agroforestry is an ancient form of land use practiced by many generations of rural people in many parts of the world, it is a relatively new field of organized scientific activity, lacking an established research tradition of its own. This is both a constraint and an opportunity. In a bid to take advantage of the special opportunity represented by the nascent state of the field, the International Council for Research in Agroforestry (ICRAF) has given emphasis in its current programme of work to the development of agroforestry methodologies which are explicitly designed to support the applied "research for development" approach. ICRAF's Diagnosis and Design Methodology (D&D) is one such methodology, the basic aim of which is to assist interdisciplinary research and development teams to arrive at good agroforestry designs for rural development (ICRAF, 1983a, 1983b).

1. SOME CRITERIA OF GOOD AGROFORESTRY DESIGN

In one of the earliest widely published attempts to outline the scope of this new field of applied science, agroforestry was defined 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 is a normative definition which states not merely what agroforestry is, but also what it should be, i.e. a land management system that is *productive*, *sustainable* and *culturally appropriate*.

While we may all agree that these three criteria are desirable attributes of agroforestry systems, strictly speaking there is little justification for assuming that all land management systems which could be considered "agroforestry" on the basis of the combination of components (trees with herbaceous crops and/or animals) will automatically satisfy these criteria. Subsequently, a more neutral definition of agroforestry has been proposed 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).

If this latter definition is adopted, the three attributes embodied in the earlier definition can still be retained as *criteria of good agroforestry design*, while recognizing that they have to be *achieved* by the developers of agroforestry systems and not just ascribed to any system which happens to meet the minimal definition of agroforestry. In operational terms then, a well designed agroforestry system should meet high standards of *productivity*, *sustainability* and *adoptability*.

1.1 Productivity Criterion

The productivity criterion applies not just to agroforestry, of course but to any innovation in technology. In other words, any agricultural, forest management, or agroforestry innovation should be more productive than what is already on the ground. There is little need to elaborate on this criterion, except to note that, because of the potential complexity and scope of agroforestry systems, a broader and more open-minded approach to productivity improvement is needed than in simpler systems possessing less scope. Well designed agroforestry systems can contribute to the improvement of rural welfare through a variety of *direct* "production roles" (food, fodder, fuel, and fiber in many different forms) as well as through a whole range of *indirect* "service roles" (soil and water management, fertility improvement, microclimate amelioration, live fencing, etc.).

In some cases, agroforestry systems designed to produce marketable commodities in excess of household consumption needs may contribute significantly to improvements in rural welfare through increased income of rural families. In other cases, it may be necessary to take a more direct approach to the satisfaction of specific consumption needs, particularly where the market mechanism is unable to supply needed commodities in sufficient quantity at affordable prices. For example, where deforestation or overgrazing have created *absolute scarcities* of fuelwood or animal feed, merely raising household income may contribute little to improving the household supply of these basic commodities. Examples of successess and failures can be found for both strategies, but it is pointless to debate the *general desirability* of "market-oriented" vs. "subsistence-oriented" approaches to agroforestry, when what is needed in each case is a careful assessment of the actual production needs and potentials of a given area in order to identify the *particular mix* of production strategies and technologies which can best contribute to the development of the area.

Given the enormous potential, moreover, for agroforestry systems making flexible use of multipurpose trees and other components, "good agroforestry design" implies a willingness to explore possibilities for achieving *multiple production objectives* through clever combinations of components in integrated agroforestry systems.

1.2 Sustainability Criterion

The sustainability criterion in agroforestry design addresses the "conservation" aspect of agroforestry's role in rural development. Atempting to address this concern directly in agroforestry designs raises considerable difficulties, however. Most farmers the world over are primarily interested in production and only secondarily, if at all, interested in conservation objectives. Expressing the goal in terms of improving the "sustainability" of the production system is simply a way of operationalizing the conservation objective in terms of the farmer's own priorities.

Thinking of it this way creates a different kind of "design problem." While it could be argued that conservation practices designed to increase the long term productivity of the production system, even at the expense of a certain decrease in present productivity, are in the farmer's own long term interest, many farmers have notoriously short time horizons when it comes to the planning of conservation measures. This applies to farmers in developed as well as developing countries, although in the latter case, where vast numbers of farmers operate close to the margin of subsistence despite decades of development, the tendency to forego long term benefits in favour of immediate production is more understandable.

In either case incentives are normally needed to facilitate the adoption of conservation farming practices. In developed countries the incentives often take the form of government subsidies. In less developed countries, where funds for massive subsidy programs may be lacking, a more appropriate design strategy for agroforestry might be to try to build the necessary incentives directly into the technology itself in the form of production benefits, above and beyond the conservation function, which come as "by-products" of the conservation practice. Again, there is enormous scope in agroforestry for combining long term sustainability benefits with short and medium term production benefits in cleverly designed multipurpose systems (e.g. fuelwood or fodder hedgerows planted on the contour and managed for erosion control).

1.3 Adoptability Criterion

The inclusion of the adoptability criterion, on an equal footing with the productivity and sustainability criteria, is an expression of the practical intent of agroforestry. No matter how productive, sustainable or indeed "elegant" it might be, an agroforestry design that is not adopted by its intended users will have little impact on the land use scene. With reference to the "cultural appropriateness" criterion, the adoptability criterion is simply a practical way of operationalizing all of those social, cultural and economic considerations which affect the acceptability of an agroforestry innovation to the intended users. It implies that the ultimate and, indeed, most relevant assessment of a new technology is that which will be made by the intended users themselves through their decision to adopt or not to adopt the technology.

The tendency, all too often, has been to design technological innovations without explicit reference to this criterion, and then to blame their non-adoption on some vague notion of "social resistance" to change or,

equally unfairly, on the extension service for failing to "sell it to the farmer." A more effective strategy might be to think of it as, in the first instance, a *design problem* and to deliberately try to build the attributes of adoptability into the new technology from the beginning. This is not to say that extension problems, or even cultural resistance to change, do not exist, but rather that the extension/adoption process, with all its difficulties, will only have a fair chance of succeeding if it starts out with a genuinely adoptable technology. One of the best ways to simplify the extension problem, and also to insure that the relevant "adoptability attributes" are identified and incorporated into the design, is to involve the intended users directly in the technology generation process through participation in the design and on-farm trial of agroforestry innovations. Not only would this give the extension process a head start, but it would also go a long way toward insuring the adoptability of the eventual technology product (Raintree, 1983b).

2. INFORMATION REQUIREMENTS FOR GOOD AGROFORESTRY DESIGN

There is no substitute for good design. ICRAF's D&D methodology is essentially a procedure for gathering and processing information relevant to the development of appropriate agroforestry designs for a given land use situation. What kind of information, then, is needed for agroforestry design? In answering this question it is possible to identify a number of general and specific requirements.

2.1 General Requirements

In general, the information input to the design process should be adequate to the development of a *complete set of specifications* for the design. An engineer, in setting out to design a bridge, a dam or a new automobile, would not proceed very far into the design activity until he had what he considered to be a complete set of design specifications to work from. The same applies, no less, to agroforestry design.

This implies two general kinds of information: information about the land use *system* for which the agroforestry technology is being designed, and information about the availability and appropriateness of *component technology* for inclusion in the design. Both types of information are necessary to complete the specifications for any particular technology. From an analysis of the existing land use system comes the information needed to define the *purpose* or *functional role* of the technology within the system, along with information on other factors which should be borne in mind when designing technology for the system (e.g. additional design constraints, positive attributes to be incorporated into the design, etc.). From a survey of existing knowledge on possible component technologies and management practices comes the information needed to give concrete substance to the design, i.e. to specify the *"nuts-and-bolts"* of the technology. Systems information, essentially, specifies the *what* of the technology, component technology information the *how.*

These two types of information are entirely complementary. If either is incomplete in some critical respect, the likelihood is increased that the design will fail. In practice, reliable information on the performance and systems impact of component agroforestry technologies may often be lacking, due to the dearth of research in the field. Difficulties of this

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type signal the need for research in order to obtain the information necessary to complete the design with confidence. On the other hand, the very process of attempting to arrive at a detailed design is part of the "discovery procedure" for identifying practical research priorities.

One general aspect of the required systems information, is the need to consider the relevant *socioeconomic* as well as the biophysical dimensions of the system under consideration. By definition, the concept of a land use or land management system implies the existance of a "user" or "manager" who exerts a controlling influence on the system. Typically, in the design of new land management technology, the environmental parameters of the target system are well understood and adequately considered, the biophysical aspects of the existing land management technology somewhat less so, and the socioeconomic and cultural dimensions of the system least adequately handled. In view of the cental organizing role of *human purpose* in such systems, the socioeconomic aspects of system structure and function are ignored at great peril to the potential success of any agroforestry design.

The D&D methodology does not, in the first instance, suggest an elaborate and separate treatment of "social factors" in agroforestry design, but rather seeks to deal with these aspects as an integral dimension of system organization, along with the relevant biophysical factors. This "discipline neutral" systems perspective has, in general, enjoyed a high degree of acceptance among members of multidiciplinary teams using the D&D methodology as a basis for the planning of applied research and development projects in agroforestry (Raintree, 1984).

A number of other aspects under the heading of general information requirements vis-a-vis the "systems" side of agroforestry design could be listed briefly as follows:

1. What is on the ground already? (minimal descriptive understanding of the existing land use system, including existing agroforestry practices)
2. What are the agroforestry-related needs and potentials of the existing system? (diagnosis of problems and potentials)
3. Systems specifications for functional improvements in system performance (positive specifications of functional roles for agroforestry, desirable attributes and suitable locations for AF technologies, etc., as well as negative design specifications or constraints on new technology based on a realistic assessment of system limitations)
4. Information relevant to the formulation of an appropriate development strategy for the system (with influence on the selection and phasing of alternative technologies).

Since most of these requirements are self-explanatory, brief comments will suffice. The existing system of land use is the "base on which improvements can be most easily grafted" (Collinson, 1981). Failure to adequately understand the organization and function of the existing system can lead to embarrassing mistakes in design, particularly if there are unperceived agroforestry practices already in place. In short, it is never a good idea to design in ignorance of what is already on the ground

in the existing system and it is particularly important to understand existing land management practices in relation to the production objectives of the local people.

Such descriptive information provides a basis for diagnosing the system to identify problems which the land managers have in meeting their objectives, which in turn defines which aspects of the system need to be examined in greater detail in order to ascertain the underlying causes of poor performance. "Trouble-shooting" the system in this way to identify its inherent constaints and unrealized potentials for meeting the producer's objectives provides a basis for identifying the "leverage points" in the system where appropriate agroforestry (or non-agroforestry) interventions have a potential to improve system performance. Once these "functional intervention points" are identified, it then becomes possible to develop functional design specifications for the relevant technologies.

The fourth of the above points raises two interelated design questions: "How much change is the system able to absorb?" and "How to deal with the time dimension in agroforestry design?" The answer to the first question determines which of two fundamentally different development strategies it is appropriate to apply to a given system: an "improving approach" or a "transforming approach" (Torres, 1980). Whereas the "improving" approach takes the existing technological base as the starting point for design activities and seeks to introduce key technological innovations at critical points in the system, the "transforming" approach more-or-less assumes a "blank slate" and proceeds to develop a completely original design for the entire system. While it is impossible to say which of the two approaches is best for a particular system without first examining the system to determine its inherent potentials and limitations, in working with small-scale, traditional farmers one is usually on safer ground vis-a-vis the "adoptability" criterion when following an "improving" approach. On the other hand, if the target system has demonstrated an openness to radical change in the past *or* if the existing system is in serious trouble and incapable of being significantly improved by limited technological interventions, then a more radical "transforming" approach may be indicated.

A related set of questions concerns the advisability of a "high technology" vs. a "low technology" approach. The D&D methodology itself has no inherent biases toward either. The point is always to use "appropriate technology." Whether this turns out to be a high or low technology or, as will often be the case, an appropriate mixture of the two, depends on the system in question. The decision must be made, but it should not be made out of ignorance about the realistic capacities of the system (including its human elements) to accept change. In practice some appropriate combination of "high" and "low" technology, system "improving" and system "transforming" approaches may be indicated, each addressing different parts of the system. In other words, a mixed or "supplemental" approach (Rocheleau, personal communication) to the development of the system may be indicated, improving the productivity of existing enterprises where profitable and adding new enterprises where relevant and possible. Even when a predominently "transforming" approach is deemed appropriate, however, it will always be conducive to a higher rate of adoption to retain some familiar elements of the existing land use system, particularly in regard to deeply entrenched production objectives or consumption preferences. Cash crop enterprises are generally more open to radical change than those geared to the production of traditional staple foods.

It is important to give careful consideration to these matters in arriving at a *realistic development strategy* for the system in question. An ambitious strategy which fails is, in the final analysis, a failure pure and simple; whereas, a less ambitious strategy which succeeds will have real gains to show at the end of the day. Public sector institutions have in the past demonstrated a remarkable capacity for self-delusion as regards their ability to legislate land use change. A more enlightened "marketing" approach, which gives people what they need, want and are willing to accept, might in the end prove to be a more effective strategy for rural development in "conservative" areas.

With regard to the time dimension in agroforestry design, it is well for agroforestry designers to take the time to plan carefully for the future, in the realization that tree-based production systems, once established, are not easily changed. The need for more careful planning of experimental agroforestry systems is in direct contrast to research on annual crop, or even livestock, systems which, because of the shorter time required to complete an experiment, are much more amenable to a "trial-and-error" approach.

In assessing the "sustainability" of proposed agroforestry designs it is, therefore, advisable to look beyond present conditions to take account of trends which may affect the future appropriateness of the proposed technologies. In many cases it may be important to estimate the future demand on the system under different population growth scenerios. If a "high growth" future seems likely to lead to far higher levels of production demand than at present, the design should include scope for intensification of land use in order to support higher future populations on the land. If, for one reason or another, it is not presently possible to get people to adopt land use practices appropriate to the high density situations of the future (Raintree, 1983a), it may still be possible to conceive of a *phased approach* to the development of the system, incorporating a *succession* of increasingly intensive agroforestry technologies. This will only be possible if present designs leave scope on the landscape for future changes. A succession of carefully planned incremental changes over time may be a way of gradually achieving total transformation of a system which could not otherwise accommodate an abrupt change of the same magnitude (Raintree, 1983b).

In any event, a few extra days or weeks of additional effort at the beginning of the research and development process to assess future requirements and develop truly well conceived agroforestry designs, may prevent years if not generations of misery for future populations.

2.2 Specific Requirements

So much for the general information requirements. A more precise answer to the question of what information is needed for good agroforestry design may be obtained by considering what information is required to answer the following set of design questions. The design of agroforestry systems and technologies normally involves either the integration of trees into farming systems or the integration of agricultural crops and/or livestock into forest management systems. For simplicity sake the following questions are expressed in terms of agroforestry systems designed around the role of the introduced tree component, although they apply equally well if other types of components are substituted in the place of trees. The point in all cases is to complement the existing production system through the addition of the "missing" components or management practices.

1. *What functions* should the tree or agroforestry combination perform within the land management system?

2. At *what locations* within the landscape should these functions be performed?

3. *What components* or component combinations are best used to perform these functions?

4. *How many* of each component is required to meet the needs of the system?

5. *What exact arrangement* of components is envisaged (details of spatial and temporal associations at a given location)?

6. *What management practices* are envisaged in order to achieve the desired performance characteristics?

These, really, are the questions that need to be answered to arrive at a specific design for an agroforestry system or component technology. More detailed design considerations may crop up at more advanced stages of research (Huxley, 1983, Huxley, in preparation; Hoekstra, 1983; Rocheleau & van den Hoek, 1984), but the above set of questions constitute a kind of minimal "design algorithm" for the initial stages of agroforestry research. To begin with, the questions may be dealt with in the sequence shown above, but because the answer to any one question may affect the answers to other questions, it will usually be necessary to repeat the sequence a few times, adjusting the various elements of the design to each other until a coherent design output results.

Possibly, the only invariant in the use of this design algorithm is to first give at least provisional answers to questions 1 and 2 before proceeding to the others. The reason for this is that these two questions fix the main systems parameters for the design and, after all, the design is presumably being developed to meet the development needs and potentials of some *particular* land use system or system type. Although systems considerations enter into each of the remaining steps, the role of "component technology" information (derived not so much from analysis of the system as from a survey of the general state of knowledge) becomes more prominent in the latter questions. The first two questions specify *what* and *where* the needed functions are to be performed, the latter answer the question of *how* it is to be done. For further discussion of this design algorithm and for a range of optional, potentiall useful analytical tools and design materials, the reader is referred to ICRAF (1983b).

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3. GUIDELINES FOR AGROFORESTRY DIAGNOSIS AND DESIGN: THE PROJECT PLANNING STAGE

If the foregoing analysis of the information requirements for agroforestry design is accepted, then the question arises: "How does one go about collecting and processing the necessary information in a timely and efficient manner?" This is the basic question which the developers of ICRAF's D&D methodology have tried to answer. Before outlining the basic procedures, it should be emphasized that the D&D methodology, in its present preliminary state of completion, is the product of vigorous collaboration and field testing of the evolving procedures with national scientists and development workers in a wide range of sites around the world. Far from being simply a "desk exercise" in methodology development, it is this "hands-on" involvement of representatives of the major users of the methodology which gives ICRAF the confidence to conclude that it is indeed an efficient and workable approach. Although we do not claim that it is the *only* workable methodology, based on feedback from users in the field we do feel justified in saying that use of the basic D&D methodology does indeed lead to the goal of good agroforestry design in a timely and cost-effective manner. We feel confident, therefore, in recommending its use as a "short-cut" alternative to more time and resource consuming approaches.

In documenting the D&D methodology so that it can be widely disseminated and independently applied by interested users, we have tried to take account of the fact that users differ in regard to the level of methodological detailed required to apply the methodology. Some users require only minimal guidelines and prefer to work out the details themselves. Others seem to appreciate a more complete set of procedural suggestions. In all cases, users seem to desire a "summary overview" of the methodology before getting into the details of the suggested implementing procedures. Accordingly, the current documentation presents the methodology at 3 levels of detail. Level 1 (Raintree, 1984) and Level 2 (ICRAF, 1983a) are summarised below for general introductory purposes. Level 3, the more detailed guidelines and optional resource materials, is presented in *Resources for Agroforestry Diagnosis and Design* (ICRAF, 1983b), available in draft form from ICRAF on request. Whichever level of detail is employed, users of the D&D methodology will still always be required to exercise flexibility and judgement in adapting the suggested procedures to the specific needs and resources of their particular application.

3.1 Level 1 'Minimal' Guidelines

At this "minimal" level of detail, there is little to say beyond emphasizing the basic principle that *diagnosis should precede design.* In applying this commonsense principle, which is fundamental to all problem-solving approaches, there are many possible ways to proceed. As long as one first takes the time to examine and diagnose the actual needs and potentials of the target land use system *before* starting to design "improvements" for it, the basic requirements of the D&D approach will have been satisfied. Still, it may be helpful to pass on some minimal suggestions, based on ICRAF's experience with the approach, on how one might organize one's thinking to deal with this task efficiently. Table 1 presents a four-stage breakdown of the D&D process which suggests certain basic questions, key factors and modes of inquiry which the ICRAF team has found useful in approaching the project planning task.

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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.

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 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

3.2 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

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. Differentiation of Land Use Systems Within the Study Area

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 to 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. Preliminary Description of the Selected Land Use System(s)

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 diagnosi 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. Diagnostic Survey

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

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).

4. GUIDELINES FOR PROJECT IMPLEMENTATION: THE CONTINUING D&D PROCESS

The usefulness of the basic problem-solving approach embodied in the D&D methodology does not end with the completion of the project planning process outlined above. As a scientist commented at a recent training course at ICRAF, "D&D Is Forever!" Although the comment was facetious (perish the thought that any methodological process should continue forever!), commonsense argues for a continuing role for the basic D&D process throughout the implementation phase of a technology-generating agroforestry project. Whereas the initial "rapid appraisal" application of the D&D logic will normally lead to the design of a "prototype" agroforestry technology which is *generally appropriate* to the target land use system, in most cases further research and development will be needed to develop and test this technology and to make it *specifically appropriate* to the system in question. Through repeated application of this same basic logic, to *re-diagnose* the system once the new technology is in place (to assess its impact on diagnosed problems and potentials) and *re-design* the prototype technology to incorporate modifications and design refinements suggested by trial application within the target system, the D&D process uses *feedback* to "zero-in" on an optimal design.

One of the most important sources of design-optimizing feedback is the participation of local farmers in the conduct and evaluation of *on-farm trials* of the prototype technology. The adoption decision itself is the ultimate form of feedback from the intended users of the new technology, but researchers should not underestimate the potential contribution of farmer-originated innovations in modifying the initial prototype to *create* an adoptable technology. To achieve the potential for really fine tuned feedback of this type, project managers must be willing to learn from farmers and encourage a vigorous *two-way* flow of information. The other important source of corrective feedback, of course, is the complementary set of detailed experimental investigations which are conducted under controlled conditions on the *research station*.

The process of "on-farm" trial and refinement of the prototype technology, complemented by more rigorously controlled "on-station" research into fundamental interactions between components and other research questions (e.g. screening of a wider range of possible components, etc), ought in principle to be conducted in a highly coordinated fashion. The iterative D&D process can provide the basis for this coordination between the two research components of an integrated research and development project, as shown in Figure 1. As such, the continuing D&D process is part of the "internal guidance system" of the project, providing a means of integrating the findings of these complementary types of research and suggesting "midcourse corrections" in project planning based upon the combined feedback.

As suggested in Figure 1, the iterative process continues until project managers feel that the refined technological product is ready for dissemination and testing in a wider range of sites throughout the "recommendation domain" of the technology. The D&D process then provides a basis for "adaptive research" to modify the technology according to the specific needs and circumstances of different sites within the range of potential application. Thus, although the process of D&D is "system specific" in its focus, systems and system types can be broadly defined and the ultimate products of the D&D process need not, and should not, be "site specific" in their application. It is up to the users of the D&D methodology to choose field sites which are representative of the major development problems of the country.

