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INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

NAIROBI KENYA
1—18 NOVEMBER 1983

P R E F A C E

Agroforestry is a collective term for land use systems and practices based on the integration of woody perennials with crops and/or animals. Ecological and socio-economic reasons for an agroforestry approach to land development include the need to counteract declining soil fertility, erosion and shortage of fuelwood, coupled with a lack of cash reserves and inadequate infrastructure among many tropical and sub-tropical farmers.

Agroforestry as a field of systematic research suffers from the fact that few scientists have received specific training in the subject. There are also relatively few institutions which focus upon integrated land use systems and the technology of agroforestry.

The International Council for Research in Agroforestry (ICRAF) has launched a series of three-week training courses to disseminate available knowledge on agroforestry practices and systems and methods for assessing land use problems and evaluating agroforestry potentials.

Together with the organization of the courses ICRAF is involved in developing training material packages in agroforestry which can be used by training institutions and organization without direct ICRAF staff participation. ICRAF is pleased to present this compendium which follows the sequential arrangement of contents and components of a course on "Agroforestry Research for Development: Concepts, Practices and Methods".

Both the training courses and the production of training packages in agroforestry are supported by the United States Agency for International Development, to which ICRAF is most grateful.

Dr. Bjorn Lundgren
DIRECTOR

INTRODUCTION

Agroforestry being a new area of scientific and academic activity, it is seldom taught formally in training and educational institutions. Therefore, there is virtually no infrastructure for training - either trained manpower or trained materials - in agroforestry. However, the recent activities of ICRAF and other institutions that are engaged in agroforestry research and development have resulted, among other things, in some advancement towards the development of the discipline: the concepts and principles of agroforestry are, by and large, clear the methodological 'procedures' to handle agroforestry are being elucidated, and efforts to collect and disseminate information pertaining to agroforestry are making steady progress.

Simultaneous to these developments, it is essential to initiate sound programmes to impart training in agroforestry to people at various levels. ICRAF's international position and Charter responsibility on the one hand, and its coordinating and catalyzing role on the other calls the Council to play a leading role in this area.

As a result of the ICRAF/USAID Cooperative Agreement, ICRAF Agroforestry Training Project began in late 1982 programming activities leading to the organization of short training courses on practical and theoretical aspects of agroforestry and the development of training materials. The training course just about to begin in Nairobi and the present package of training materials in agroforestry represents an important initial step in this direction. Both of these activities will continue to run concurrently and both are to be constantly refined and modified based on past experience and fresh results.

The Agroforestry Course (Nairobi, 1-18 November 1983)

The overall objective of the course is "to enhance the professional capabilities of research scientists and development planners from developing countries for initiating and implementing agroforestry research, leading to the development of systems and technologies that are both suited to local conditions and adoptable by farmers".

Specifically, by the end of the course participants are expected:

(Main)
- To become familiarized with the concepts and procedures of ICRAF's methodology to diagnose agroforestry related land use problems/potentials and design appropriate agroforestry systems.

(Complementary)
- To become acquainted with ICRAF's institutional organization and programme of work.

- To become updated on available agroforestry research information and appropriate experimental approaches.

The three-week training course is intended for research scientists and development planners responsible for agroforestry research or rural development projects or programmes. In general terms, the scope and content of the first week focus on the conceptual and technical background of agroforestry while on the second and third weeks it concentrates on methods to diagnose agroforestry related land use problems/potentials and design appropriate agroforestry systems and technologies.

Training sessions will include lectures, workshops, discussions groups, case studies and field exercises as well as independent/study work by participants. ICRAF's multidisciplinary team will participate in the training activities of the programme.

The Training Materials

Since agroforestry training is a new area, so is the development of appropriate training materials. The method being followed in this is essentially the same as in developing research methods, viz. collation and evaluation of relevant information from cognate disciplines and integration of such information into a new format. Once such a framework is developed, materials can be "tested" in the training courses. The present package contains a compilation of existing knowledge and selected information about agroforestry principles, practices and methods gathered from different sources and arranged in an orderly form for ready and accessible use as training materials.

1. *The package of training materials itself* has been placed in a two-ring binder that should be used as a convenient, portable system to add and revise important information.

2. *The dividers* establish five sections or modules on: ICRAF's Role and Programme (Section 1), Agroforestry Conceptual and Technical Background (Section 2), A Diagnostic Approach to the Design of Agroforestry Systems (Section 3), Agroforestry Experimental Approaches (Section 4), the Course Evaluation (Section 5).

3. *Sections 3, 5 and 4* include the main notes and/or key articles, practical exercises (in the field, case studies) and lists of supplementary materials and reference required/recommended for the activities of the programme.

4. *Additional information* is provided in the Introduction, Section 5 and Appendices on the training course objectives, organization, evaluation, participants and programme of activities as a guideline for the organization of similar model - courses on agroforestry research for development.

Ester Zulberti

C O N T E N T

PREFACE

INTRODUCTION

SECTION 1 - ICRAF'S ROLE AND PROGRAMME

SECTION 2 - AGROFORESTRY CONCEPTUAL AND TECHNICAL BACKGROUND

SECTION 3 - A DIAGNOSTIC APPROACH TO THE DESIGN OF AGROFORESTRY SYSTEMS

SECTION 4 - RELEVANT EXPERIMENTAL APPROACHES

SECTION 5 - COURSE EVALUATION

APPENDICES.

I PARTICIPANTS' NAMES AND ADDRESSES

II LIST OF ICRAF STAFF, INVITED SPEAKERS AND INTERPRETERS

III TIME TABLE AND DETAILED PROGRAMME OF ACTIVITIES

ICRAF

The International Council for Research in Agroforestry (ICRAF) was established in 1977, following an initiative by the International Development Research Centre (IDRC) of Canada. With IDRC as initial executing agency, and with the Swiss Development Corporation, the Dutch Ministry of Development Cooperation and the Canadian International Development Agency (CIDA) as co-sponsors, ICRAF was chartered and set up its headquarters in Nairobi in 1978, under an agreement with the Government of Kenya.

ICRAF is an autonomous, non-profit international council governed by a Board of Trustees with equal representation from developed and developing countries. With the exception of a representative of the host country, Kenya, trustees do not represent countries or organizations but are elected on individual merit. ICRAF derives its financial support from voluntary contributions from governments and international private and public organizations and agencies. The ultimate objective of ICRAF's work, as laid down in the charter, is "to improve the nutritional, economic and social well-being of the peoples of developing countries by the promotion of agroforestry systems designed to result in better land use without detriment to the environment". Being a council, with neither the mandate nor the necessary resources to carry out its own field research on a large scale, ICRAF fulfills objectives through acting as an international catalyst in agroforestry research. As such, ICRAF initiates, promotes and supports research for the development of appropriate agroforestry systems and technologies.

More specifically, ICRAF's activities include:

- the systematic collection, evaluation and dissemination of information on agroforestry;
- providing training facilities (courses, internships, fellowships) to scientists and development experts from tropical and sub-tropical countries;
- developing methods which aim at helping research institutions to identify relevant research which addresses real problems in land-use systems;
- developing methods for evaluating agroforestry technologies, e.g. multipurpose trees;
- arranging or co-sponsoring workshops, seminars, conferences and other meetings relevant to agroforestry;
- undertaking collaborative projects with national, regional or international institutions in field research, information exchange, publi-

cations and training;

- general promotion of the concept of agroforestry through participation by ICRAF staff in various local and international meetings and by publishing in popular and scientific media articles which aim to broaden and deepen awareness of it, etc.

Programme of Work

In order to provide a structured and efficient tool for fulfilling its mandate, the Council developed a programme of work which become operational on 1 January 1982. The programme is built around three local points which summarize our mandate.

- the development of methodologies for identifying social, economic and ecological constraints in land-use systems and for assessing the potential of agroforestry technologies to overcome such constraints;
- the systematic collation and assessment of methods of studying and evaluating agroforestry technologies;
- the efficient dissemination of methodologies and knowledge to scientists and development planners in the tropical and sub-tropical developing world.