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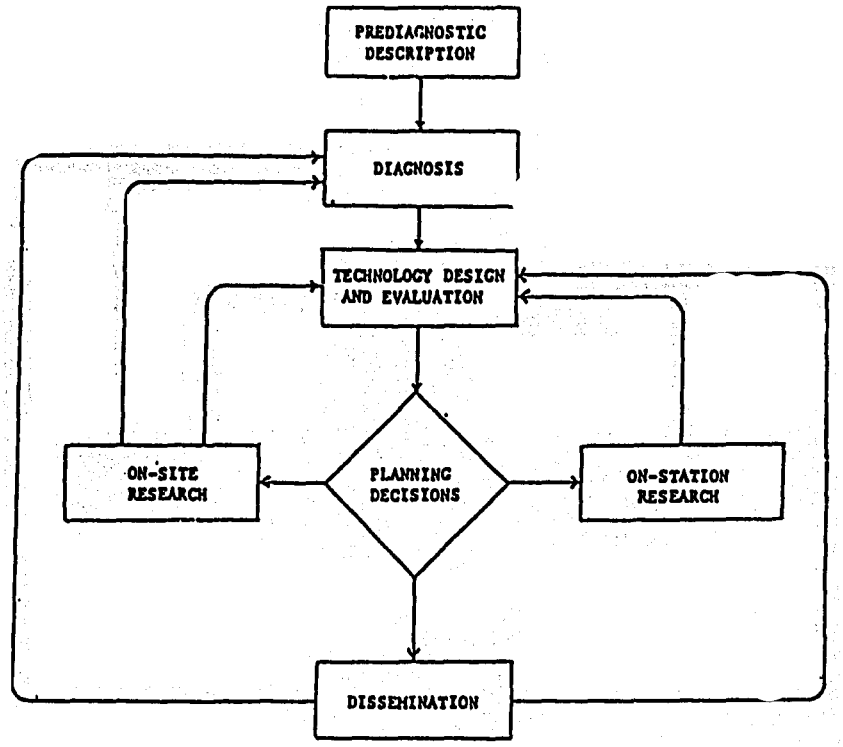

Figure 1. Components of project design incorporating the D&D process as part of the project's internal guidance system. Note feedback linkages.

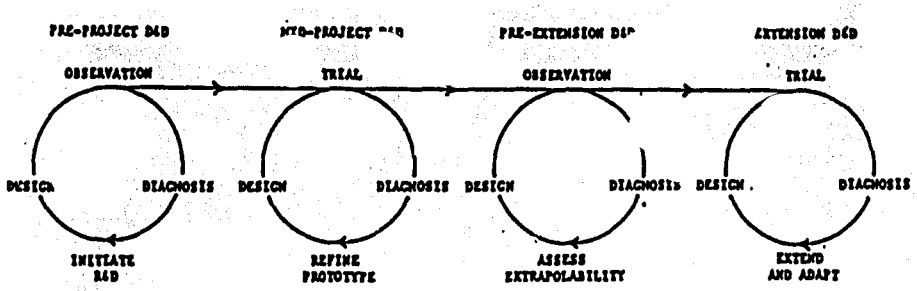

Figure 2. Repetition of the basic D&D process in different forms for different purposes at successive stages in the life of a technology generation and dissemination project.

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Figure 2 summarizes the different uses to which the basic D&D process can be put at different stages in the life cycle of a research for development project. The schematic representations shown in Figures 1 and 2 together constitute a kind of "minimal" set of guidelines for the use of D&D at latter stages of the project cycle. Unfortunately, because of the longer time required to gain experience with the latter stages, more detailed guidelines comparable to the level 2 (ICRAF, 1983a) and level 3 guidelines (ICRAF, 1983b) currently available for the project planning stage, are not yet available for the project "implementation" and "technology dissemination" stages. In response to considerable demand from rural development projects, however, preliminary guidelines are now being prepared at ICRAF which will be published in draft form and, in due course, subjected to the same kind of collaborative testing and refinement which has characterized the development of the D&D guidelines for research project planning.

5. CONCLUSION

As the saying goes, "there are many ways to skin a cat." The Diagnostic and Design methodology is one approach to the design of agroforestry systems and technologies which has been specifically developed to meet the urgent requirement for a coherent approach to rural development. Like any "tool," the D&D methodology relies heavily on the skill, resourcefulness and intentions of its users.

In itself, the methodology has no inherent bias toward either a "high technology" or a "low technology" approach to agroforestry, but rather is intended to assist its users to arrive at *appropriate agroforestry technologies for a given set of design conditions*. Although the D&D methodology is not inherently limited to solving the development problems of "resource poor farmers" (Chambers and Ghildyal, 1984), it is certainly *hoped* that research and development planners will make use of the specific in-built capabilities of the methodology (in its more detailed forms), to address the urgent needs of this group and that they will give priority to the developmemt of agroforestry's special potential in this regard (Lundgren and Raintree, 1983; Raintree, 1983c; Bentley, Chambers and Ghildyal, 1984; Chambers, 1984).

At the same time, ICRAF recognizes that a balanced approach to national development may also seek to raise the general welfare through commercial development of highly sophisticated agroforestry-based systems of industrial production, and it is hoped that the D&D methodology may also contribute in this regard (Lundgren and Raintree, 1983). Although the events of recent decades have made it difficult to countenance uncritical acceptance of the "trickle down" theory of development, a balanced view requires that due acknowledgement be given to positive elements of the classical modernization process.

In order to facilitate the successful harnessing of national technological research capabilities to the real needs and potentials of rural development, it is necessary to give careful consideration to the social dimensions of agroforestry design. The D&D methodology seeks to accomplish this objective not, in the first instance, by turning the treatment of social concerns into a separate technical exercise conducted exclusively by social science experts, but by a more integrated approach based on a discipline-neutral systems perspective in which the socioeconomic and biophysical aspects of agroforestry design are seen as integral dimensions

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of the land use systems and technologies to be developed. It is hoped that ICRAF's rather positive experience with this systems approach to date can be replicated by users, and that the continued development and refinement of the D&D methodology may be assured through the continued and active participation of its users.

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APPLICATION OF THE D&D METHODOLOGY AT VARYING SCALES OF ANALYSIS

By D. Rocheleau

The potential applications for agroforestry (AF) technologies often extend beyond and within the farming system as a unit. Based on apparent needs (felt or demonstrated) and on expressed interest, many of the client or target groups are:

1. Rural agricultural populations plagued by failure of existing production systems to meet basic needs as perceived by the policy sector and the people themselves (including farmers, farm families, farm-workers and other sectors of the population).

2. Populations living in or dependent on fragile environments plagued by soil and water conservation problems (e.g. problems of quantity, quality, and distribution in surface waters, soil water, ground water, problems or erosion, deposition, nutrient depletion, cementation and other forms of soil degradation).

Given the nature of the problems encountered thus far on-farm and the potential application of agroforestry explicitly for rural development and watershed management purposes, there is often a need for rapid appraisal, technology design and implementation at varying scales of analysis. This is particularly important for diagnosis and solution of: watershed problems (including conflicts in land and water use, and regional ecological constraints on target land use systems); development problems affecting the landless and near landless; and intra-household problems affecting family members differently based on age, sex and marital status.[1]

The terms applied to AF technologies in rural development (agroforestry, community forestry, social forestry, farm forestry) reveal a polarization between farm and community applications. The choice to concentrate on farming system, population sub-group, community, ecosystem, or landscape units often reflects the orientation of the R&D agencies rather than a deliberate consideration of the scale most appropriate to each step of the R&D process in a given situation. The scales of observation, analysis, design, implementation and evaluation should, however derive from specific rural development objectives, the client population and target area characteristics in each case.

How do questions of scale relate to problem diagnosis and technology design at the farm level?

For cases where the farming system(s) has been identified as the primary focus, there is a need to identify and influence farming systems opportunities and limits that reside (or originate) in the next larger systems of which they are a part or in sub-units of the farm house-hold. A brief look at the next level in the hierarchy can indicate whether the external constraints on farming systems are changeable, and whether the sub-system

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1. Family composition affects both household and individual needs and priorities for AF interventions; a women-headed household with young children caanot be treated the same as a household with several adults (men and women) and school-age children. Neither will the same family remain static, so future developments must be considered in AF technology design (e.g. land sub-division; marriage, out-migration; re-distribution of labour and control by age group).

and/or larger system are resilient enough to support such changes if introduced. Such constraints may be ecological or socioeconomic.

In the case of farming system dependence on apportunities within the larger system (abundant labour, free fuel, abundant water) the sustainability of these resources and their availability to the farm household[1] must be considered. The mixed management of "free" goods such as water and fuel, with owned land, cattle and equipment, and the combination of family, communal and paid labour in many rural production systems requires a scale of analysis beyond the farm. Changes in farm technology may affect the larger systems and then feed back indirect impact on the farm household in the form of changing prices, availability or quality of basic resources (fuel, water, food, shelter, raw materials) or production inputs (agro-chemicals, labour, equipment). The results may also be a change in demand for farm products. Both production and sustainability of farming systems are subject to "boomerang" effects from technology change (farm-ecosystem[2] - farm).

The interdependence between household members and the farming system is equally important. Intra-household units may vary according to circumstance, distinguishing between: men, women and children; wage-earners and non-wage earners; heads of household and "others"; producers and dependents. The differential demands of existing and new technologies on these groups and the variable returns for their respective inputs will influence the welfare of the entire family and the farm as a whole.

Projects geared toward specific farming systems or agroforestry production research *per se* would be concerned with ecosystems and intra-household analyses primarily in this context. Family-farm - ecosystem interactions are viewed with respect to their eventual impact on the farm.

A more explicit emphasis on sliding-scale (intra-household, farm, ecosystem, community, regional) diagnosis and design is appropriate for regional development and settlement projects, and for special interest projects for fuelwood production, watershed protection, environmental rehabilitation or large scale diversification of agricultural and forestry production. All of these serve a broader client group than a particular type of farm household. Projects directed towards women, children or specific socioeconomic groups also require multiple-scale analysis.

In development, settlement and large scale special purpose programs there is a need to first identify clearly the project objectives and the client group(s)[3]. On this basis target area(s) and target groups[4] and their interactions can be defined, then surveyed, described at appropriate scale(s). The subsequent scales of analysis, design, implementation and evaluation would then follow in logical succession from the results of the initial survey, mapping and systems analysis (subject to change based on experience and information gained in subsequent steps).

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1. The farm household may or may not be a clearly defined, easily recognizable land management unit. In some cases groups of households share management of common lands and public resources. In other cases different family members manage separate plots for distinct purposes, based on age, sex and marriage.

2. The most generally appropriate ecosystem unit for farming system applications is the small watershed ($\approx$1-25km^2), although other biophysical or socioeconomic boundaries will be more applicable in some cases.

3. The client groups is the group intended to benefit from the project.

4. Target groups are those involved in or affected by the project and should always be considered as clients to some extent.

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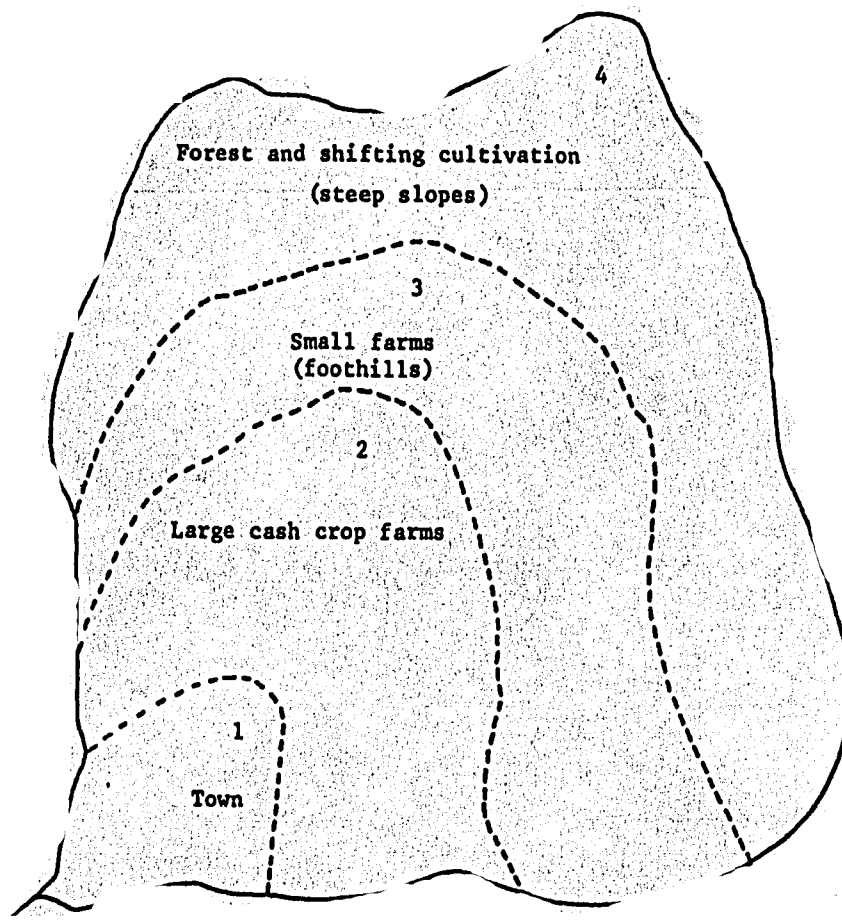
The illustrations which follow give examples of differences within household types, and between geographical units all of which are relevant to AF diagnosis and design.

Figures 1 and 2 illustrate two different criteria for subdivision and analysis of watershed units. Figures 3 and 4 demonstrate the nesting of AF technologies within a landscape design for productive rehabilitation (sketches viewed along a topographic profile). Figures 5 and 6 show two examples of spatial division of labour and decision-making within households in single farms.

Within-household specialization may also apply to activities more than to spatial units. For example men, women and children may perform very different tasks of equal importance in food crop lands, or men and women may take decisions on sales and production, respectively, for the same cash crop.

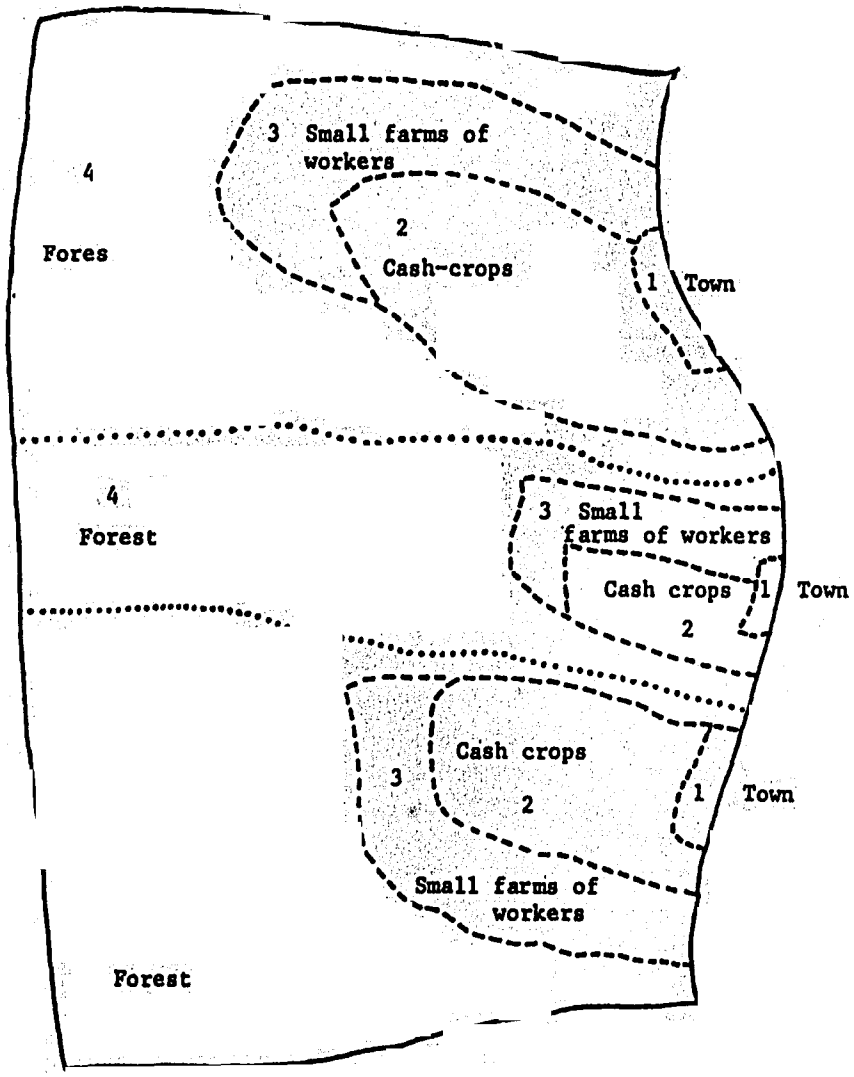
You may wish to consider the kinds of spatial and functional divisions of labour, decision-making, and benefits in your own client systems and the implications for agroforestry research and development.



Watershed bounda.

Sub-unit boundary

Figure 1. Geographical stratification of a watershed

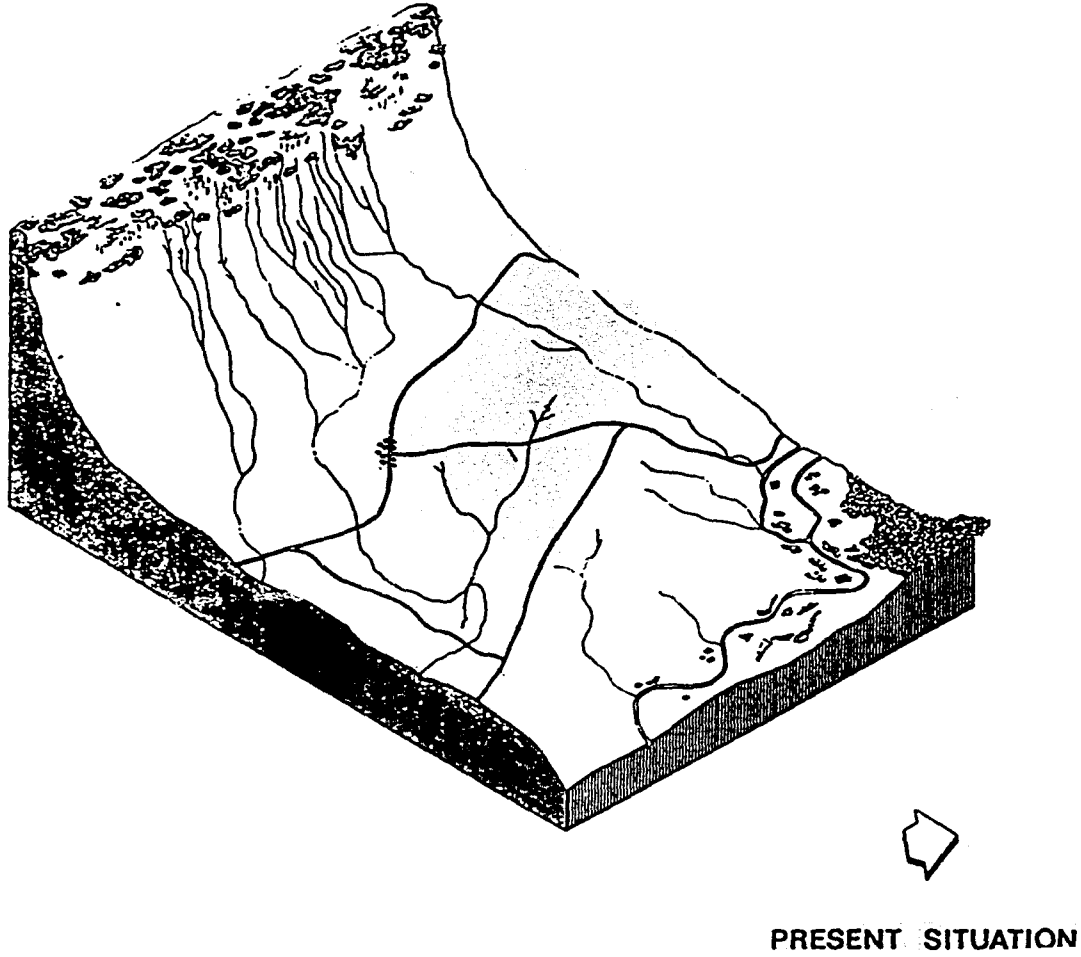


Administrative Boundary (bounded by river, roads)

Sub-unit Boundaries (Land Use)

Property line - estates

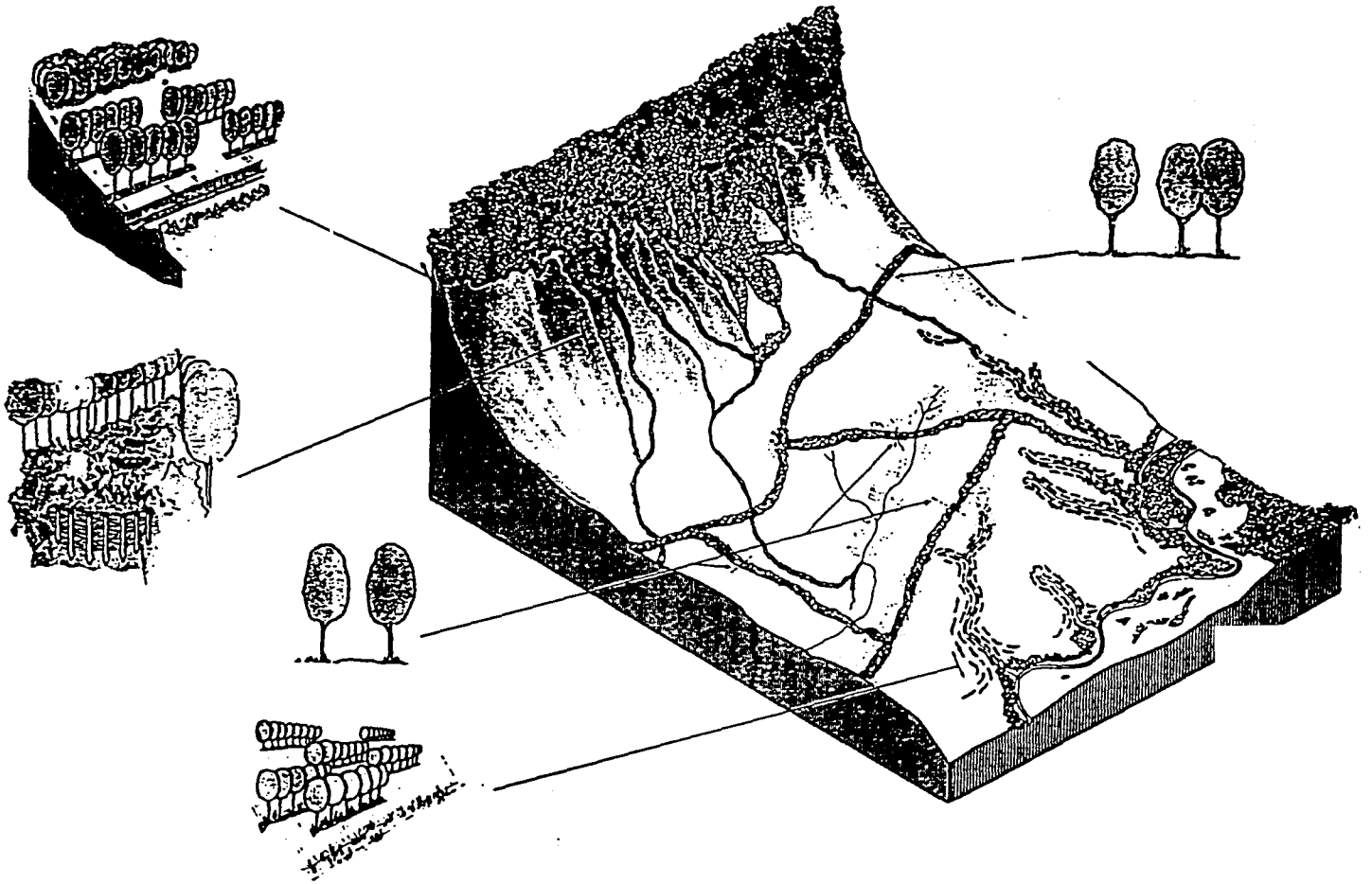
Figure 2. Functional stratification of a watershed.