The programme of work is implemented through eight closely interactive programmes, each with a number of projects and activities.

The work programmes are:

1. Management and Administration	Service
2. Field Station, Machakos	programmes
3. Agroforestry Systems	Development
4. Agroforestry Technology	programmes
5. Information	
6. Training	Dissemination
7. Collaborative and Special Projects	programmes
8. Agroforestry Advisory Unit	

The last programme, the Agroforestry Advisory Unit, will be run on a cost-bearing basis separate from the seven core programmes. In order to ensure interdisciplinarity in all ICRAF's work, the programmes are not demarcated by disciplinary boundaries. All core senior staff members will provide their respective disciplinary input into all programmes and most projects.

There are, of course, specific programme coordinators and project leaders who are responsible for the planning and implementation of individual activities. The programmes are interlinked and there are also strong and essential feed-backs from scientists and institutions at the recipient end of our dissemination programmes.

SECTION 2. AGROFORESTRY: the Conceptual and Technical Background

2.1 Main Notes

- AGROFORESTRY: CONCEPTS AND PRACTICES (FILEMON TORRES)
- THE USE OF AGROFORESTRY TO IMPROVE THE PRODUCTIVITY OF CONVERTED TROPICAL LAND (BJORN LUNDGREN)
- AGROFORESTRY - DEVELOPING A NEW RESEARCH DISCIPLINE

  (Peter Huxley)
- WOODY PLANTS AND LAND USE

  (Peter Huxley)

AGROFORESTRY: CONCEPTS AND PRACTICES

*Dr. Filemon Torres**

1. *Introduction*

Woody components have traditionally been included in small-holder management systems of the American, African and Asian Tropics as a source of fuel or food, and to restore soil fertility, particularly in the so-called shifting cultivation areas.

The traditional use of land by the small-holder of the tropics has been particularly affected by demographic pressure, leading to an increase in the proportion dedicated to cropping (either for household consumption or marketing the latter to meet higher cash needs), with corresponding shortening of the fallow period necessary to restore soil fertility (Fig. 1).

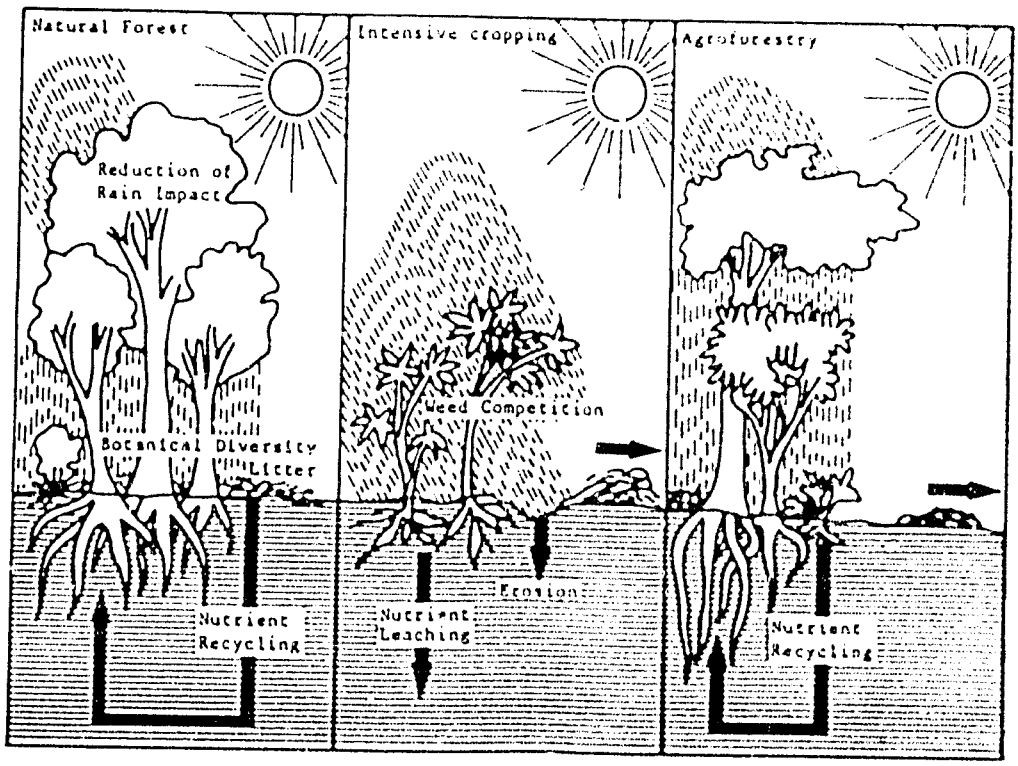
As a consequence, food production *per capita* in developing countries with a market economy has been kept almost constant, leading to an increase in the food deficit over time (Fig. 2).

The high input requirements of temperate zone tech ology (high-yielding varieties & fertilizers) and their detrimental effect upon natural renewable resources and social equity have tempered the enthusiasm initially aroused by their application.

These circumstances have led to the revival of an old practice, now called agroforestry, based upon the development of the interface between the agricultural and the forestry use of the land.

**Senior Research Scientist (Range Management & Livestock Production) at ICRAF.*

Fig. 3: *Comparison of an agroforestry system with other systems*



The amplitude of that definition implies that several agroforestry systems can be generated according to the components included in the combination, the role of the indispensable component in the system (the woody one), the type of interaction between these components and the others in the system (spatial or temporal), and the way in which the woody component is distributed in space (Fig. 4).

Fig. 4: *Agroforestry systems*

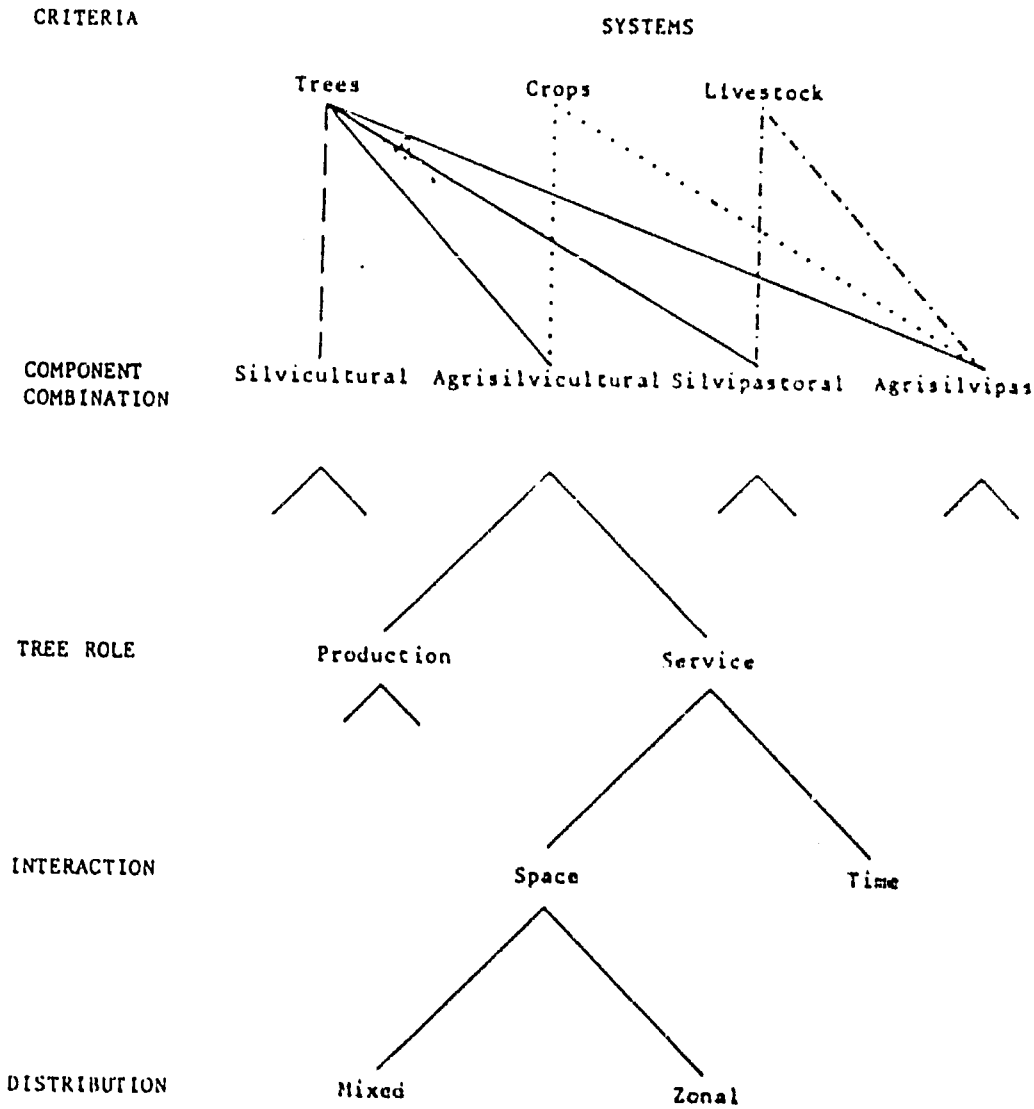
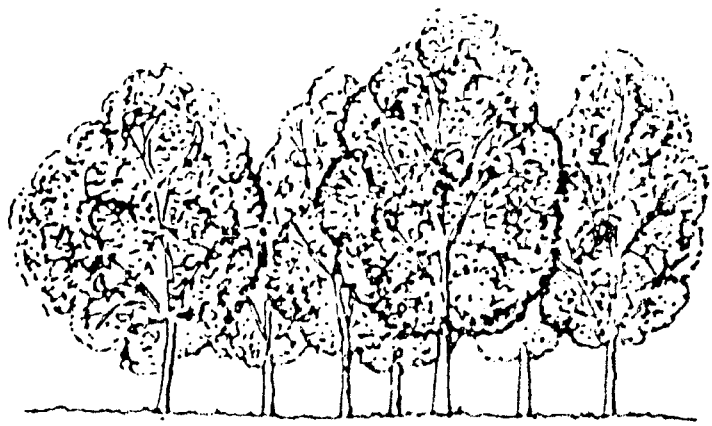