(Hoek, 1983)

Figure 3. Landscape drawing of a denuded watershed; topographic section of a semi-arid landscape in Machakos District Kenya.

Landscape Design Sketch



(Hoek, 1983)

MASTER PLAN

Figure 4. Conceptual drawing of agroforestry interventions nested within the landscape

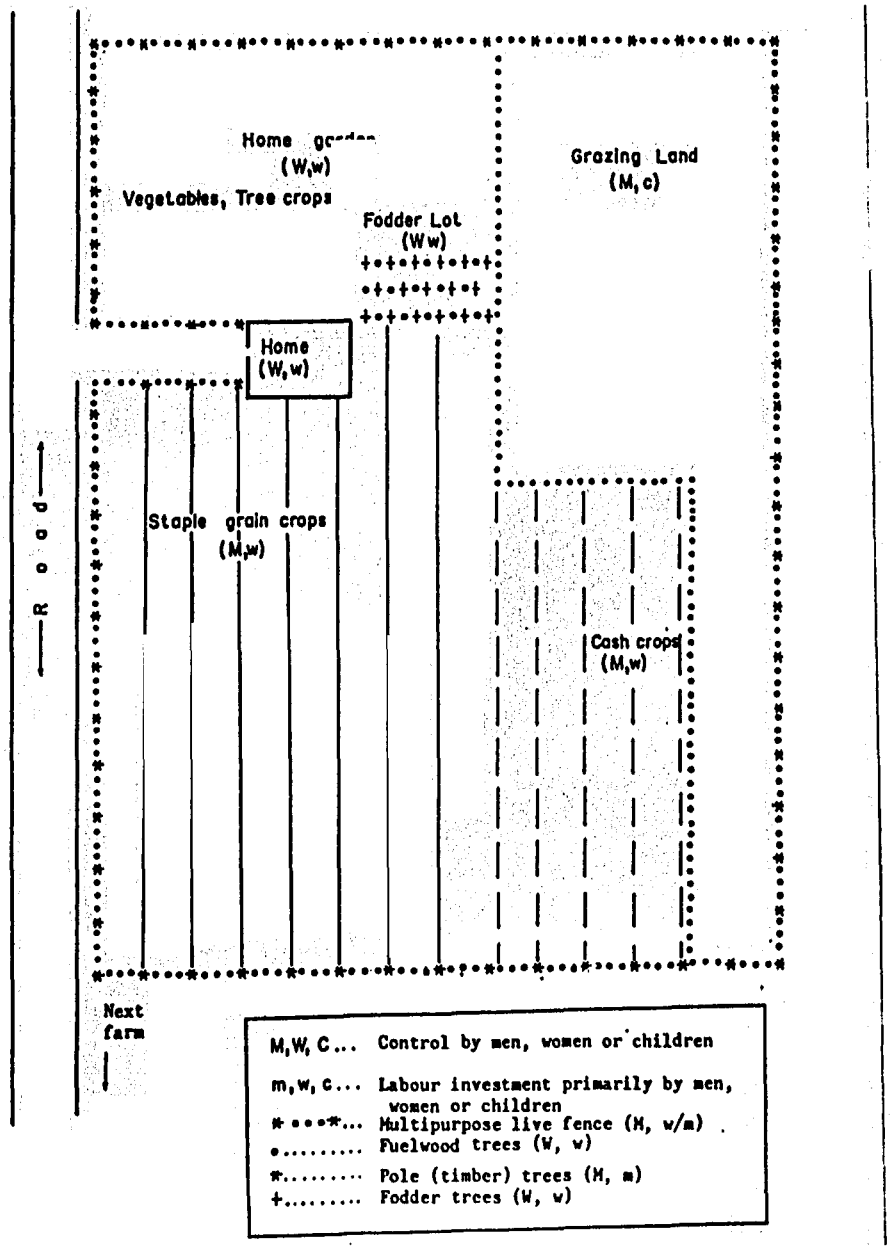


Figure 5. Subdivision of a hypothetical farm into domains of control and labour investment

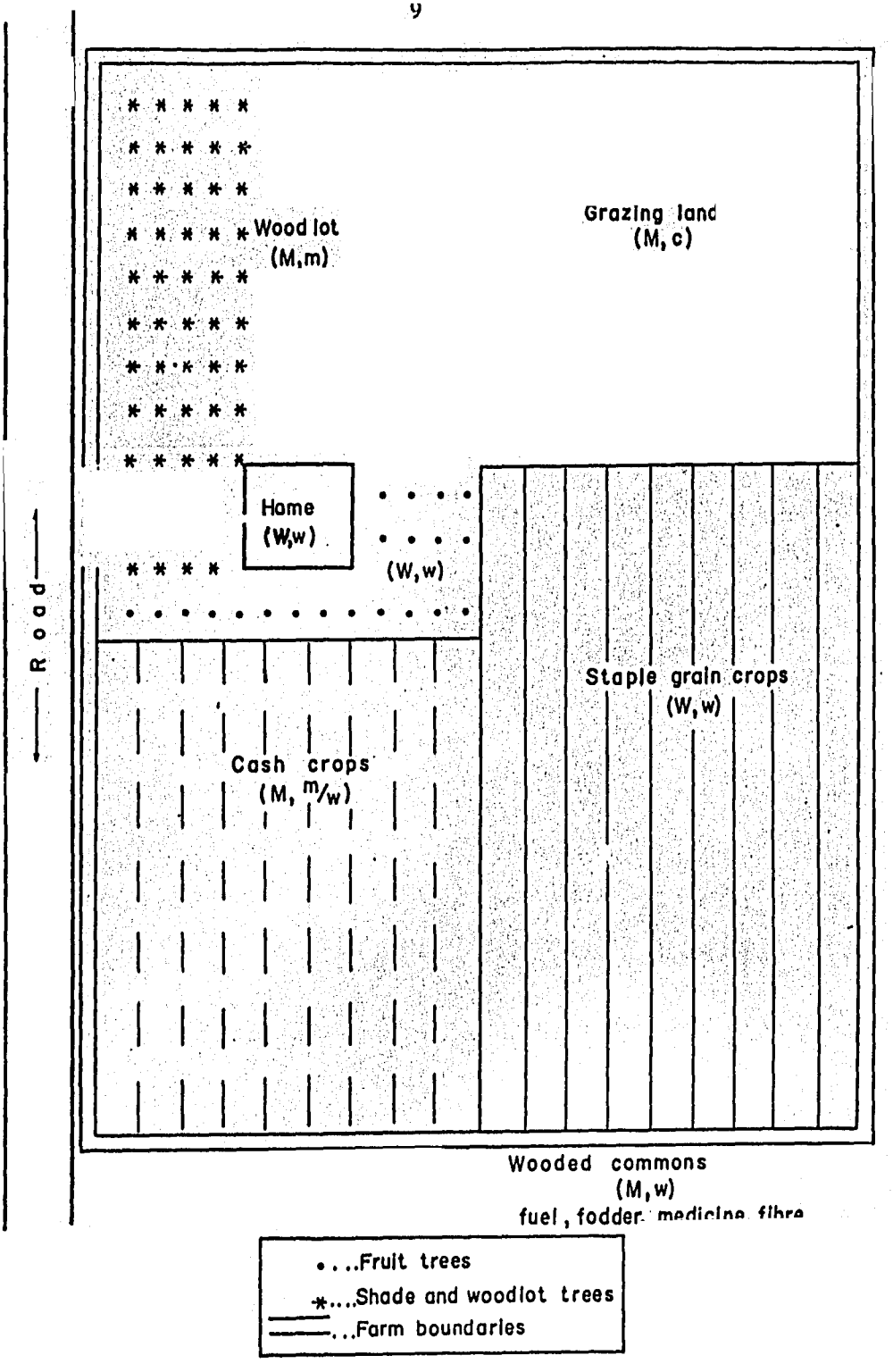


Figure 6: Subdivision of a second hypothetical farm based on domains of control and labour investment

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HUMAN FACTORS IN AGROFORESTRY

Attention will be focused here on some of the critical "human factors" which should be taken into consideration when developing agroforestry systems for rural development. This is not to say that other socioeconomic factors not explicitly mentioned in this presentation are unimportant. Perhaps the course participants can elaborate on other sociocultural aspects of agroforestry relevant to thier own work.

The perspective presented here is basically drawn from "human ecology." In this perspective there are fundamentally two types of interaction of interest to agroforestry, Man-Man interactions and Man-Land interactions:

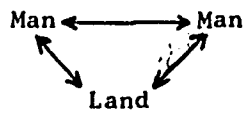

Figure 1. Fundamental interactions

Man (in the generic sense, including all age and sex categories) interacts with the Land in order to obtain a livelihood. Man interacts with other Men for social reasons stemming from the nature of human beings as a gregarious species, whose survival depends upon culturally inherited knowledge and social cooperation. Some of the Man-Man interactions exert influence and control over Man-Land interactions of crucial significance to agroforestry.

Any approach to agroforestry which hopes to have an impact on the landscape of rural development, must insure adequate participation of local people in the research, development and dissemination of appropriate agroforestry systems.

We will consider each of these topics in turn: Man-Land Interactions, Man-Man Interactions, and People's Participation in Agroforestry Initiatives.

1. MAN-LAND INTERACTIONS

We can distinguish two aspects of Man-Land interactions:

1) human populations as components of ecosystems; and
2) human beings as managers of ecosystems

Human populations as components of ecosystems

Human beings have evolved as components of local ecosystems, responding to ecological pressures and taking advantage of opportunities to exploit particular ecological niches. A measure of human "success" is the prodigous growth of human numbers over the course of time.

We are all aware that rapid population growth may be a temporary and self-limiting phenomenon, and we are all familiar with dire predictions of the consequences of unchecked population

growth, but it may be relevant to an understanding of the context in which agorforestry is developing to have another look at the familiar population growth curves.

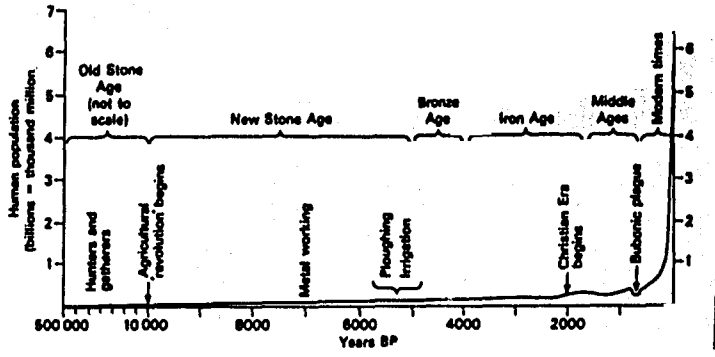

Figure 2. Human population growth over the past half million years, showing the impact of technological development on human numbers. Note the exponential upturn in recent years.
(Source: Goudie, 1981 after Ehrlich et al., 1977)

The recent popularity of agroforestry may be seen as part of society's response to the ecological challenges posed by the sudden "bloom" of human numbers. Our knowledge of biology tells us that the curve must eventually flatten out. There is, of course, the possibility of "over-shooting" the sustainable human carrying capacity of the earth, with obviously disastrous human consequences.

If we plot the same population data on a log-log scale, the last million years would look something like this.

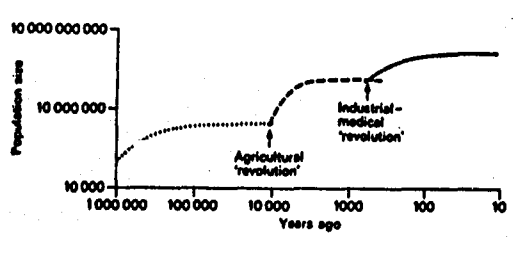

Figure 3. Log-log plot of human population, showing the impact of technological 'revolutions.'
(Source: Goudie, 1981 after Ehrlich et al., 1977)

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The number of people the earth can support depends very much on the kind of technology available to them. Does agroforestry have the potential to extend the human niche? Can it, in combination with other technologies which make intelligent use of the earth's resources, contribute to the needed increase in the human carrying capacity of local ecosystems?

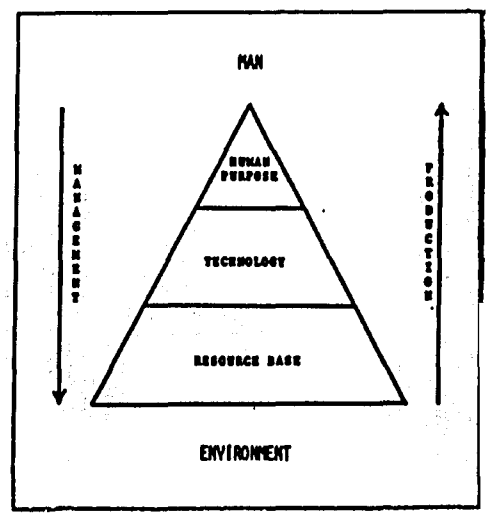
It has been observed that the use of particular kinds of land management technology is not random. Land use systems correlate, quite obviously, with environment. Somewhat less obviously they also correlate with population pressure.

Agroforestry may have a role to play in many different land use systems, but we cannot expect that the technology appropriate to one system will be equally appropriate in another. To be effective and adoptable, technologies must be matched to systems.

Population pressure plays a role in making more intensive technologies acceptable to users,but it is usually futile to try to introduce very intensive and labour demanding practices into systems in which less land and labour intensive alternatives are still capable of meeting the local people's objectives. Failure to take this population-related factor into account is one of the most common reasons for non-adoption of newly developed technologies.

Human Beings as Managers of Ecosystems

There is hardly any ecosystem in the world which does not show the impact of human influences. Many of these influences are non-deliberate, but may be side effects of deliberate management strategies. In developing agroforestry systems we are concerned, in the first instance, with those MAN-LAND interactions which are part of the local group's deliberate strategy for obtaining a livelihood from the land. We may define this complex of interactions as a "land use system." Figure 4 illustrates what we mean by this.



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The land use system (triangle) is that part of the total human ecosystem (square) which comprises those interactions by which Man exploits the local resource base by means of available technology to satisfy human purposes. In developing agroforestry systems to make best use of available resources, we should never forget that the "systems" we are trying to influence are organized by human purpose. In technology generating research typically the physical resource base is well described and understood,the existing technology somewhat less so, and the objectives of the producers (including their own perception of their resource base and technology) least well understood. Unless all three levels in the functional organization of land use systems are adequately understood, however, it is unlikely that the technology generating effort will result in adoptable technologies.

2. MAN-MAN INTERACTIONS

These interactions refer to the explicitly social side of human ecosystems. Human social behavior is largely organized by certain conscious and unconscious categories and rules, which are transmitted from generation to generation with modification from time to time in response to changing social and environmental circumstances. The inhereted knowledge of local resources and technology is also an important aspect of human culture, without which Man could not survive. The knowledge, categories and rules of greatest interest to us here are those that regulate competition and cooperation between individuals and groups with respect to the distribution and use of resources, production opportunities and benefits within land use systems. Without an orderly social life, land use systems would fall into disorganization and fail to meet human needs.

Social categories and groups

People classify themselves and others according to social categories based largely on sex, age, kinship, social class (or caste) and ethnic identity. These categories exert a strong influence over the individual's access to resources, the kinds of work he or she may perform, and the benefits he or she may expect to receive. Some of these categories form the basis for social groups in which members act collectively toward common goals, others merely designate "types" of individuals which do not necessarily coordinate their activities as a group.

How a particular individual or group responds to a technical innovation may be strongly influenced by social category and group membership.

Production Units

For our purposes the most important type of social group is the production unit. In many cases the household is the basic unit of production. This is often where most of the important land use decisions are made and it is these decisions which must be influenced if new technologies are to be adopted and put into practice. Different societies,

however, have different way of defining the household, based on different systems of kinship and different rules governing cooperation between kinsmen.

Within the household relations between individuals are mostly, but by no means always,cooperative. Men and women may have different production opportunities and responsibilities and the products may not always be equally shared. In many parts of the world, for example, men may be primarily involved in cash crop production and marketing, while women are responsible for food crops, firewood and water. Women may join with women in other households to cooperate in certain production activities, and men may do likewise. While the land use objectives and decisions of the household production unit must be taken into account, it is dangerous to assume that the household always operates as a unit or that it does not also contain independantly operating subunits.

There may also be important larger-than-household units of production in a given area. While the household may be the basic social unit of residence and consumption, households may join together for production purposes, as in many communally-oriented systems of production, or in commercial corporations. Even where, for most purposes, the household is the basic unit of production, certain special production activities (e.g. village woodlots) may be based on larger cooperative units.

The important thing is always to identify the relevant production and decision-making units, whatever their social composition and scale of operation, and address our efforts to them. In some cases, new forms of social organization may be needed if the benefits of agroforestry are to be widely realized and distributed. This is particularly relevant to systems in which production is currently organized along highly inequitable lines (e.g. exploitative landlord-tenant relationships), but may also apply to relatively equalitarian systems in which the necessary organizational forms have simply not yet been created.

Relations between production units

Even where production activities are clearly associated with well defined production units, relationships between units are mediated by various forms of exchange. In order to sort out the likely benefits of new technology it may be necessary to understand which of several different forms of exchange are important in a given area. These include:

> loose reciprocity -- in which goods and services are exchanged between units without strict accounting and with only a loose informal expectation of eventual repayment; "borrowing" between neighbors is often an example of informal reciprocity, as is the giving of something in return for "prestige" or political influence.

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strict reciprocity -- in which close account is kept of what is given with the expectation of equivalent repayment in one form or another in the not too distant future; reciprocal exchange of agricultural labour or specialized products are usually of this type; political influence may also be bought in this way, but here there is usually the clear understanding that the debt must be repaid on demand.

cash transaction -- this is a formof exchange in which the social dimension has been reduced to a minimum and in which repayment for goods and services is governed by contractual agreement, usually determined by the market price, and must be made either immediately or within a prescribed time.

Exchange mechanisms come into play particularly where production is or could be somewhat specialized, where different production units exploit different resource or management potentials to produce surplus goods which are desired by others. Commercial production of cash crops is the obvious example, but too great a preoccupation with market-oriented production can obscure other forms of exchange which could also provide incentives for adoption of improved technology.

Social interaction itself is a valued form of exchange which can sometimes be harnessed in the service of improving local land use systems. For example, there are indications from ICRAF's work in Kenya that one of the most importance incentives for individual participation in tree nursery work undertaken by neighborhood self-help groups is the opportunity which this provides for social interaction while working. While the economic benefits to the individual may be quite real, they may be secondary, at least in time, to the immediate social benefits of group participation. By such means the people encourage each other at their work and make light work of tasks which might be considered tedious if undertaken individually.

Land and tree tenure

One of the most ubiquitous and powerful of the social regulatory mechanisms relevant to agroforestry is the body of customary or modern legal principles and decisions collectively known as land tenure. Since trees may often be owned, used and disposed of independently of the land on which they stand, we have to consider both land and tree tenure.

Tenure considerations are fundamental. Outright ownership is not always necessary, but without some form of secure, long term use rights to land on which to plant trees and the trees themselves, there is little incentive to engage in agroforestry. The tenure factor can also work in the opposite direction, i.e. where the planting of trees established the planter's right to exercise a legal claim over the land on which they are planted, tree planting may be a cover for "land grabbing."

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Agroforestry innovations, whatever else they might do, will almost certainly alter the biotic resource base of the land use system, and this will have an impact on the established system of use rights. For example, the introduction of agroforestry technology which makes it possible to extend arable farming into marginal lands may deprive local herders of grazing lands on which they possess traditional grazing rights. It may be very difficult to establish trees on land over which the use rights are in dispute. Likewise, the establishment of commercial woodlots on large farms may prompt the land owners to withdraw the traditional fuelwood collection rights held by small or landless farmers in the area. As this may be a major source of household income for poor people in the area, the negative impacts may outweigh the positive.

Tenure issues can be quite complex and significant. To sort out who will benefit and who will suffer as a result of particular technical innovations, and to be able to modify the design to mitigate negative impacts or develop project components specifically addressed to the disadvantaged group, it may be necessary to undertake a systematic analysis of existing tenure arrangements and assess the impact of proposed land use changes. This analysis may be guided by the following set of questions: Who has (will have) what use rights to what land, what plants and animals, when and under what conditions?

3. PEOPLE'S PARTICIPATION IN AGROFORESTRY INITIATIVES

The issue of people's participation in agroforestry developments is addressed in a practical way in ICRAF's Diagnostic and Design (D&D) methodology, along with technical issues in an integrated systems perspective. This will be the focus of the second and part of the third week of the course. It will suffice here to highlight the crucial aspects of people's particiaption in the various phases of an agroforestry research and rural development project.

Project planning

The crucial thing here is to involve the intended users of agroforestry innovations in the identification and design of technologies which will meet their actual needs and be consistent with their realistic development potentials. Thus, the diagnostic part of the D&D "discovery procedure" aims to find out what people's production objectives are, what problems they have in meeting their objectives, what are the causes of the identified problems, and what are the realistic potentials for improvement of the existing land use system. This is done through a combination of in-depth interviews with production unit managers and workers together with the D&D team's own perception of technical and management constraints and opportunities.

This, then, serves as the basis for development of "system specific" agroforestry designs which have the realistic potential to guide the research and development process toward effective and adoptable improvements in the productivity and sustainability of particular land use systems. The people must be actively consulted, not only

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in the diagnosis of their problems (in which they possess an undeniable expertise), but also in the development, evaluation and modification of impact-maximizing design concepts. It is important also to insure that the range of people consulted is adequate to assess the impact of proposed technology on the wider community beyond the specific target group of the project.

The D&D exercise at the Batu Arang Forest Reserve represents a special case insofar as the proposed site for agroforestry development is not currently occupied by the people who would eventually be involved in managing the land. Also, there are at least two sets of relevant objectives: those of the Forestry Department and those of the farmers. In principle, the same logic of Diagnosis and Design applies, but the application is more complicated, requiring the team to extrapolate from the people's current pattern of land use outside the reserve, in order to anticipate and avoid potential problems in the yet to be developed agroforestry system within the reserve. An additional aim will be to come up with a mutually beneficial "compromise" land use system, which meets the fundamental objectives of both the foresters and the farmers. The challenge is great, but so is the potential.

Implementation of R&D activities

The application of the D&D approach at the research project implementation stage is based on the premise that, in most cases, two complementary kinds of research will be needed to develop the envisaged agroforestry systems: "on-station" research under controlled experimental conditions to screen components, investigate interactions, identify optimal spacing, arrangement and management practices, etc; and "on-site" (or "on-farm") trials of prototype technologies to see how they work under realistic field conditions and to obtain feedback from the eventual end-users. Farmers participation in the "on-site" trials is essential as a source of "adoption facilitating" information, leading to modifications in the initial prototype designs.

The potential contribution of actively participating farmers to the innovation process should not be underestimated Farmers are capable of coming up with precise, sometimes seemingly minor design modifications, which dramatically enchance the workability and adoptability of the technology. When innovative farmers are allowed and encouraged to really get involved they are often capable of suggesting completely new technological approaches to the design objectives. If the truth were told, it might be surprising to see how many of the "breakthrough technologies" currently being promoted as a product of national and international research programmes actually originated independently on farmers' fields.

To tap the creative potential of a participatory approach to R&D, it is necessary to eschew the traditional "top down" model of research in favour of a model based on an active two-way flow of information and a genuine willingness to learn from the farmers. It also require the institutionalization of two-directional feedback between "on-station"

and "on-site" researchers. On-site researchers, likewise, will miss an important source of information if they neglect to involve extension workers in the research process.

The general aim of a participatory R&D phase is to lay a solid foundation for a smooth and rapidly activated dissemination process in the extension phase.

Extension of prototype technologies

The choice of a site for this type of "system specific" research should be made with a view to the wider applicability of the technologies to be developed. Agroforestry research should be system specific, but it should never be purely "site specific" it it is to make good use of limited research funds. Sites should be chosen which are representative of "recommendation domains" which are sufficiently large in area and/or the number of people involved to be significant for rural development.

Once the prototype technologies and land use systems are judged sufficiently develop to warrant wider extension, the logic of diagnosis and design continues to apply to the trial of the prototype technologies under a wider set of site-specific conditions. The participatory D&D process applied to this type of "adaptive research" during the dissemination phase can suggest further technological refinements which would increase the adoptability of the research product in a broader set of circumstances, thus adding further to the cost-effectiveness and overal impact of the total research for development effort.

While the main thrust of the D&D process is to develop ecologically effective and socially appropriate technologies for improvement of land use systems, the potential impact on improved MAN-LAND interactions may not be fully realizable without an effort to effect complementary changes in MAN-MAN interactions. Changes in technology often require corresponding changes in the social organization of production. It may be that a relatively small change in social relations (e.g. an improved model for the role of existing self-help groups) will be all that is needed to bring a new technology into effective use. On the other hand some technologies require major changes in the institutional structure of the target community.

By asking ourselves "What social organization does the effective use of this technology require?" we can try to avoid the type of failures which result from an overly narrow concentration on "nuts and bolts" issues and try to perceive the social dimensions of technology. As technologists, our first aim should be to come up with socially feasible technologies in the first place, but we should not shy away from pointing out the kinds of social changes which could facilitate the adoption of truly promising technologie The feasibility of certain social changes may directly affect our assessment of technological alternatives.

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As project planners we may have greater scope for social components of project design, including research. Social change can be a painfully slow and difficult process, requiring uncommonly sustained and well directed effort. Perhaps the first requirement is to insure that the technologies requiring such change are worth the effort. If it is decided to tackle the issue in project implementation, it is generally a better strategy to build on existing social institutions rather than try to introduce entirely new ones.

Perhaps the greatest challenge to project developers is to learn how to do away with projects. Let's face it, there will never be enough projects in the world to solve all of its problems. The aim of projects should be to set in motion a process of rural adaptation and change that is self-spreading. Truly adoptable technologies and social institutions ought to have the characteristics which make them self-spreading. It is not beyond the wit of Man to learn how to bring applied science to bear in the pursuit of this goal.

J.B. Raintree
September, 1984

ANNEX 7

WORKING PAPER

TECHNOLOGY AND RESEARCH
CONSIDERATIONS IN ICRAF'S
"DIAGNOSIS AND DESIGN" PROCEDURES

by

P.A. Huxley and P.J. Wood

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TECHNOLOGY AND RESEARCH CONSIDERATIONS IN ICRAF'S "DIAGNOSIS AND DESIGN" PROCEDURES

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INTRODUCTION

The derivation, evolution and implementation of ICRAF's land use "Diagnosis and Design" (D&D) methodology to date is well-documented in various publications (e.g. Steppler and Raintree, 1983; Raintree, 1983, 1984; ICRAF, 1983a, 1983b). The methodology offers one possible set of procedures for a logical and step-wise approach to the evaluation of land use systems* through a pre-diagnostic analysis, a rapid field appraisal (of selected land use systems), and additional focussed surveys of how a system works. These are integrated within an analysis of systems constraints high-lighting potential key interaction ("leverage") points. Solutions to improving the system can then be focussed on these, which should include not only agroforestry proposals but agricultural, forestry and any other interventions, for objective comparison.

The "diagnostic" stage is complete when *general systems* specifications for candidate technologies are promulgated that are derived from and relate to overall land use development strategies, the functional needs of the system (or systems), resource contraints and the specific objectives of the farmer (within the context of local, regional, and national needs).

Diagnosis is followed by a "design" stage in which the proposed new general systems specifications are translated into direct technical proposals. At all times the feasibility of achieving a satisfactory level of change in the system, and of being able to implement proposed technical changes, are kept in mind and related to the knowledge of the land use system that has been derived from diagnosis, as well as any regulatory condition and/or objectives imposed by local or national government policies.

If the "D&D" methodology is to remain consistently logical and complete the progress from "Diagnosis" to "Design", with a subsequent transition into "Planning" and "Implementation", it involves a series of considered steps that *must* clearly show that the ultimate action programmes for extension and/or research relate to the systems analysis procedures that have initiated them. Heuristic 'jumps' into apparently-likely technical improvements are not allowed! In the "design" stage ICRAF is concerned only with possible agroforestry solutions whilst fully accepting that there will often be other equally promising, or perhaps better, approaches.

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* The choice of area to study is not dealt with here.

Thus the full D&D procedure will result in extension and research programmes that are site-specific and largely or completely, problem-oriented. There are, of course, other ways to derive relevant On- and Off-station research programmes depending on the overall objectives and the available resource base. The steps in the "diagnostic" stage have now been widely field-tested under a range of different conditions and at a variety of sites, and their implementation has been shown to produce effective and cost-efficient results. (See the series of case studies being published through ICRAF's Systems and COSPRO Programmes).

The present paper is concerned with the transition to, and development of, the procedure within the "design" stage through to the completion of research programmes. The underlying concepts and requirements of agroforestry field research have been the subject of attention at ICRAF in a programme concerned with the development of a series of source documents covering the conceptual basis and proposed implementation of research for the exploration and assessment of multipurpose trees (a project carried out in part with the Commonwealth Forestry Institute, Oxford, and co-sponsored by the Board on Science and Technology for International Development of the US National Academy of Sciences). This is now available in 24 parts at present (P.A. Huxley 1984, Ed). The two sets of activities, land use diagnosis and research planning, can now be linked so as to complete the "D&D" procedures, with the exception of the planning of extension and an eventual evaluation of the system's performance and the impact of research and extension activities. These have yet to be considered.

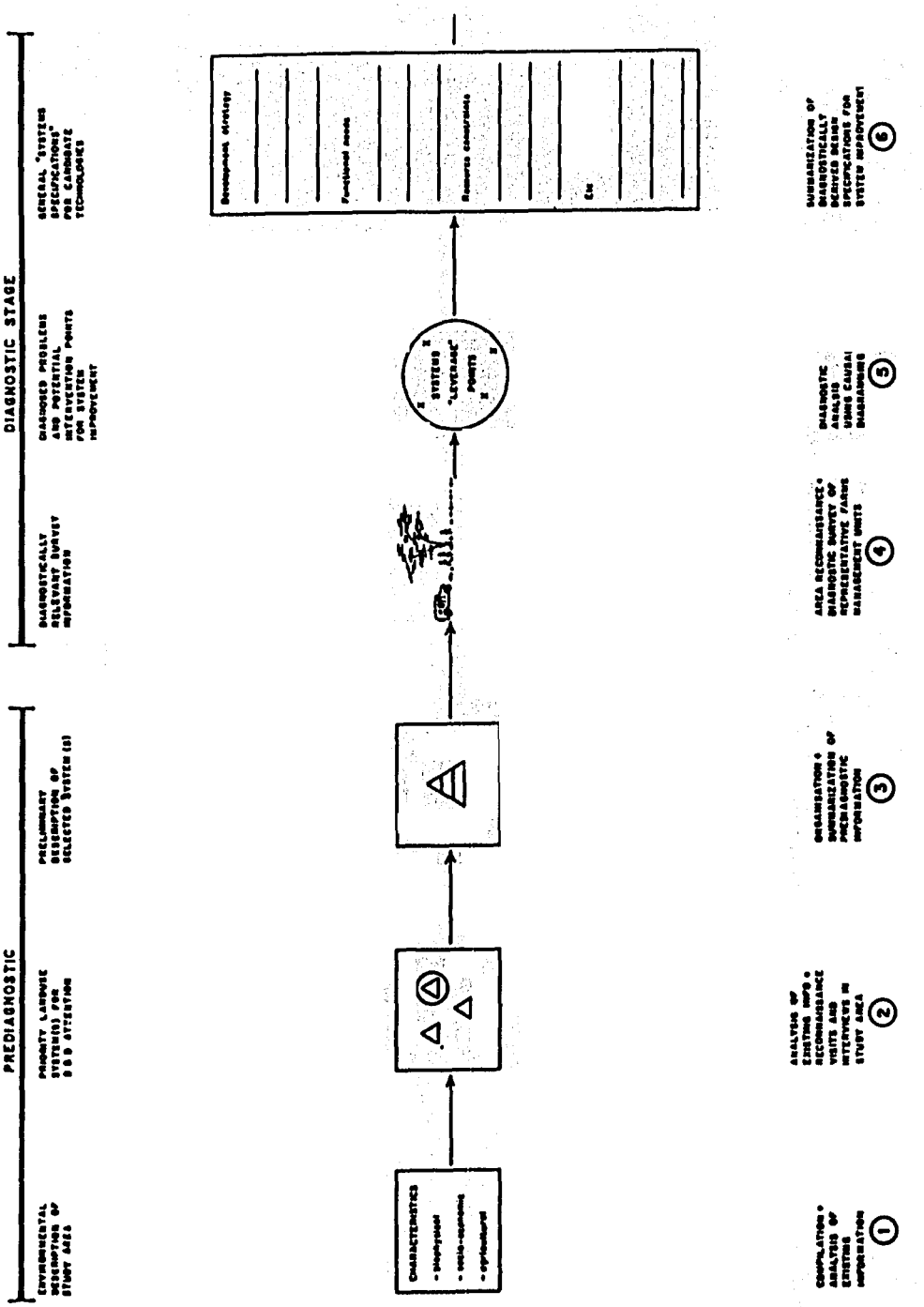
DESIGN - PLANNING - IMPLEMENTATION

"Pre-diagnostic" and "Diagnostic" stages provide an analysis of constraints and an outline of the *kinds* of changes in the system/s that can be seen to be needed (Fig.1) Following these are the "Design", "Planning" and "Implementation" stages.

The "Design" stage proper starts by listing all the possible kinds of technologies that can be considered to help overcome the identified key systems constraints (the 'leverage' points). It finishes with a highly-prioritized and critically-evaluated list of precisely-designated technical proposals which clearly state the species to be used and the management practices to be tried, with an indication of what is already known and/or what has to be found out about these.

The "Planning" stage starts by summarizing what can immediately be put into practice and, at the same time, providing an annotated list of research needs. The second step, to finish this stage, is to design overall plans for extension and research in parallel.

Fig. 1 The "Pre-diagnostic" and "Diagnostic" stages of the "D&D" Procedures. - from Raintree, 1983, 1984; ICRAF 1983a; 1983b.



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The penultimate "implementation" stage requires the formulation of detailed plans for individual investigations which designate precise objectives, experimental designs, resource allocation and methods of data evaluation.

The whole process is shown in the fold-out diagram at the end of this paper. What follows are some further explanations and examples of each of the steps. As with previous stages the operator/s have the choice of level of activity which they undertake for any particular step, depending on preference and the resources available. However, the finalization of the "Design" stage (step 11) which requires a detailed scientific, technical, economic and sociological appraisal, is an operation which *must* be undertaken as thoroughly as possible, and this may take some time, as it must evaluate not only technical proposals, as such, but test these within the systems context also.

EXPLANATION OF STEPS

The causal diagram produced towards the end of the diagnosis stage exposes the system's main 'leverage' points where interventions of the right kind will have the most positive effects in improving the system (Fig. 2) Functional ("systems") specifications for these priority interventions will then be a series of statements or directives attached to each, such as:

"Improve on-farm grazing"

"Utilize off-season labour, especially in April and May".

"Improve on-farm water-use efficiency"

"Contribute to the control of animal access to common lands".

"Increase productive use of external farm boundaries and linear features off-farm"

- and so on.

This step No. 6 in the pre-diagnostic and diagnostic procedures (see fold-out diagram) is still considering the *system* as a whole, and it forms a transition into "design" where actual stated technical proposals are to be put forward. It is a good point of entry for research planning members of the team who may not have been taking part in the actual land use diagnostic procedure (although to do so is always desirable).

Design

Step 7 (Fig.3) Takes each of the general system's specifications statements one by one and lists all apparently feasible interventions (whether agroforestry or not).

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- This is clearly a multi-disciplinary activity, and it should include both those who have been involved in the diagnostic and those who are more concerned with research planning/implementation.

- Examples might be as below, bearing in mind that any one proposed intervention could well address more than one constraint. In practice, and as many of the step sequences in this whole procedure are best re-iterated, it is helpful to write down not only the proposed intervention, but also the restraint/s it addresses. For example:

A. Improve on-farm grazing *by introducing new fodder grass species* (Agricultural)

B. Provide off-season forage *by planting fodder shrubs on farm boundaries* (agroforestry).

C. Improve use of adjacent forest lands for grazing cattle and/or collecting forage *by enrichment planting of multipurpose trees* (forestry).

All these address a hypothetical "poor level of animal production" system's restraint, but there could be further implications in improvements in crop production (if more manure becomes available), and in alleviating labour shortages (if excessive labour is used at present on fodder collection,and overall lack of farm labour is a serious system's restraint). A simple 3 or 4 column table is suitable for such lists: (a) restraints addressed and (b), (c) and (d) potential agroforestry, agricultural and forestry interventions. The last two can be combined, if preferred - see Form A-1.

Step 8. Because the list made in step 7, above, is likely to include suggestions for *numerous* candidate interventions some process of rapid technical/economic/social appraisal and selection has to be done at this stage in order to reduce it to those considered most feasible, and then to set tentative priorities. Here the description of any intervention is still in non-specific terms (that is it does not yet *name* species/varieties or *designate* actual management procedures). Furthermore it is important to consider all promising interventions , whether agroforestry or not, up to this process of establishing a prioritized shortlist. (Agroforesters may then, in practice, go on to consider and evaluate the potentials of just the agroforestry interventions).

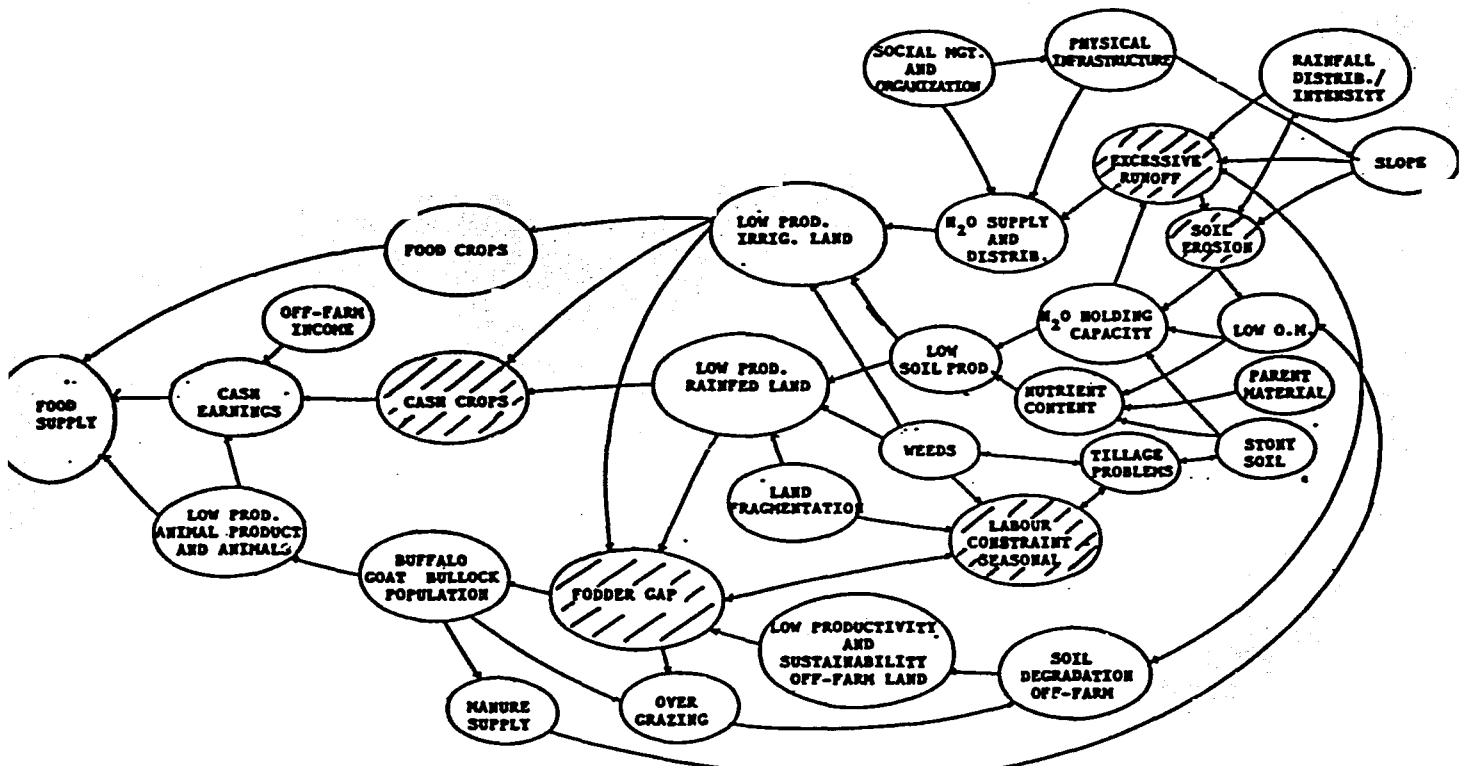

Fig. 2. Causal diagram of land use system's problems (from a "D&D" exercise at Fakot, India). Some "leverage" points are hatched.

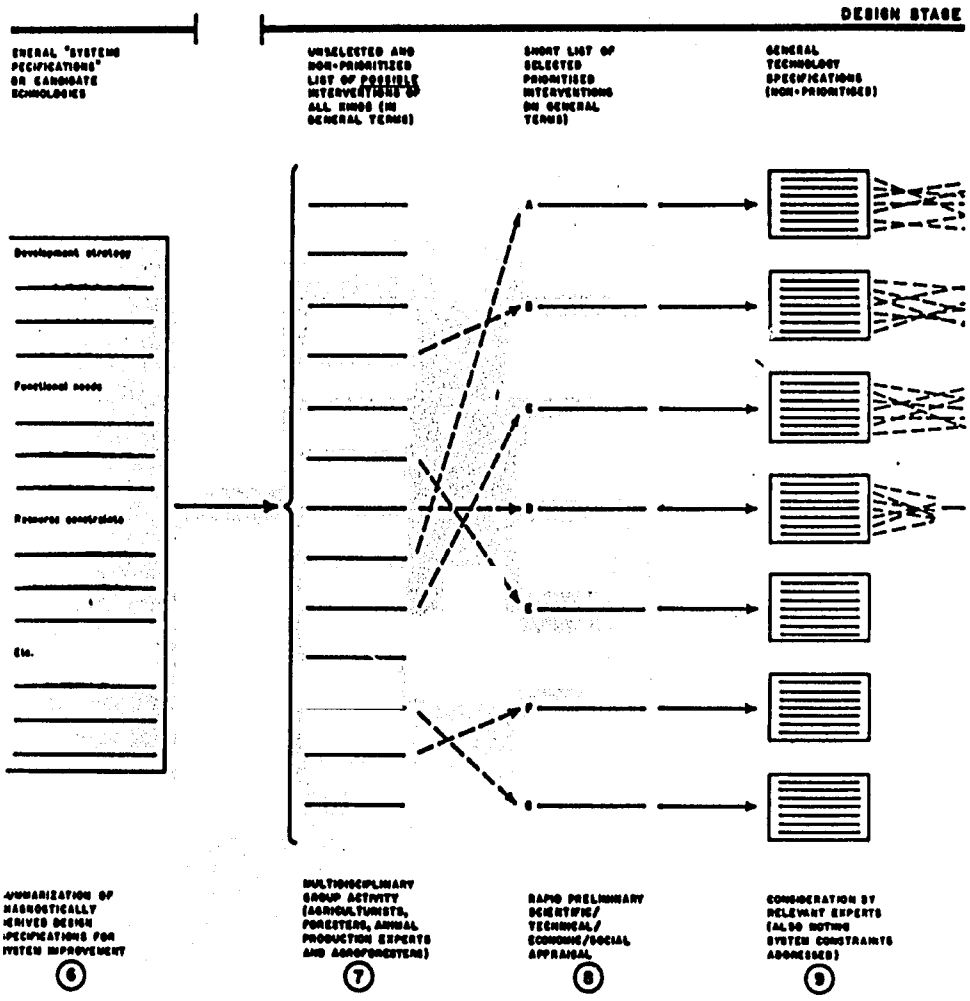

Fig. 3. Listing all feasible interventions (step 7) and selecting and prioritizing them (step 8)

The "Design" stage can be considered to start with either step 6 or step 7.

Diagnosed Problems and Potentials	Non AF Interventions	AF Interventions
I. Cash and Food Shortages on-Farm		
A. Low food and cash crop production in irrigated and non irrigated plots		
1. low soil fertility	inorganic fertilizers; fallow with grass leguminous cover crop	high-nutrient mulch from woody perennials; off-cropland block planted intercropping
2. excessive run off	terracing improvement, mulch	mulch from woody perennials in hedges, later as physical barriers
a) soil erosion	terracing, mulch	
b) soil water deficit and/or irrigation water deficit	extend irrigation and/or improve efficiency water distribution and use change plant spacing	mulch from woody perennials as soil cover
2. weediness (nutrient/water competition	minimum tillage with herbicides	mulch from woody perennials supress weedgrowth
B. Low production, animals/animal products		
1. fodder shortage (general: seasonal;	Increase proportion of dairy animals/ decrease draught animals	
a) high labour required for collection (distance)	plant herbaceous fodder in cut-and-carry lots on commons, near farms	storage of leafy forage from woody perennials plant small cut-and-carry fodder lots in commons, near far
b) inadequate supply fodder on farm	plant herbaceous. fodder on terrace risers.	plant high-protein woody perennials on terrace risers or in hedgerows
c) declining supply and quality of fodder in common and reserve lands	subdivide commons for rotational grazing	use live fences for subdision of commons for rotational grazing enrichment planting herbaceous species tree and shrub planting on commons
C. Seasonal labour shortage		
1. Pronounced peak labour demands	improve tools, timing of tillage to reduce tillage labour and weeding	
a) tillage	minimum tillage with herbicides	
b) weeding		
c) repair terrace risers	stabilise terrace risers with hert. grass cover	stabilize terrace risers with shrubby legumes and/or trees.
2. constant high labour demand	plant herbaceous fodder on terrace risers	
a) fodder collection	plant grass in cut-and-carry lots on commons, near farm	plant fuel and fodder shrubs trees on risers
b) fuel collection		plant cut and carry fuel and fodder trees/shrubs on lots on commons or on fallow plots

Form A-1. In step 7 lists of potentially useful non-agroforestry and Forestry interventions are made in relation to the systems' constraints which they address.

Examples will be in exactly the same form (statements) as in Step 7 (above), from which they have been *selected* and *prioritized*.

Step 9 (Fig.4) Is to derive *technical* specifications for each of the chosen interventions. For example, "B" in the list given to illustrate step 7 above, might have been included in the priority interventions for further consideration (step 8), but it now becomes necessary to define what is intended in more detail. Thus:

"Provide off-season forage by planting fodder shrubs on farm boundaries" would require us to list some of the important attributes the shrub must have *bearing in mind what we have learnt from the pre-diagnostic and diagnostic procedures*. The characteristics we set down are, therefore, not just a generally accepted set of useful attributes, but relate specifically to the needs of the whole land use system that has generated this particular technical proposal. For example the shrubs might have to have the following attributes which form a "technical specification":

a. ease of propagation;
b. fast-growing/high leaf production rate;
c. small-structure (possibly multi-stemmed?);
d. capacity to be pruned/lopped frequently;
e. low competitiveness to adjacent crops (especially for shade and water); and
f. will not encourage pests.

Clearly the field investigations and activities in the diagnostic stage should bear in mind the need to be able, later, to define clear technical specifications.

Step 10 (Fig 4) Having considered all the important attributes that are required the next step is, again, to set priorities within the order of the items in each specification, as far as this is possible. Personnel involved here will need increasingly more access to informed technical/scientific advice if they are not, themselves, experienced in particular subject areas. Again, the process of prioritizing the specification will be related to what is known to be especially important for the particular land use system under study.

Example:

In step 9 (above) the order (a) to (f) might be re-arranged, or some items grouped together as having a similar priority.

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Step 11. (Fig.4) This is the most difficult step of all because it involves making the actual choices of plants and management procedures considered best to satisfy the prioritized technical specifications, and to evaluate how they fit into the proposed system. (i.e it has to be a social and economic, as well as a technical appraisal). The process could well take a considerable time if it means consulting other experts, or requesting further information through literature sources, for example. In undertaking this step the specifications (steps 9 and 10) may need to be reconsidered as more informed technical information is brought out.

For example, there may be an almost equal choice between two multipurpose tree species, both of which seem highly promising, but which differ in the ability to satisfy particular criteria in the specification. However, it may be more feasible to chose one rather than the other on purely technical grounds (e.g. availability of germplasm).

What will become apparent during this part of the procedure, particularly for potential agroforestry interventions, is the extent and reliability of the information available on which to base decisions. In some cases it may be fragmentary ("Is there no more than bibliographic references available about the suitability for this ecozone of a particular MPT species"), or quite consolidated ("Yes, we can use the results of the last 10 years on site selection and management trials with a range of MPT species so as to chose just the one we need!).

In practice, it will usually fall between these two examples, although there may often be much more substantial agricultural information as compared with any knowledge of the technical potentials for agroforestry.

The simple form (A-2) may serve to help arrive at a summary of the status of knowledge about any proposed intervention. This is needed for all proposed interventions as the first step in the "Planning" stage which follows.

The procedures listed so far will have been carried out for each of the selected interventions derived in step 8.

Step 12. (Fig. 5) In turn each should now be assessed for its suitability for:

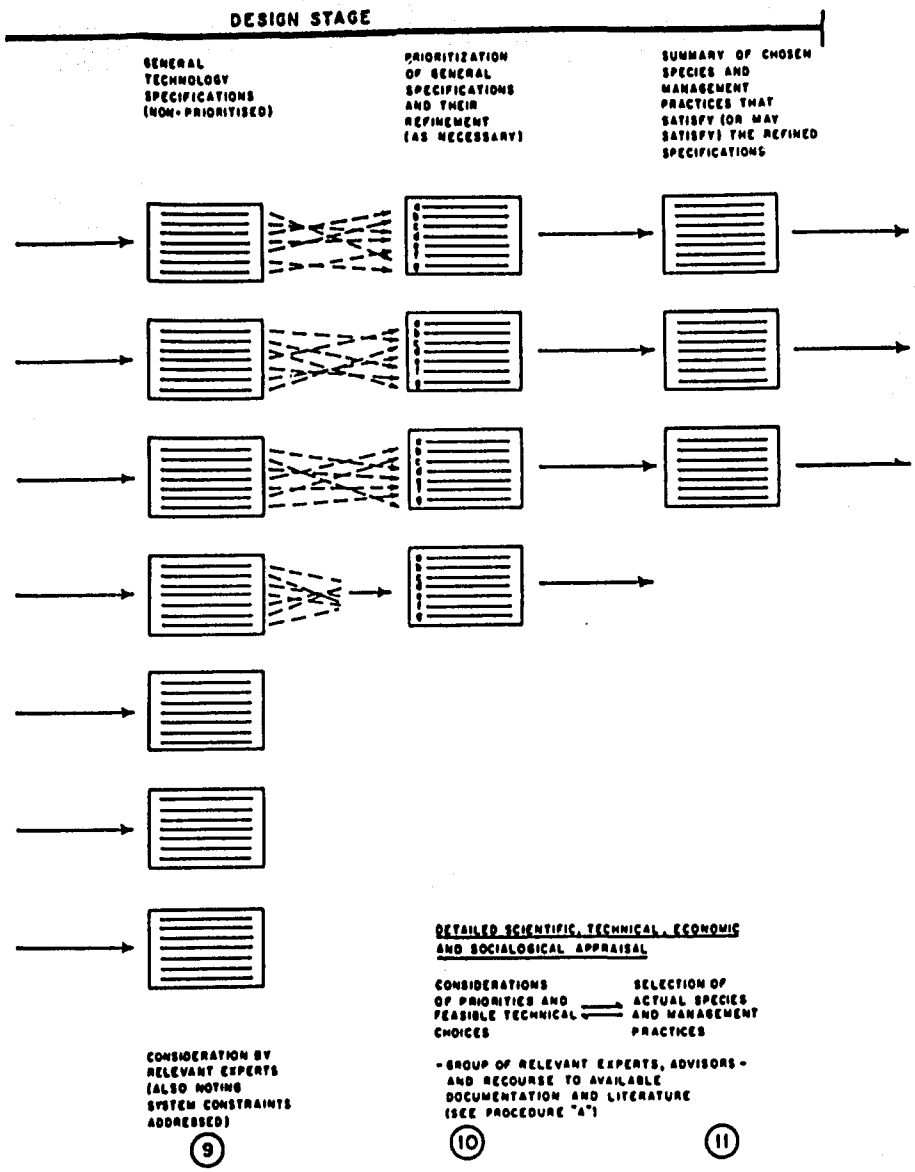

Fig. 4. List general technical specifications for prioritized interventions (step 9) and then prioritize each set of these (re-casting if necessary) - step 10. These sets of specifications, carefully chosen and ranked, now have to be "translated" into absolutely specific statements giving the names of species and proposed management practices etc. that will best fit the individual specifications (step 11). Steps 10 and 11 may need to be re-iterative to achieve feasibility.

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FORM A-2/B-2
(Carry out Procedure A and then B on this same form. One form for each proposed intervention).

PROCEDURE A - MAKE NOTES ON THE STATUS OF INFORMATION AND AVAILABILITY OF PLANTS AND MATERIALS REQUIRED

PROCEDURE B - MAKE STATEMENTS OF TYPE AND EXTENT OF ANY PROPOSED INVESTIGATIONS

INTERVENTION Selection, design and management of suitable Tree/crop combinations

A	on-site	locally/same ecozone	regionally/nationally	world-wide
What is known? (Information sources)	Farmers mainly have experience with Grevia, Bauhinia, Quercus (all local species) mixed with cereal (wheat) as intercrop.	More extensive list of combinations (see Extension Serive Reports)	National trials just starting - see 1984 Agric. Rept. Report	See list of references about multipurpose Trees (attached)
	Simple On-farm geometric designs with farmer's own species combinations - Test also for best management	Repeat throughout whole area	On-station experiments with: (a) Local spp. at different spacings (? systematic layout?) and (b) all candidates introduced MPT's (screen with local crops using a geometric design?)	Link in with other Tree/Crop interface trials in similar eco-zones (check with ICRAF)
What has already been done? (Experimental data available)	Many examples on farmers' plots, but no data recorded	Many examples covering all soil types and both upper and lower zones	Trials with Leucaena and Calliandra with Maize, grain legumes and vegetables at (name of regional research centre).	- Research methodology (from ICRAF) including suggested field layouts. - Similar trials in dry regions (see FAO reports and National Academy of Sciences "Tropical Trees" Programme Reports. - See also list of spacing references to relevant field trials.

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a) immediate extension, and
b) the need for further research.

The information collected on any Form relates to the site itself, to local research experience, to regional or national research experience, and to data available world-wide. The set of forms (one for each intervention) will indicate what is required for the programme as a whole. What is needed now is to sort this information so as to provide the raw material fo: planning both an extension and a research programme.

Although only research planning is discussed further here there is clearly a need to develop research and extension in parallel in a time-compatible way, so that extension activities and research outputs are co-ordinated (perhaps by using simple critical path analysis).

Form A-2 can be additionally annotated (B-2) at this step, through inputs from suitably-experienced personnel, so as to indicate *what level and kind* of investigation is required. For example:

"A literature-search is all that is required taking 3 man months"

"Extensive field-testing programme required lasting at least 5 years"

"Additional on-site field trials needed coveri upland and lowland farms"

etc. etc. (another set of examples is given on form A-2/B-2 (see back).

There is a good opportunity here to indicate whether it is felt that on-station or on-farm investigations are needed for particular interventions, and to indicate a first approximation to the resources needed (e.g. for time).

Step 13. (Fig. 5) This is the derivation of an overall *research plan* to deal with the proposals that have arisen. We are now on familiar ground and the brief outline set out for this and suceeding steps can be supplemented for a more-extended treatment in the "Methodology for the Exploration and Assessment of Multipurpose Trees", P.A. Huxley, 1984 (Ed). Or a "Manual on Species and Provenance Research with Particular Reference to the Tropics" Trop.For. Papers No. 10. CFI, Oxford, by J. Burley, and P.J. Wood (1976); and numerous other texts on research planning.

Some general considerations are contained in the Appendix, but the process of drawing up research plans is one in which the general principles of good planning often have to to be tempered by the expediencies imposed by resource and administrative constraints. A rigorous ranking and selection of proposals must be an integral part of the early stages of the research planning process.

Step 14. (Fig.6) The overall research plan (which may cover both On- and Off-Station activities) has to be translated into detailed planning of individual investigations.

This operation similarly covers a whole range of considerations (some of which are discussed also in the Appendix).

Step 15. (fold-out diagram) It is essential that research and extension goals are closely integrated. On the one hand extension services should be ready to apply the outputs from research without delay, on the other, scientific enthusiasm (for diversion into esoteric pathways) should not divert effort from planned targets. The achievement of a smooth flow of useful information from the research services into field application, and the reverse flow of updated information about responses, change of needs, effectiveness and adoptability factors etc. is, of course, now considered mandatory. This is often, in part, achieved through interchanges within national research and advisory committees as well as structural attempts to integrate the activities of research and extension groups. The "D and D" Procedure is one activity that can provide common interests and a basis for continuing association between such different professional groups.

Step 16. (fold-out diagram) Evaluation of the outcome of the implementation of the proposals resulting from, a complete "D and D" exercise, in terms of improvements in the land use system/s, will necessarily involve waiting some years for such improvements to take effect. Such evaluation will provide information about the value of individual technological interventions as well as their functions in that particular system, and the effects on such a system as a whole.

Some form of interim monitoring by field staff may be desirable, but the procedures for a full evaluation might start by reversing the "D&D" steps (go from right to left).

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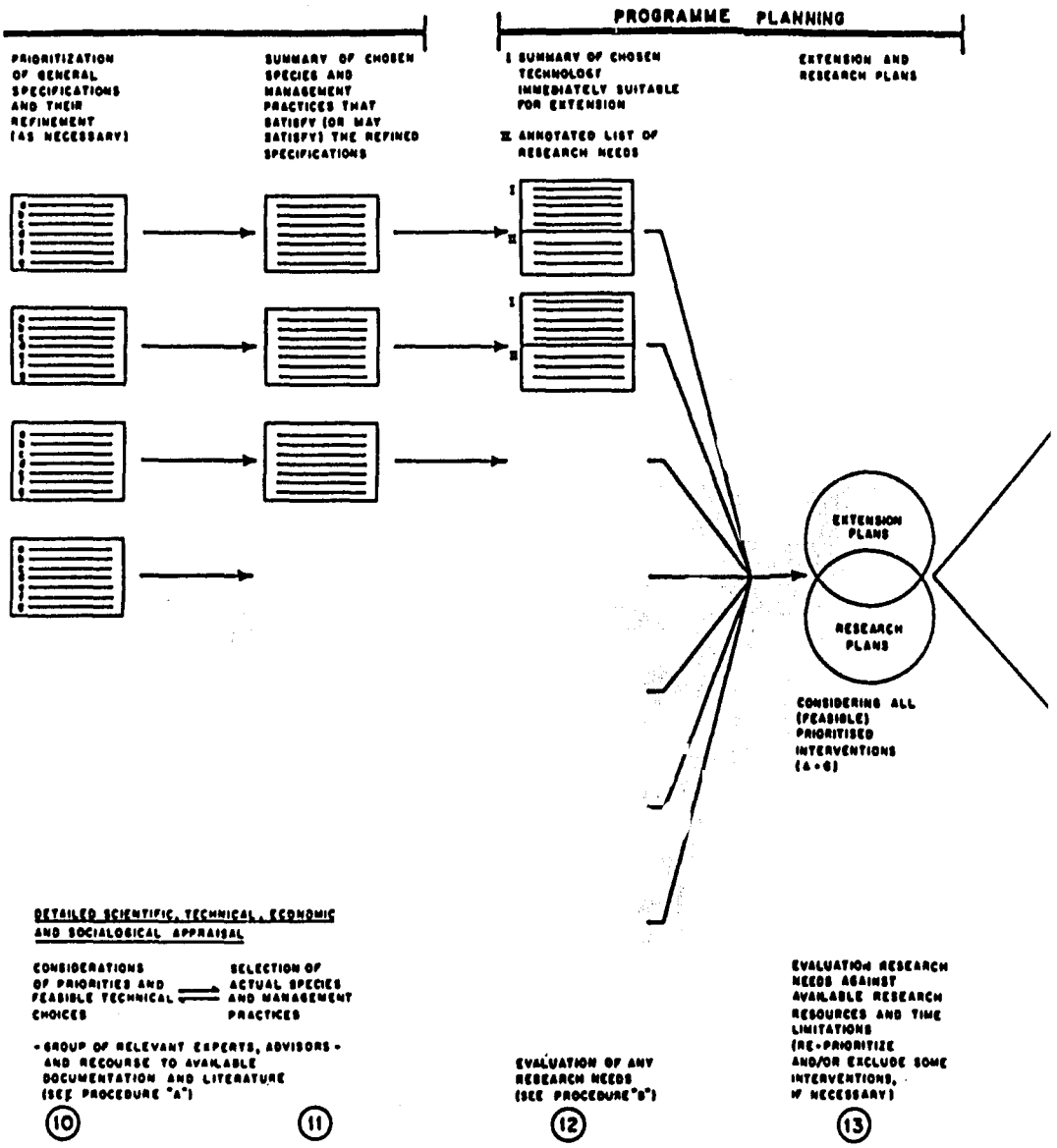

Fig. 5. Assessing what is already known and what needs to be known (step 12). - Form A-2 can be used to make sets of notes (for each proposed intervention) and the same form overwritten (B-2) with outlines of the scope and kind of any research needed. These form can then be used as a starting point to plan parallel programmes (step 13).

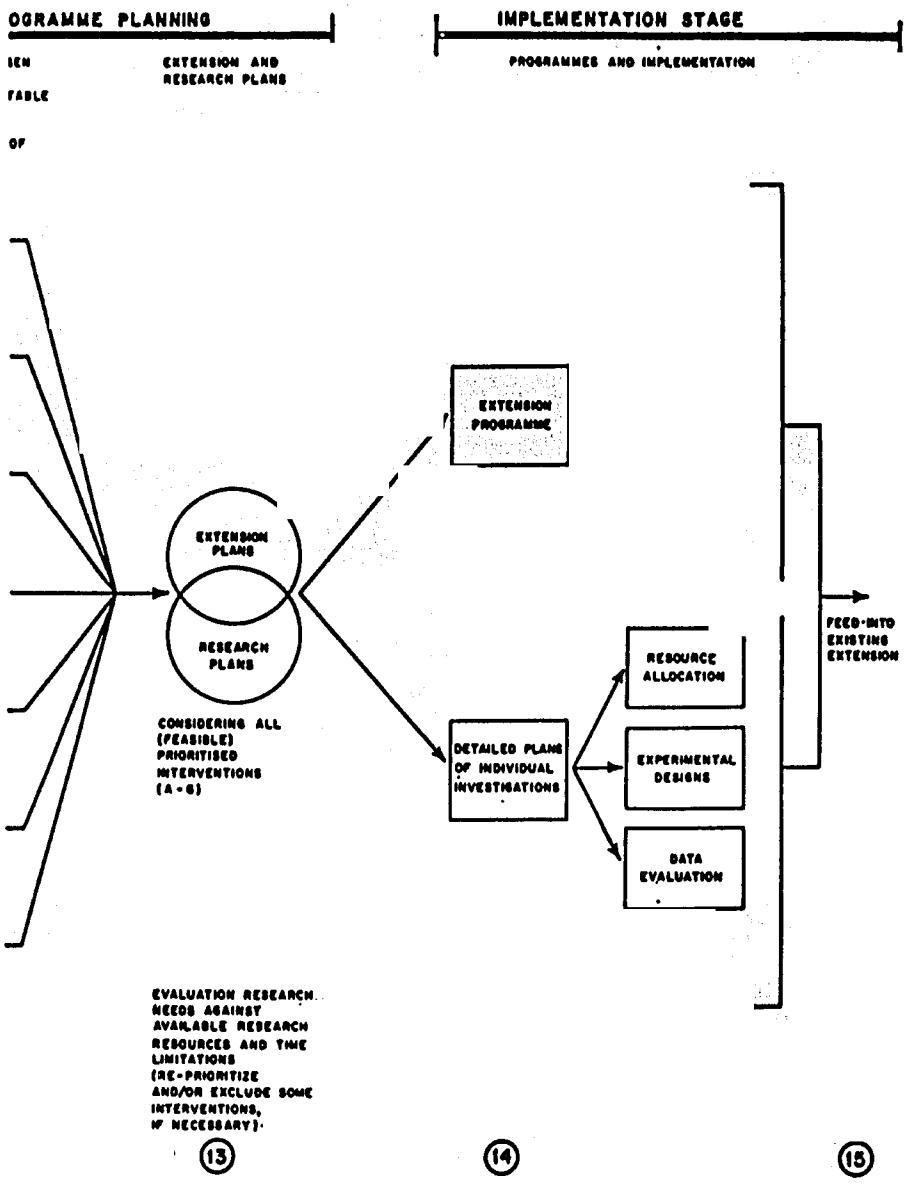

Fig. 6. The conversion of an overall research plan into detailed plans for individual investigations (step 14). The equivalent procedure for detailed extension is not included here, but it is equally necessary.

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That is to evaluate, in the first instance, the effectiveness of research and to test, in the light of subsequent experience, the assumptions made which influenced choices and decisions at earlier design steps.

In a full evaluation it would probably be also necessary to repeat the "D&D" Procedure (in its normal left to right sequence). As has been suggested (J. Seyler, pers. comm.) the "D&D" in its now more complete form provides a mechanism for carrying out Project Evaluation which could well be useful for National Governments, Donor Agencies,etc.

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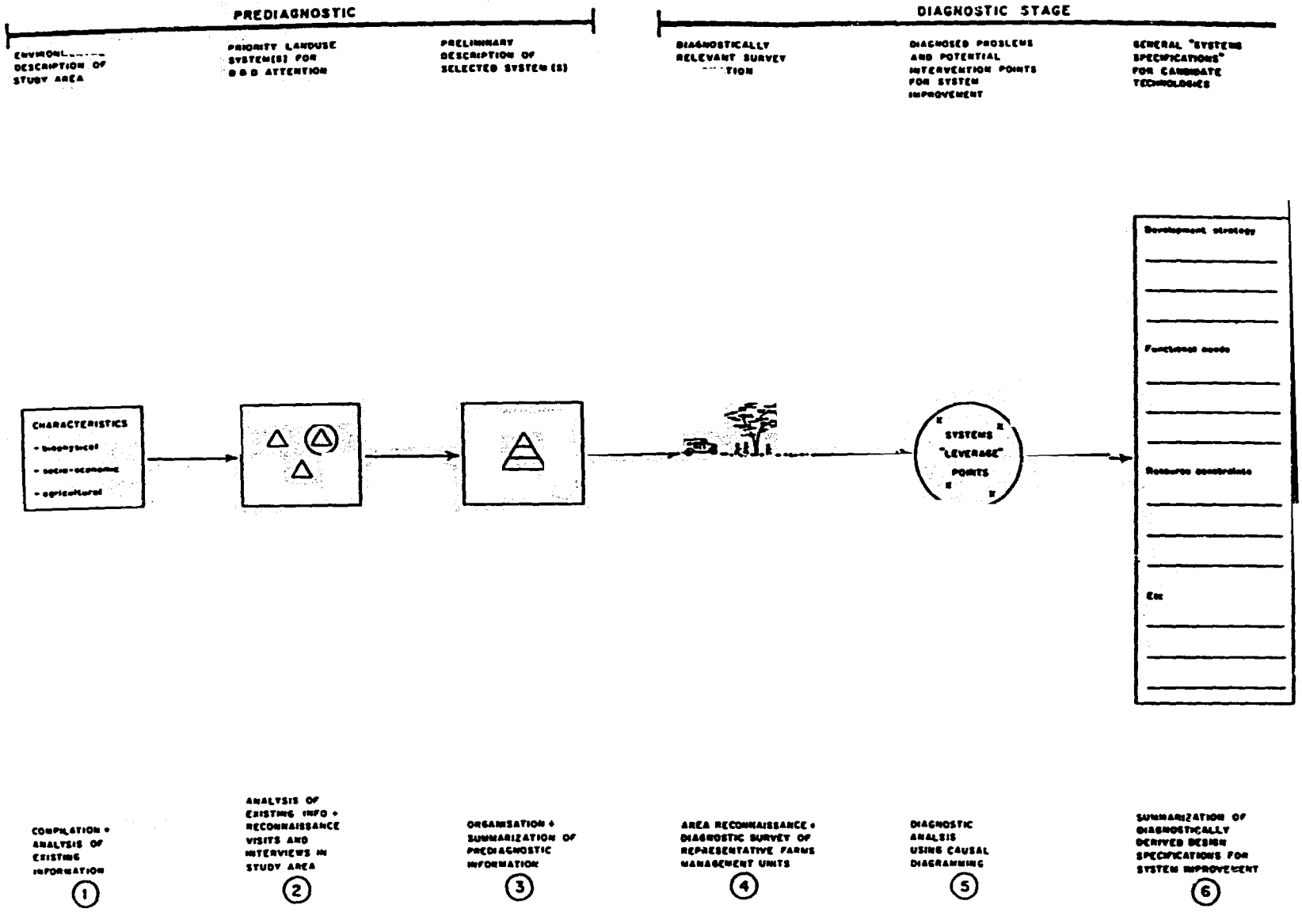
PREDIAGNOSTIC
DIAGNOSTIC STAGE
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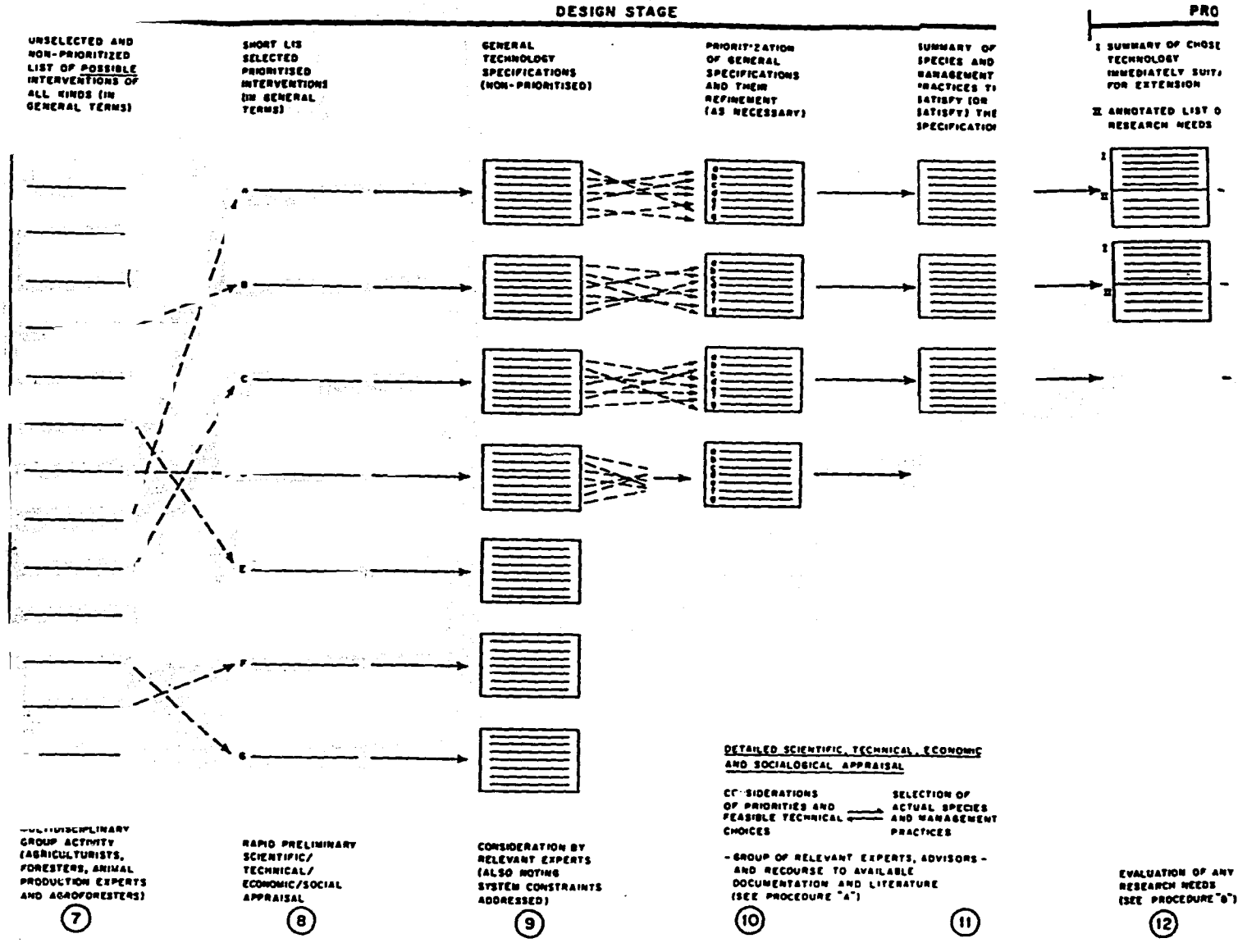
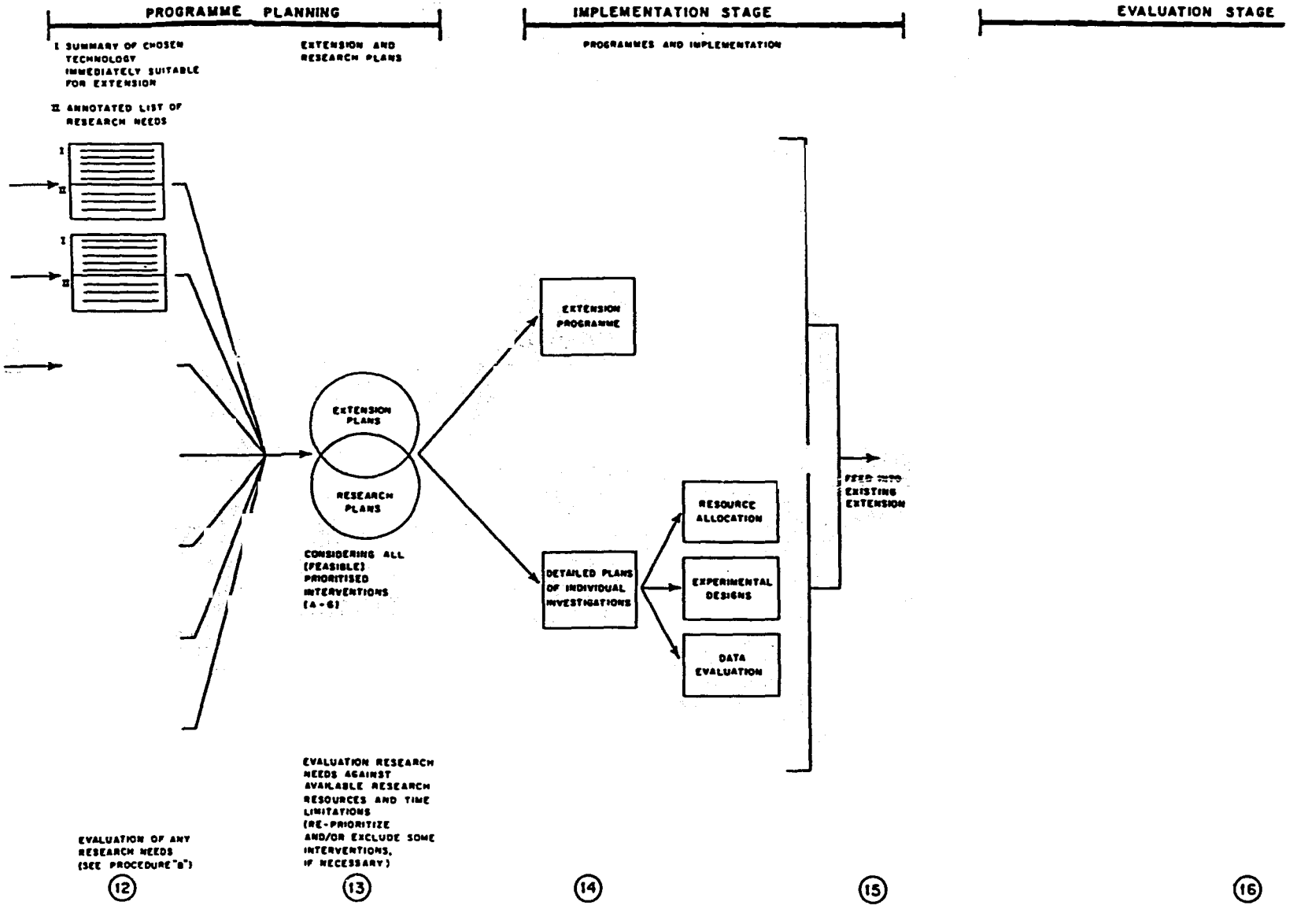
DESCRIPTION OF
STUDY AREA
PRIORITY LANDUSE
SYSTEM(S) FOR
D & D ATTENTION
PRELIMINARY
DESCRIPTION OF
SELECTED SYSTEM (S)
DIAGNOSTICALLY
RELEVANT SURVEY
....TION
DIAGNOSED PROBLEMS
AND POTENTIAL
INTERVENTION POINTS
FOR SYSTEM
IMPROVEMENT
GENERAL "SYSTEMS
SPECIFICATIONS"
FOR CANDIDATE
TECHNOLOGIES
CHARACTERISTICS
- biophysical
- socio-economic
- agricultural
SYSTEMS
"LEVERAGE"
POINTS
Development strategy
Functional needs
Resource constraints
Etc
COMPILATION +
ANALYSIS OF
EXISTING
INFORMATION
1
ANALYSIS OF
EXISTING INFO +
RECONNAISSANCE
VISITS AND
INTERVIEWS IN
STUDY AREA
2
ORGANISATION +
SUMMARIZATION OF
PREDIAGNOSTIC
INFORMATION
3
AREA RECONNAISSANCE +
DIAGNOSTIC SURVEY OF
REPRESENTATIVE FARMS
MANAGEMENT UNITS
4
DIAGNOSTIC
ANALSIS
USING CAUSAL
DIAGRAMMING
5
SUMMARIZATION OF
DIAGNOSTICALLY
DERIVED DESIGN
SPECIFICATIONS FOR
SYSTEM IMPROVEMENT
6


DESIGN STAGE
PRO
UNSELECTED AND NON-PRIORITIZED LIST OF POSSIBLE INTERVENTIONS OF ALL KINDS (IN GENERAL TERMS)
SHORT LIS SELECTED PRIORITISED INTERVENTIONS (IN GENERAL TERMS)
GENERAL TECHNOLOGY SPECIFICATIONS (NON-PRIORITISED)
PRIORITIZATION OF GENERAL SPECIFICATIONS AND THEIR REFINEMENT (AS NECESSARY)
SUMMARY OF SPECIES AND MANAGEMENT PRACTICES TO SATISFY (OR SATISFY) THE SPECIFICATION
I SUMMARY OF CHOSE TECHNOLOGY IMMEDIATELY SUITA FOR EXTENSION
II ANNOTATED LIST O RESEARCH NEEDS
A
B
C
E
F
G
I
II
DETAILED SCIENTIFIC, TECHNICAL, ECONOMIC AND SOCIALOGICAL APPRAISAL
CONSIDERATIONS OF PRIORITIES AND FEASIBLE TECHNICAL CHOICES
SELECTION OF ACTUAL SPECIES AND MANAGEMENT PRACTICES
- GROUP OF RELEVANT EXPERTS, ADVISORS - AND RECOURSE TO AVAILABLE DOCUMENTATION AND LITERATURE (SEE PROCEDURE "A")
GROUP ACTIVITY (AGRICULTURISTS, FORESTERS, ANIMAL PRODUCTION EXPERTS AND AGROFORESTERS)
7
RAPID PRELIMINARY SCIENTIFIC/ TECHNICAL/ ECONOMIC/SOCIAL APPRAISAL
8
CONSIDERATION BY RELEVANT EXPERTS (ALSO NOTING SYSTEM CONSTRAINTS ADDRESSED)
9
10
11
EVALUATION OF ANY RESEARCH NEEDS (SEE PROCEDURE "B")
12


PROGRAMME PLANNING
IMPLEMENTATION STAGE
EVALUATION STAGE
I SUMMARY OF CHOSEN TECHNOLOGY IMMEDIATELY SUITABLE FOR EXTENSION
II ANNOTATED LIST OF RESEARCH NEEDS
EXTENSION AND RESEARCH PLANS
PROGRAMMES AND IMPLEMENTATION
I
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EXTENSION PLANS
RESEARCH PLANS
CONSIDERING ALL (FEASIBLE) PRIORITISED INTERVENTIONS (A-G)
EXTENSION PROGRAMME
DETAILED PLANS OF INDIVIDUAL INVESTIGATIONS
RESOURCE ALLOCATION
EXPERIMENTAL DESIGNS
DATA EVALUATION
FEED INTO EXISTING EXTENSION
EVALUATION OF ANY RESEARCH NEEDS (SEE PROCEDURE "B")
EVALUATION RESEARCH NEEDS AGAINST AVAILABLE RESEARCH RESOURCES AND TIME LIMITATIONS (RE-PRIORITIZE AND/OR EXCLUDE SOME INTERVENTIONS, IF NECESSARY)
12
13
14
15
16

APPENDIX

Extracts from

Research Methodology for the Exploration and Assessment of Multipurpose Trees.

(Ed. P.A. Huxley)
ICRAF

Extract from

SECTION ONE

Part 1B

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TABLE 1 Different phases of field research for studying trees/shrubs suitable for agroforestry systems.

POSSIBLE OBJECTIVE	TYPE OF EXPERIMENT	TYPE OF LAYOUT	PROJECTED TIME SCALE
A. Appraisal of environment-related factors which affect growth and yield of different species already in natural or suitably-modified associations.	Survey of plant associations and environmental characteristics on a seasonal basis.	Multivariate techniques	Over 1 - 2 years.
B. To determine if the plant species are adapted and to select those which establish and grow well.	Elimination trials for: a) establishment and b) adaptation - providing *minimum* management such as fertilizer for the planting hole and/or *minimum* irrigation at planting.	Replications of: Well spaced-plants *and* close-placed plants (hedgerows)	4 - 7 years
C. To determine the phenology and the influence of management on growth (perhaps of the *single* plant).	Vigour/phenology trials Single-tree plots, fully randomized. Plants may be subjected to a range of different but very simple management treatments.	Fully randomized plots	4 - 7 years
D. Performance/management trials. Either on *single* plants or on plots containing *groups* of plants of any one species. a) without animals so as to optimize productivity and	For community studies these would be especially to establish the interactions of spacing and management treatments.	a) Parallel row designs *or* factorial experiments with fixed/variable inter row populations.	All these trials might be laid out so as to investigate the juvenile phase (1-5 years) or the adult phase (6 years onwards) separately.

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	OBJECTIVE	TYPE OF EXPERIMENT	TYPE OF LAYOUT	PROJECTED TIME SCALE
D	b) with animals, if appropriate i.e. if the species have a browse function and so as to investigate the plant-animal interactions.	(note that feeding trials with animals kept separately could be carried out if sufficient materials are available from this type of experiment, or any of the proceeding ones).	b) Randomized blocks with plots arranged to facilitate grazing or very simple systematic designs for farmer evaluation trials.	as above
E	To test a selection of viable alternative components or sub-systems based on the information from proceeding experiments (A-D).	a) Tree/crop interaction trials. b) Large plot investigations using only *highly selected* treatment combinations. Also to include economic assessments such as labour, costs, etc. etc.	Geometric designs (to study the tree/crop interface). Randomized block layouts with or without internal guards and with provision for thinning of the woody component/s.	4-7 years (if trees newly planted or 2 or 3 seasons (if mature trees used).
F	Evaluation of complete systems	Large area investigation to appraise a combination of technical, ecological, social and economic factors	Replication difficult	Very long term

Extract from

SECTION THREE

Part 3A

"General consderations for the evaluation of MPTs"

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Planning and Control of Research* - by J. Burley

Research activities

In all species and provenance research, whether for dense plantations or agroforestry systems, planning is required at several levels. These range from an overall plan by the central coordinator of an international collaborative programme through national plans for the overall control of the investigation in relation to objectives and policies, to detailed methods and procedures for each specific experiment.

The overall plan should proceed from the definition of objectives and the broad statement of policies that will be pursued to achieve them to deal with the following:-

- The selection, grouping, phasing and designing of research projects leading to the preparation of appropriate programmes of work,

- The operational requirements for research units to put these into effect.

More detailed plans for specific experiments in projects, and for services such as experimental design, computing and analysis should be in the form of appendices to the project plan. This will increase the usefulness of the plan as an operational document and will facilitate the addition of new research and the updating or amendment of existing projects and services.

Research programmes and projects

Research programmes will differ considerably depending on the requirements of particular countries but it would be of considerable advantage, in organising or benefitting from co-operation between countries, if research programmes are compiled from considerations of an agreed standard list of the main activities in this sphere of research. It would be a further advantage if, for individual projects, the detailed procedures could also be agreed and standardized in so far as this is possible.

Outline of research activities (suggested standard list)

The main activities in species and provenance research are as follows.

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* See also Part 3C

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- A review of literature, correspondence and personal knowledge of distribution and variation of species likely to be of value. Discussions with international, regional and national organisations concerned with these species.

- A choice of species and of provenances to test

  - selection of parent stands in natural forest where possible based primarily on their seed production, yield production and genetic quality and position in natural area

  - selection and management of seed stands in plantations where possible

  - procurement, treatment and storage of seed.

- Design, layout and analysis of species and provenance experiments

  - assessment and selection of sites

  - selection of systems of silviculture and standard management

  - planning and design of experiments and their interpretation

  - analysis and interpretation of actual experimental data

  - reports and dissemination of results

- Techniques and assessments in the nursery stage, including early test methods

  - nursery conditions and cultural treatments

  - design and conduct of nursery experiments

  - nursery assessments

  - early test methods including biochemical and anatomical studies, juvenile-mature correlations.

- Techniques and assessments in the juvenile to mature stages

  - definition of types of trials and their objectives

  - design and conduct of mature stage experiments

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Assessments in the mature stage, including the following:-

- survival
- form and yield of individual trees and plots
- wood quality, the factors that influence it, and their implications for utilization
- growth form, fodder yield and characters
- chemical observation of wood and other products
- managerial properties (e.g. coppicing or pollarding ability)
- effects on site
- effects on agricultural crops.

Research Management and Monitoring- Some Comments - by J. Burley

Research management and monitoring comprises the following.

- A detailed appreciation of the experimental objectives
- The use of "control plans" to carry out the experimental prescriptions
- Field management and assessment at the prescribed times
- Continuous monitoring of the health and condition of the experiment
- A capacity to "look ahead" and be prepared for unplanned events.

Objectives

Each trial should, from the planning stage, have clearly defined overall objectives for example:

"To compare the survival, growth rate and leaf production of three provenances of *Acacia tortilis* at two sites in northern Kenya"

Further amplification should also be given describing what is expected from the results especially the possibility of obtaining data on a wider variety of outputs (other products e.g. fuelwood, and/or a "service" e.g. data on microsite enrichment).

Planning and control

The experimental or "control plan" sets out the work to be done. It should be kept as simple as possible, but should contain all the essential information to enable another research worker to carry out the work. The basics are as follows.

- The objectives of the experiment translated into a step-by-step review of how the observations and measurement data to be obtained will achieve these. This may also include some outlines of the magnitude of likely errors or bias in order that the more sensitive procedures can be watched and the irrelevant ones ignored.

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- The actual detailed programme of work, phased with dates (or growth stages) for completion, and careful descriptions of how observations and measurements are to be made and recorded and how the experimental diary is to be kept.

Field management

In common with any kind of field experiment the allocation of tasks and responsibilities must be very clearly defined. Observations and data collection, which are likely to be more complex for multipurpose trees than in traditional forestry practice, must be carefully supervised and checked whether "on" or "off" station. Because the size of a research programme depends on the resources available, which are always limited, it must be kept practical from a management point of view. The need for testing a number of sites, for instance, will be balanced against logistical considerations such as maintenance. Also from the practical point of view of management *simple* statistical designs and field layouts are desirable whenever possible.

Continuous monitoring

Regular data collection needs to be supplemented by management observations by *all* field staff. They should be told what to look for in terms of general plant development, health (plant wilting or the onset of pests and diseases), accidents, unusual weather effects, etc. Such observations, both in the nursery and field stages, can give valuable guidance for future research work and early warnings can sometimes save whole experiments.

Wider issues

Any species field trial or experiment is likely to form a part of a wider national program of evaluation work on that species and on multipurpose trees (FGNFTs) in general. This wider programme will take into account the broader national objectives of agroforestry research and development and so will include the following.

- Overall objectives of the national research programme for multipurpose trees (FGNFT's) i.e. with regard to a renewable energy programme, the development of animal resources, food production or the rehabilitation of degraded lands.

- A time scale for this research and development programme (in relation to government targets for national development).

- A set of priorities for the outcome of research with MPT's (FGNFT's). That is priority regions , land use types (intercropping combinations), cash or subsistance systems etc.

- Any general limitations regarding management and labour organisation which might influence the experimental approach, assessment procedures, etc.

- Requirements for staff, materials and finance for higher priority national assignments, and so on.

Clearly any *specific* research programme has to be planned against a background of national objectives and resource allocations. It should also take into account the two-way possibilities of exchanging both information and experience on an *international* level in view of the enormous world-wide interest which MPT's (FGNFT's) have now aroused (see Appendix 1, for some international and national organisations concerned with research in this field).

The Need for Phased Trials* - by J. Burley

General considerations

More often than not adequate information is lacking either on the requirements of the species, or on the characteristics of the site, or both. In such cases embarking on agroforestry or afforestation schemes without a carefully planned and executed experimental programme has often led to costly failures.

The choice of species to use for agroforestry involves the extrapolation of information from elsewhere. Climatic and ecological matching of a new site and the original habitat of a species is rarely enough since it cannot reveal the adaptability of the species to new conditions or its ability to grow satisfactorily in a range of sites. When information is lacking, the best way to acquire it is through trials of a number of species in *small* plots on *representative* locations within the area of the proposed afforestation project. Provided the locations are carefully selected to sample the range of planting sites and are properly looked after, extrapolation of perfomance from small plots to the whole area should involve far less risk than imprecise comparison, based on inadequate data, between widely separated regions of the world.

The advisability of species trials is now generally accepted, but the need for their careful planning and for high standards of maintenance and assessment has often been less appreciated. Species trials themselves can be wasteful and misleading if badly planned or executed and proliferation of plots, if they are ill-sited, ill-tended and ill-protected, is no substitute for a small, wisely planned programme which is tailored to the staff and financial resources available. The objective is to derive the greatest possible information from a given cost or, the other way to obtain the desired information at the lowest possible cost.

For species with naturally wide geographical or ecological ranges, provenance testing is essential. It is easy to be misled in the comparison of species for agroforestry, or for some form of afforestation (including fuelwood lots), if the total range of intra-specific variation is not known.

Identification and comparison of sites must be done on an ecological not a national basis. Results from species trials in other countries in the same climatic zone and on similar soils may

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* see also Section One

be of closer application than those from trials on completely different sites within the same country. In order to make results in one country readily interpretable in another, the value of standardizing methodology, design, methods of assessment and recording, etc, cannot be over-emphasised. The remaining parts of this Manual are intended to facilitate this standardization.

If detailed information is available on all factors significant to the success of a species in plantation and on the status of these factors at the site to be planted, it may be possible to start agroforestry or afforestation without preliminary species or provenance trials. More commonly, however, information has to be acquired gradually. Ideally, when starting from scratch, species and provenance trials should be phased according to the successions:-

Few data on species or on sites.	Increasing data on species/site characteristics
Many species and provenances tested by small plots for short periods.	Fewer species and provenances tested by increasing plot size for longer periods.

Type and duration of trials

In classical species and provenance research for industrial afforestation, distinct phases are commonly encountered and these may be required either singly (sequentially), or in combination (telescoped) or at the same time (parallel) depending on the state of knowledge of the species and afforestation sites.

The ultimate phase is, of course, the complete agroforestry or afforestation project where the source populations are reduced to one or two provenances of one or a few species and where the annual planting area is, in forestry, reckoned in hundreds of thousands of hectares. It must be recognized that there is no standard procedure or time schedule for passage through successive stages of testing; nor is there always a need to use every stage.

A comprehensive phasing in forestry research would include the following.

The species elimination phase (step 10 in the flow diagram)* is the mass screening of a large number of possible species in small plots for a short

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* See below

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period (1/10-1/5 rotation) to determine survival and promise of reasonable growth. The *species testing phase* (step 11) is assigned for the critical testing or comparison of a reduced number of promising species in larger plots for longer periods (¼-½ rotation). The *species proving phase* (step 12) is designed to confirm, under normal conditions, the superiority of a few probable species. Three similar stages apply to provenance testing for species with a wide natural distribution, a *range-wide provenance sampling phase*, a *restricted provenance sampling phase* and a *provenance proving phase*. Since these are generally applied to species that are promising or probable their plot size and duration can be larger than the comparable phases of species testing.

In dealing with MPT's (FGNFT's) for land use of one kind or another the experience gained from forestry research is clearly a place from which to start We do, however, have a range of different end-uses to which the species will be put, and a much wider range of species, of vastly different habit and growth forms, from which to chose. The experience of tree crop specialists (for example, dealing with fruits, nuts and beverage crops) and of range ecologists is also relevant, and particularly so where it comes to the later stages of evaluation that involve management treatments and testing for agroforestry systems.

Although the research phases mentioned above apply, in principle, also to multipurpose trees in agroforestry situations, four levels of experimentation are considered in this manual which are covered by the individual steps in the accompanying flow diagram (see the end of the Section).

- Introductory "Elimination" field trials (step 10) maintained for 1 or 2 years, to determine the capability of each population to withstand the initial transplanting shock and to become established under local conditions of site and management. Again these apply to as many natural origins and land races of each species as it is possible to obtain. In view of each species urgency for placing MPT/FGNFT species in trials in as many sites as possible, and the low probability of obtaining range wide provenance collections for many of the species, the sequence of species and provenance trials outlined above are not mandatory.

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- Vigor/phenology field trials (Step 11) of the most promising (8-10) sources observed in the elimination field trials, and perhaps in large replicated plots, under the expected "best" management treatments, assessed for all production characters over several rotations.

- Performance/management trials (Steps 12a & b) where optimum management techniques are worked out with regard to individual species, potential sites and end-uses. These will also include nursery experiments (which may also include some comparisons in the field with directly sown material); these apply to all seed sources collected.

- Intercropping trials with mixed tree/crop components:- First to determine the optimum mixture of trees and agricultural crop species (Step 16), second to obtain initial information on their possible "design" factors for various types of agroforestry systems (intercrop screening trials); and third, to include or proceed to full management trials (Step 18) with mixed tree/crop components to evaluate the best ways of handling the species mixtures in actual agroforestry systems.

IMPLEMENTATION FLOW CHART FOR STEPS IN EVALUATION OF MULTIPURPOSE WOODY PERENNIALS.- by P.A. Huxley

The flowchart at the end has been prepared in order to draw together some of the point raised earlier about field trials with MPT's, and to combine these with the usual considerations of planning and resource appraisal undertaken when undertaking an experimental programme.

The steps have been elaborated in some detail much as an "aide memoire ". Clearly some have more weight than others, but they are all part of the logical process of planning and implementing a sound experimental programme. If the researcher wishes to "skip" some sections he may chose to do so, but this should be done knowingly and not by default!

Circles represent inputs (e.g. of information and/or germplasm) rectangles "action steps", parallelgrams are "states" and diamonds are "decision processes". Fig. 1 gives an outline of main flowchart sequences.
Following on from the implementation flowchart presented in Section 2 outlining a national strategy for MPT exploration we can assume that there is at least some assess to existing information about both indigenous and exotic MPT species (and, in fewer cases at present, provenances), together with a knowledge of how to obtain supplies of the required, authenticated germplasm.

The latter may present some difficulties at the present time and the reader can be directed to the Proceedings of the Planning Workshop on MPT Germplasm* for a fuller account of these. Also, to Part 4A of this manual which includes some preliminary ideas about the problems of chosing appropriate species and provenances of MPT's.

Notes on the various steps

1 to 5 These arise from and/or relate to the processes involved in chosing appropriate species/provenances. In particular, for Step 1, the choice of provenance may offer an opportunity to extend the accepted range in which a species is generally found to be adapted in its indigenous state (see Part 4A).

Held in Washington D.C. USA June 1983 by ICRAF/IBPGR/CFI/NAS.

If a detailed diagnosis is available of the land-use systems for which the MPT's are potentially useful then the "specification" arising from this will have defined the character and purpose of the woody plant component in some detail for Steps 2 to 4 (see Part 6G and refer to the manual on Diagnostic and Design Methodology" for more details of the land use diagnosis and design procedures).

The outcome, then, will be a list of MPT species/provenances which might be considered suitable, after testing as required, for the purposes and sites outlined by an initial specification.

6 to 8 This list might well be rather lengthy and the overall scope of the experimental programme has to be known, or estimated, at this stage in order to further refine it.

Depending also, for example, on the urgency with which results are required and the feasibility of "telescoping" the various parts of the programme, the question of arranging to overlap different phases needs to be carefully evaluated. In many cases it will be likely that the pressure to arrive at practical results as quickly as possible, so as to provide technical answers for development programmes, will almost certainly eliminate the opportunity to procede in a strictly stepwise fashion by completing each phase of the experimental programme before moving on to the next - this may not be strictly necessary, in any case.

Finally, the initial concepts of "end-use", together with the information gap which has initiated the need for an experimental programme in the first place, will have given rise to a set of research objectives which have, at this point, to be weighed against the resources available to achieve them.

The cost-benefit of different possible ways to provide the answers must always be assessed in terms of a) the integrity of the experimental

procedures b) the level of information required in order to achieve a satisfactory technically operational outcome at a practical level and c) the fulfillment of an adequate set of answers tailored to the socio-economic situations in which they are to be used (see also Part 6B). There may, also, be a case for considering the establishment of a sound scientific and/or technical basis for the elaboration of future experimental programmes, if this is clearly apparent at this stage. But the extent to which this can be provided for, if it does not co-incide with current goals, is probably largely dependent upon the richness or otherwise of the experimental resources available (although the possibilities of obtaining some "basic" information, e.g. about plant responses to the simple management procedures, by adding some simple, additional measurements at low cost, should never be overlooked if it can be done without straining the programme as a whole).

Especially with multipurpose tree experimentation, one should always check whether the programme is feasible before embarking on an overambitious scheme that has, later, to be curtailed. This applies, especially, because of the relatively long-term nature of the field trials involved (see Table 1 Part 1A) and the need for a *sustained* provision of experimental inputs. At this stage (Step 8) it is not too late to go back and revise the scope of the experimental plans to take into account the likelihood of future budget cuts, the loss or transfer of skilled project personnel, the breakdown of equipment that is not easily maintained (and on which the acqusition of essential data depends), and so on. Basically, this is an assessment of risk.

Experimental plans can be very varied depending, to some extent, on the scope of the programme and the amount of detail to be included that personal preferences and the level of organisational ability of support staff dictate. There are some common features that can be listed as generally desirable, such as stating or defining the following.

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- A title
- Project leader/s and other participants
- Location/s and dimension and characteristics of site/s
- Objectives
- Goals (summary of outcome and in what form/s and when)
- Time plan/s of operations
- Support personnel required and when
- Equipment/facilities required and when
- Germplasm sources and plant acquisition/plant raising requirements and provisions (in detail).
- The full description(and map) of the chosen experimental layout.
- Planting out and subsequent plant/soil management procedures to be conformed to.
- Main procedures for data acquisition (mandatory)
- Supplementary data acquisition (intermittent and/or optional)
- Reporting procedures and checks
- Data processing and storage procedures including statistical analysis
- Procedures for disseminating results
- Report and accounting operations

With field trials of MPT's there is a need to be especial careful in planning (apart from choice of species/provenances) over such consideration as:-

- The acquisition of *authentic* germplasm in good time to start the field trials (and the testing of its viability.
- The treatment of young plants to ensure survival and a plant stand with minimum variability (in other than elimination/ survival trials).

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- Possibilities for gapping up early plant losses (and how best to do this so as to reduce variability and to avoid experimental bias).
- The need to impose a standard tree form through early training
- Assessing the needs to explore the juvenile or the mature growth stages (or both)
- The time at which records should commence (bearing in mind the, usually, high variability in the early stages of field trials with woody perennials)
- The possibilities/desirability of sequential thinning operations
- The effects of intermittent or sequential harvesting of different kinds of plant parts.
- Soil management (including times when the plants are to be coppiced)
- The scale of the field trials (in relation to land and labour resources available and the homogeneity of the experimental site/s)
- The possibility of amending management treatments at a later stage when these might be made more precise and/or more information becomes available (implications for the experimental design)
- The need for guard rows/areas (both external and internal)
- The possible occurrence of particularly adverse weather features during course of the experiment (extreme droughts, floods, cyclones etc.).

- Guarding against the depredations of animals at all times (e.g. browsing animals, birds, rabbits, wild pigs, monkeys etc., and at later stages, of thefts by humans).

- Pest and disease control including termites and other soil-borne pests (in view of the scarcity of data for many MPT species).

- The likelihood of some species growing/developing/ageing faster than others.

- Evaluation of the effects of the development of the plant canopy (especially in trials on communities of plants in plots), and a clear indication of how this is to be dealt with if the extent is not previously known.

- How the yield data are to be handled if "seasonal bearing" is found to be a feature of some species but not others.

- When the trial is to be considered over.

10 to 12 It is here that a decision about some level of overlap will often be necessary If little or nothing is known about the survival and/or adaptability of an introduced species (and this includes species or provenances indigenous to a country but being grown outside their natural range or area of natural stands). Thus it makes little sense to embark on higher orders of experimental evaluation (Steps 11 and 12) before *at least* one or two seasons of trials to assess the survival and early growth phases are completed. This applies with even more force to embarking on intercropping trials (Step 16).

In practice, more may well be known about some of the species/provenances selected for a field trial and less about others. In this case a decision has to be taken on whether to include a few "unknowns" at the risk of leaving gaps in the trial later if some do not survive, or have to be ignored due to

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the onset of extreme variability, (perhaps using a layout such as the "augmented designs described in Part 3C), or whether to plan for two separate trials for "unknowns" and "knowns" respectively.

The experience gained from elimination trials in industrial forestry research would indicate that merely "matching-up" tree species according to similarity of ecozone in the countries of origin and introduction may not always result in success, and *vice-versa* (This is due to a number of reasons and the reader is referred to some of the papers given in the selected references for further reading).

Nomenclature

An explanation may be required for the nomenclature used in this flowchart (and the manual as a whole) with regard to the main types of trials. (See also "Research Management and Monitoring" earlier on in this Part). Although "Elimination Trials" (Step 10) are coincident in scope with those normally carried out by foresters, being the mass screening of relatively large numbers of species/provenances, the data collection and scope of the subsequent types of trials - "vigor/phenology trials (Step 11) and "Performance/management trials (Step 12) are likely to involve a greater degree of sophistication and research management with MPT's than their industrial forestry equipment - at least in some respects. They are, indeed, more akin to the types of field experimentation (and laboratory back-up) that tree cash crop and range management specialists are more familiar with.

This is because the potential for multiple outputs may require the acquisition of data about the production of leaves, leafy twigs, small stemwood, flowers, fruits, seeds, bark, gums and secreted compounds and medicinal products as major objectives, as well as roundwood. And the sustainability and/or service factors that may be required of MPT's may, additionally,

demand a knowledge of the potential for nutrient cycling, soil conservation attributes, nitrogen fixation potentials, shelter and shade characteristics, and so on. Furthermore, at a later phase (Step 16), the capacity of a woody species under trial to associate with agricultural crops, grasses, or even other woody crops in mixed cropping schemes has to be evaluated.

Table 1 indicates the *approximate* similarity between trial descriptions used by foresters and those used in this manual.

11 Vigour/phenology trials, as explained in Table 1, will be carried out in order to determine, as completely as possible how different, selected species/ provenances behave at any particular experimental site. There may be a chance here to ascertain the genotype-environment interactions if single-tree or small plots are used over a wide range of sites in different ecozones, at least for juvenile - early mature characteristics (early vigour, duration from planting out to flowering etc). By studying the *individual plant* a great deal can be learnt about within- and between-season phenology and the species growth habits and some clues obtained about possible "best-bet" plant management techniques Early rates of growth may give an indication of biomass potentials, the parts adaptability, "competitiveness" and possible value for producing various outputs (i.e. whether it is a leafy or stemmy type, etc).

Although this phase is pre-eminently still a study at the plant introduction level it may be feasible to introduce some extremely *simple* management treatments in relation to appropriate phenophases (e.g. removing the apices of single sample shoots at different times in the dry and wet seasons in order to ascertain the plant's capacity to re-grow after coppicing/browsing).

12 and 13 Performance/Management trials. In this phase the number of selected assessions (species and/or provenances) are likely to be much fewer and plot experiments

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Steps	Forestry Trial Phases: Nomenclature	Forestry Trial Phases: Scope	Multipurpose Tree Trial Phases: Nomenclature	Multipurpose Tree Trial Phases: Scope
10	Species elimination trials and Range-wide provenance sampling trials	Mass screening in small plots or lines - short-term	Elimination trials	Mass screening in small plots - short-term
11	Species testing trials and Restricted provenance sampling trials	Reduced number of promising accessions only, in larger plots - longer-term	Vigour/phenology trials	Reduced number of promising lines of anything from single tree plots up. Especially to study plant behaviour with a view to helping assess potentials for selection (later) of plant management techniques and for preliminary assessment of output potentials ("multipurpose" traits).
12	Species proving trials and Provenance proving trials	Few selected accessions, large plots and long-term	Performance/management trials	Few selected accessions in either: a) single tree plots (if for wide-spaced systems) and/or b) Small to large plots (if for "crop" situations)
16	Not strictly applicable except, perhaps, trials on suitability of taungya-type plantation establishment methods		Screening intercropping trials	Tree/crop interface trials
			Management intercropping trials	Full scale plot trials with intercrops.

TABLE 1: APPROXIMATE EQUIVALENCE OF TERMS USED TO DESCRIBE CONVENTIONAL FORESTRY FIELD TRIALS AND MPT FIELD TRIALS (AS DESIGNATED IN THIS MANAUL)

will not take up so much space. However, it should be borne in mind that the landuse system for which they are ultimately destined might require them to be used as single, well-spaced species (they may be "trees in farmer's fields"), or as hedgerows in boundary plantings. In this case single tree plots and or lines (at different within row spacings) could be a more appropriate layout for field trials than conventional multi-tree plots.

The levels of applied plant management will be more sophisticated and the data acquisition to measure performance will need to estimate yields (of whatever outputs are chosen) in a quantitative manner. This might well necessitate a higher level of research inputs in terms of measurement equipment and even laboratory analysis than was considered necessary in the, essentially, screening trials which preceded this phase.

14 At this point it would seem prudent to make a thorough assessment so as to interpret and evaluate the information obtained about any particular species or provenance in order to determine whether it can be "promoted", complete with the details of how to manage it, in order to maximize any particular output or group of outputs in the various land use situations it has been designated to provide for (that is, to what extent can it fulfill the original diagnostic "specification"?). If a selection is released before this has been achieved it would be a similar situation to that in which an agricultural crop breeder released a cultivar before it had been satisfactorily tested. There could, of course, be a strong arguement for introducing selections into on-farm trials, even at the early stages of Step 12 (Performance/ Management trials), as part of the evaluation process.

14 and 16 These steps in the flowchart remind us, at the point where a decision is taken to look into intercropping possibilities with MPT's, that there are four sources

of information that should be tapped. In the first place, (Step 14) there are probably considerable data available about any agricultural crop components that might be potential candidates one form or another of intercropped systems (the various alternatives in space and time are outlined in Appendix 3). However, it should be remembered that virtually all selection of genotypes for the major agricultural crops has been directed at maximizing yields, and obviating pest and disease damage, *under sole crop situations*, and certainly not for compatibility in tree/crop associations. Nevertheless, some sensible choices can be made in terms of plant stature, length of the growing season and drought and/or shade resistance (if the latter is known). There will, in nearly all cases, be a number of specific cultivars to chose from.

The basic, comparable information about the multipurpose tree will be that obtained from the published literature, communications from those with any experience elsewhere with the selected species/ provenances and the results of the evaluation programme that have emerged to date. There may be rather scanty information about the performance of provenances for most MPT species, an exception being *Leucaena leucocephala* which has been the subject of world wide trials for at least a few years.

In such circumstances it is probably wise to investigate intercropping possibilities in two stages so as initially to screen, in a relatively simple way, as many possible combinations of MPT's and crops as may be required to satisfy the specifications of relevant agroforestry landuse systems; or as are required by a purely scientific evaluation of combinations chosen to establish any particular hypothesis (Step 15). This number of combinations can then be reduced to only a few and fully explored in terms of management options in a series of final tests (Step 17).

Both the intercrop screening and management trials can draw on two other sources of information (Steps 16a and 16b): a) data obtained by

interplanting existing stands of selected MPT species with crop species (obviously this tests the combinations only in the mature stages of MPT growth and does not exactly simulate what would have happened if intercropping had commenced, *de novo*, on farmer's fields); and b) information about plant compatibility obtained from detailed inventories of existing agroforestry land use systems in the world using the same (or similar) species combinations. The manipulation of mature stands of MPT's might well be considered, equally, to be in the mainstream of experimental steps in the flowchart. However, because it involves a somewhat different experimental approach to that so far covered in the manual this has not been done. Data from such investigations and from a detailed inventory of existing agroforestry land use systems can be of value to both the intercrop screening trials (to help select appropriate and compatible combinations) and, if enough detail is available, to intercrop management trials (providing guidelines for possible plant and soil management treatments)

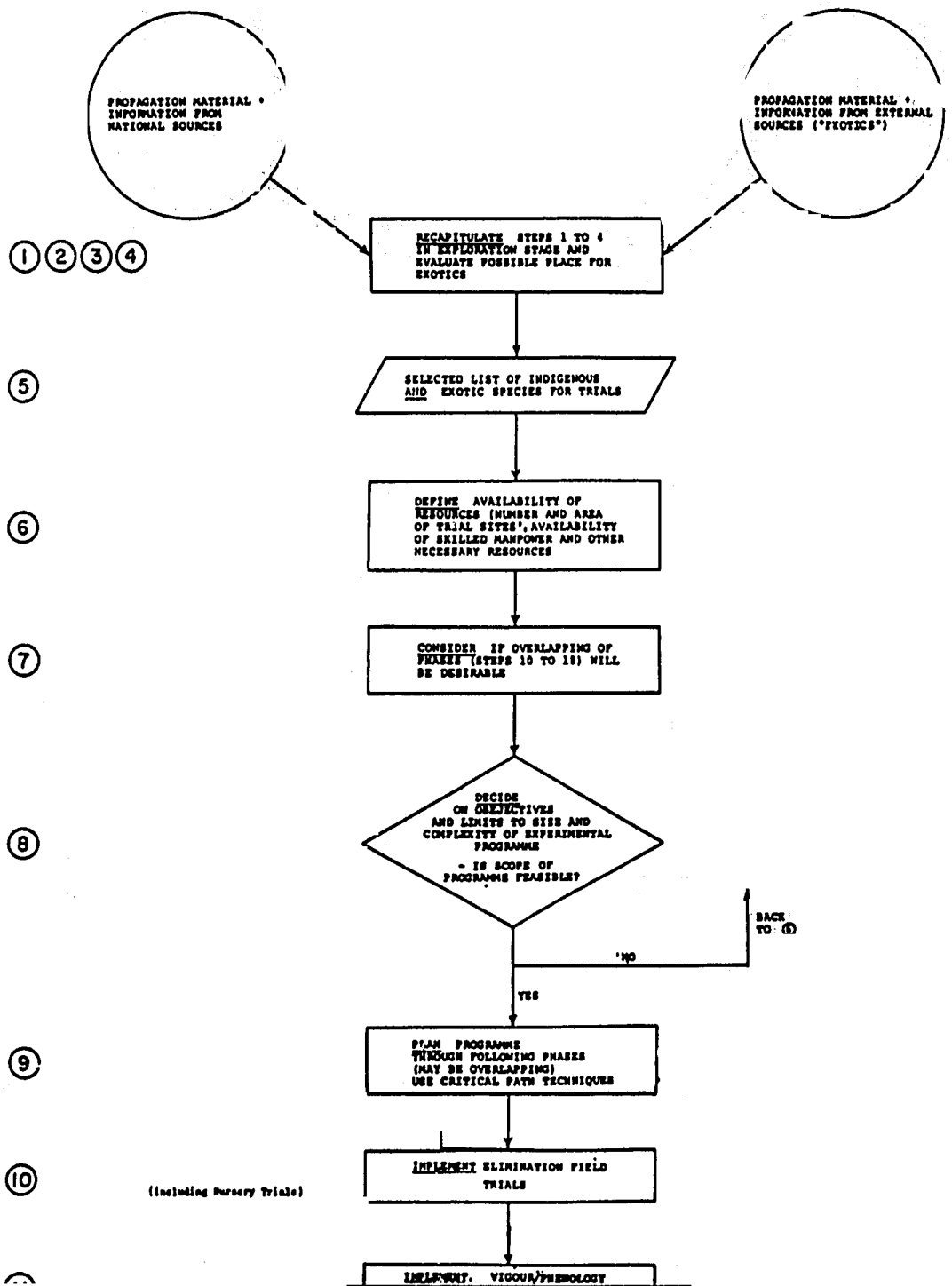
15 and 17 The possibilities of obtaining a good deal of information about tree/crop interactions, and the potential performance of each component in the presence of the other at any one site, by "tree/crop interface" experiments is described in another part of the manual (Part 4C). At this level (the equivalent, for intercropping, of "range-wide provenance tests" for foresters, or "vigour/survival trials" for purely MPT testing) the numbers of combinations for study is still likely to be relatively large. In the next step (17) only a selected few would be further examined, but the number of possible management options (spacings, time-of-sowing, degree and time of lopping/pruning, soil management etc. etc) could be large. Possible ways of considering the selection of experimental variables, depending on the objectives of the experiment, are discussed in other parts (Part 3C "The scope and design of field trials"; 4B Compatibility in mixtures and tree/crop optimization.

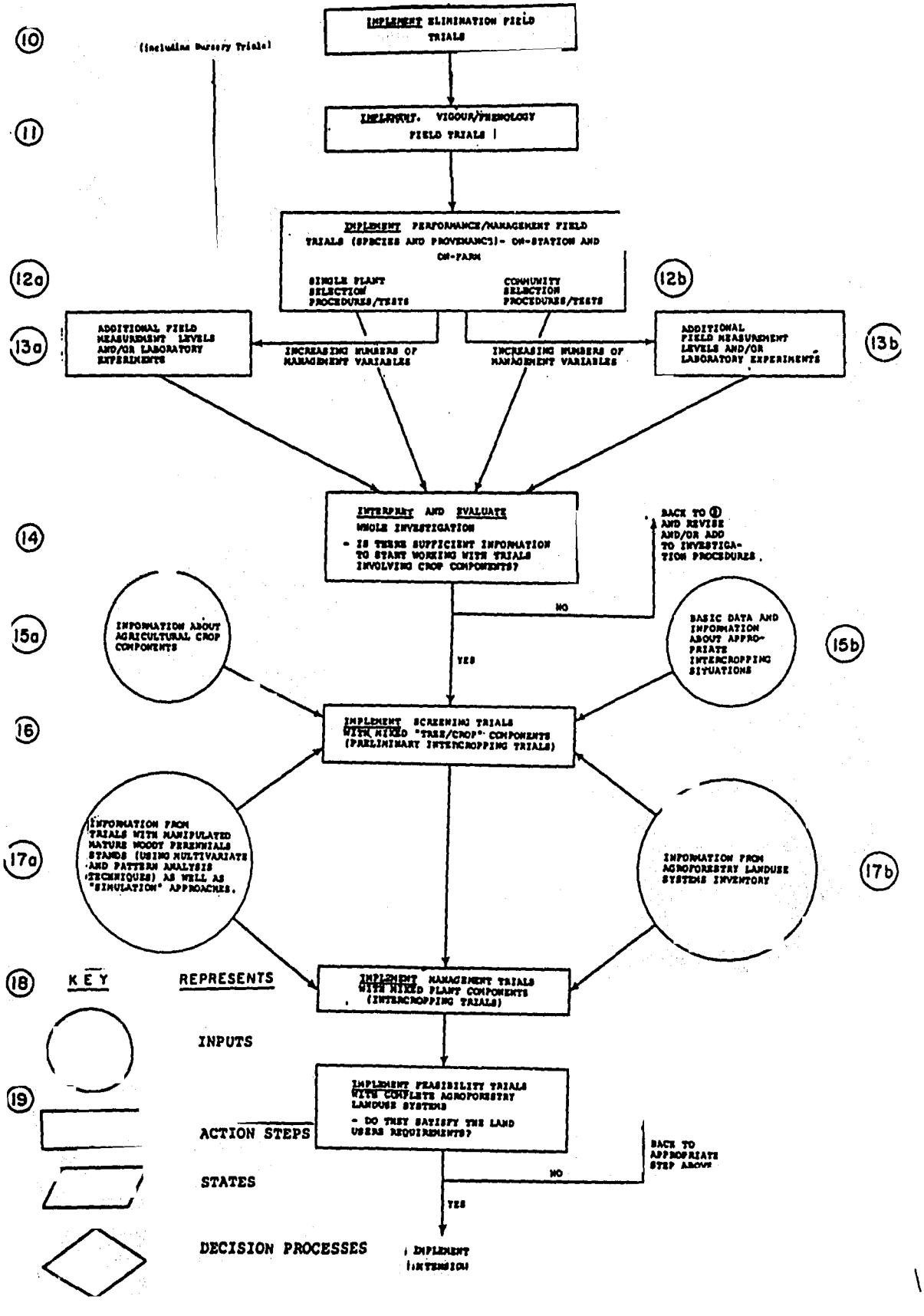
Part 4D "Considerations when experimenting with changes in plant spacing" and others to follow).

18 A final step to take before implementing the results of any experimental programme is to re-examine all the experimental results in the light of the landuser's requirements. "Do they satisfy the specification obtained from the landuse diagnosis? Or, that conceptualized from the experience and knowledge of qualified informants?"

Where it is possible the plant combinations and their management "packages", should be tested in complete systems under the socio-economic state in which they are, if proved successful, to be implemented and extended. Where some of the previous work has been accomplished through on-farm trials this will clearly be easier than if all the work has been confined to research stations. The merits of achieving technical answers in one way or the other will depend on the type of experiment and the resources available. Only local knowledge of the research and farming situations can be of use here, but most experimental programmes with MPT's will, at least with some steps, involve a mixture of the two approaches.

IMPLEMENTATION FLOWCHART FOR
STEPS IN EVALUATION OF MULTIPURPOSE
WOODY PERENNIALS




10
(including Nursery Trials)
IMPLEMENT ELIMINATION FIELD TRIALS
11
IMPLEMENT VIGOUR/PHENOLOGY FIELD TRIALS
IMPLEMENT PERFORMANCE/MANAGEMENT FIELD TRIALS (SPECIES AND PROVENANCE) - ON-STATION AND ON-FARM
12a
SINGLE PLANT SELECTION PROCEDURES/TESTS
COMMUNITY SELECTION PROCEDURES/TESTS
12b
13a
ADDITIONAL FIELD MEASUREMENT LEVELS AND/OR LABORATORY EXPERIMENTS
INCREASING NUMBERS OF MANAGEMENT VARIABLES
INCREASING NUMBERS OF MANAGEMENT VARIABLES
ADDITIONAL FIELD MEASUREMENT LEVELS AND/OR LABORATORY EXPERIMENTS
13b
14
INTERPRET AND EVALUATE WHOLE INVESTIGATION
- IS THERE SUFFICIENT INFORMATION TO START WORKING WITH TRIALS INVOLVING CROP COMPONENTS?
BACK TO 1 AND REVISE AND/OR ADD TO INVESTIGATION PROCEDURES.
NO
YES
15a
INFORMATION ABOUT AGRICULTURAL CROP COMPONENTS
BASIC DATA AND INFORMATION ABOUT APPROPRIATE INTERCROPPING SITUATIONS
15b
16
IMPLEMENT SCREENING TRIALS WITH MIXED "TREE/CROP" COMPONENTS (PRELIMINARY INTERCROPPING TRIALS)
17a
INFORMATION FROM TRIALS WITH MANIPULATED MATURE WOODY PERENNIALS STANDS (USING MULTIVARIATE AND PATTERN ANALYSIS TECHNIQUES) AS WELL AS "SIMULATION" APPROACHES.
INFORMATION FROM AGROFORESTRY LANDUSE SYSTEMS INVENTORY
17b
18
KEY
REPRESENTS
INPUTS
19
ACTION STEPS
STATES
DECISION PROCESSES
IMPLEMENT MANAGEMENT TRIALS WITH MIXED PLANT COMPONENTS (INTERCROPPING TRIALS)
IMPLEMENT FEASIBILITY TRIALS WITH COMPLETE AGROFORESTRY LANDUSE SYSTEMS
- DO THEY SATISFY THE LAND USERS REQUIREMENTS?
BACK TO APPROPRIATE STEP ABOVE
NO
YES
IMPLEMENT (INTENSION)

Extract from

SECTION THREE

Part 3C

"Field Trials Some General Considerations"

by P.A. Huxley

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Table 1 Selection of approaches for MPT trials of various kinds.

Degree of control over local environment variation	Type of study requires: Single plants	Community-grown plants
None *or* Minimal	Well-spaced fully randomised (individual or lines)	Simple replicated plots *or* systematic designs
Definitely required	Single tree plots	Multiple tree plots

arranged in:

- Randomized complete blocks
- Latin squares
- Rotating designs (e.g. Augmented layouts)

Consider raising efficiency and/or effectiveness by the use of:

- Partial replication (e.g. Lattice designs)
- Split plots/factorial arrangements
- Covariance/Nearest neighbour analyses

Design of Experiments

Stating the objectives

1. Have you stated clearly and explicitly the objectives of the experiment and the reasons for undertaking it?
2. Have you translated these objectives into precise questions that the experiment can be expected to answer?

Defining the population about which inferences are to be made

3. Have you defined carefully the population about which you are seeking to make inferences from the results of the experiment?
4. Is the site or location of the experiment representative of that defined population?
5. If not, what do you need to do to find a representative site?
6. Is the experimental material to be used in the experiment, e.g. plants, animals, soil, water, etc., representative of the defined population?
7. If not, how can representative material be obtained?
8. If either the location or the experimental material is not representative of the population about which you wish to make inferences, is it worth doing the experiment at all?

Selection of experimental treatments

9. Have the experimental treatments been defined sufficiently precisely for them to be applied correctly by the experimenter or by those wishing to repeat the experiment, and are they realistic?
10. If the "treatments" consist of species, varieties, or strains of organisms, are they representative of some defined population of organisms?
11. Can the experimental treatments be expressed as "factors", that is as groups of treatments at two or more levels?
12. If so, can all combinations of factors be achieved and are these combinations realistic?
13. Is the number of levels within each factor restricted to two or three?
14. If not, is there any real advantage in using more than three levels to determine the shape of the response curve?
15. Do the levels of any one factor change by a constant amount or in a constant ratio?
16. If not, is there a good reason for departing from linear relationships, or relationships which can be made linear by an appropriate transformation?
17. Is the number of factorial combinations so large that there would be some advantage in considering only some of those combinations, perhaps sequentially?
18. Is there a naturally defined control treatment which should be included in the experiment?

Plot shape and size

19. Is the plot size for the experiment defined by the nature of the experimental material or the site?
20. If not, will the proposed plot size enable the treatments to be applied and allow the desired records to be made?
21. Is the plot shape defined by the nature of the experimental material or treatments?
22. If not, will the proposed plot shape enable the treatments to be applied and allow the desired records to be made?
23. Are the experimental plots all of the same size and shape?
24. If not, are you aware of the problems that may be encountered during the analysis of the results of the experiment?
25. Is there likely to be interaction between the individual plots of the experiment?
26. Can this competition be reduced by increasing the space between plots, or surrounding each plot by a buffer zone?
27. Are the plots of the experiment of the smallest size consistent with the other constraints?

Number of replications

28. Do you have any preliminary estimates of the precision likely to be achieved by the experiment (expressed as a coefficient of variation, for example)?
29. Is it possible to conduct a pilot experiment to determine the coefficient of variation likely to be encountered, and to test the experimental procedures?
30. Have you determined the size of the difference between treatment means which you would regard as of practical importance, if such a difference were to exist?
31. Have you calculated the number of replications that would be necessary to match the size of the differences likely to be detected as significant with the size of differences you regard as of practical importance?

    (E.g. $N = \left(\frac{c}{s}\right)^2$

    where N = number of replications
    c = coefficient of variation
    s = standard error of means)
32. If there is insufficient land or experimental material for the number of replications required to give significant differences of practical importance, is it worth doing the experiment at all?
33. Do the controls need to be replicated more or less frequently than the other treatments, in order to place greater emphasis on particular comparisons?

Layout of the experiment

34. Is it possible to divide the site of the experiment or the experimental material into blocks within each of which there will be less variation than over the experiment as a whole?
35. Is the size of these blocks sufficiently large to contain at least one plot of each treatment and controls?

36. Have you considered the advantages of robustness and ease of analysis of a randomized block design?

37. If the blocks are not large enough to contain at least one plot of each treatment and controls, is there some way of allocating the treatment replications so that the important comparisons are estimated with the greatest precision?

38. If the treatment comparisons are not orthogonal, do you know how the data can be analysed, and will that analysis answer the questions the experiment is designed to pose?

39. Are there any regular trends across the experimental site or material? If so, are these trends in one or both directions?

40. Have you considered the use of row and column designs to remove the effects of one or two-way trends?

41. Is there likely to be any advantage in the use of a split plot design?

42. If so, are the treatments applied to the sub-plots the ones for which the greatest precision is required?

43. Will confounding of treatment factors or interactions with block differences improve the efficiency of the design?

44. Have you planned to use the blocks of the experiments to absorb as much as possible of the extraneous variation in the execution and conduct of the experiment?

45. Is it possible that plots may be lost through accidents or mishaps?

46. If so, does your choice of experimental layout allow for a meaningful interpretation of the results?

Randomization

47. Have the treatments and controls been allocated to the plots of the experiment by an explicit randomizing procedure?

48. Was a separate randomization carried out for each block or row of the experiment?

49. Were the constraints on the randomization correctly applied?

50. Were you tempted to re-randomize any part of the allocation of treatments and controls to plots because of apparently unfortunate coincidences?

51. If so, do you have some knowledge of variation in the site or experimental material which has not been incorporated into the design of the experiment?

52. Does a plan exist, showing the allocation of the treatments and controls to the individual plots?

Recording of results

53. Does each plot of the experiment have a clear number or designation, linking it unambiguously to the plan of the experiment?

54. Have you defined the time intervals at which assessments of the experimental results are to be made?

55. Have you defined the variables or attributes to be counted or measured at each assessment?

56. If so, are the measurements meaningful and relevant to the objectives of the experiment?

57. Are any of the assessments to be made from samples of the experimental plot rather than from the whole plot?

58. If so, has the efficiency of the sampling been tested?

59. Are any of the assessments to be used as covariates to correct for unavoidable but measurable differences between the plots?

60. If so, will these assessments need to be made before any of the experimental treatments are applied, or can take any effect?

61. Have you planned to use the blocks or rows of the experiment to absorb any unwanted variation in assessment, e.g. different observers, assessments on different days or at different times of the day?

62. Have you designed a record form which will ensure that all assessments are complete and are recorded against the correct plot?

63. Have the assessors been trained to measure and count the variables or attributes efficiently and accurately?

64. Is there space on the record forms for observations to be recorded of unexpected changes or effects, and have the assessors been encouraged to look for these effects?

Planning for analysis

65. Have the hypotheses to be tested in the analysis of the results of the experiment, and their alternatives, been defined *a priori*?

66. Are these tests expressed, as far as possible, as null hypotheses?

67. Have any special contrasts to be tested or estimated in the analysis been defined in advance of a first inspection of the results of the experiment?

68. Do you understand the methods of analysis that will need to be used for this experiment and made arrangements for the computations to be done on a computer, or elsewhere?

69. If the computations are to be done on a computer, does the necessary program exist, and do you understand the constraints that the program places on the data set?

70. If not, have you obtained advice from a qualified statistician on the analysis and interpretation of the results, preferably before starting on the experiment?

The final (and most important) question

71. If you are in doubt about the purpose of any of the questions in this checklist, should you not obtain some advice from a statistician with experience of your field of research before continuing with the experiment?

There is usually little that a statistician can do to help you once you have committed yourself to a particular experimental design.

TABLE 2 OBJECTIVES AND DESIGNS FOR FOUR DIFFERENT TYPES OF FIELD TRIALS WITH MPT'S

Types of trial	Objectives	Suggested design(s)	Comments
1. Nursery	To explore the ways of optimising the plant-raising conditions of selected species using relevant nursery practices.	Fully-randomized plants, or plots; or randomized complete block design.	May also involve separate direct-sowing trials, if appropriate. (Studies on biosystematics, juvenile-mature correlations, seed source identification and specific physiological/microbiological responses would be treated as separate experiments).
2. Elimination/ Survival (= "species elimination" or "Range-wide provenance trials")	To test, in the short-term (2 to 4 years, maximum) the ability of any interesting species (and/or range-wide provenances) to establish and flourish.	Fully-randomized single plants or *small* plots (no guards needed). Split into several experiments if needed to obviate local environmental variation.	The inclusion of some, known well-adapted species is useful in order to have a 'controlled' estimate of potential growth in view of year-to-year climatic variations over the short term of these trials.
3. Vigour/Phenology (="Species testing or "Restricted provenance trials")	To re-evaluate, and critically compare the growth performance of apparently adapted *selected* species (or provenances), and to obtain information concerning plant behaviour.	Depending on whether a) single plant b) community grown assessments are required: a) Fully-randomized or lattice designs or b) Augmented design in randomised blocks.	Species (or provenances) of very different structure should not be included in the same 'community-grown' trial. The repetition of trials in both space and time at this phase will enable GxE evaluation to be started.

TABLE 2 Cont.

Types of trial	Objectives	Suggested design(s)	Comments
4. Early management ("species or provenance proving")	To compare a selected range of management techniques for one or more chosen species (or provenances) with a view to obtaining *extrapolatable* information on how best to optimize chosen outputs (products and/or services) in a range of practical situations.	Fully-randomized for single-plant studies. Randomized complete blocks (possibly with split-plots or a full factorial arrangement) for community-grown studies. Systematic designs where spacing is a prime variable.	See the 'Evaluation' flow diagram. As more is known about the species (or provenance) and the land use system for which it is destined, then increasingly complex management trials will be required. At this stage vegetatively propagate material can help cut down unwanted variability.