Fig. 4 (b): *Silvicultural systems*

System	Tree role			Distribution	
	P	S		M	Z
Fuelwood	✓	✓			✓

Fuelwood



3. *Agroforestry systems*

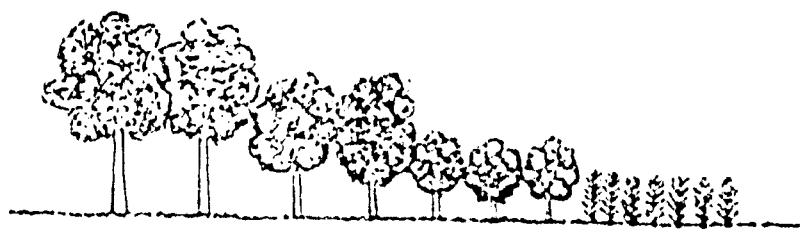
3.1 Agro-silvicultural systems are those dealing with the concurrent production of food crops and either forest (with a "productive" and/or "service" role) or tree crops. Fig. 5 systematically represents the architecture of some conceptual system of the agro-silvicultural type, and its "classification" according to the criteria mentioned in Fig.4. Fig. 6 and 7 indicate the effect that woody species could have upon soil fertility, as components of potential "improved fallow" systems, or when combined in space. Fig. 8 shows the "service" effect of an alley cropping system upon maize production, as compared with fertilizer application.

3.2 Silvo-pastoral systems integrate trees (timber, food or fodder producing ones) with pasture and livestock. Fig. 9 is an attempt to represent the architectural profile of conceptual combinations of the silvo-pastoral type, and its corresponding "classification".

Fig. 3 : *Agri-silvicultural systems*

Systems	Tree role			Interaction			Distribution	
	P	S		T	S		M	Z
Improved fallow	✓	✓		✓				✓
Alley-cropping		✓			✓			✓
Multi-storey	✓				✓		✓	

Improved fallow

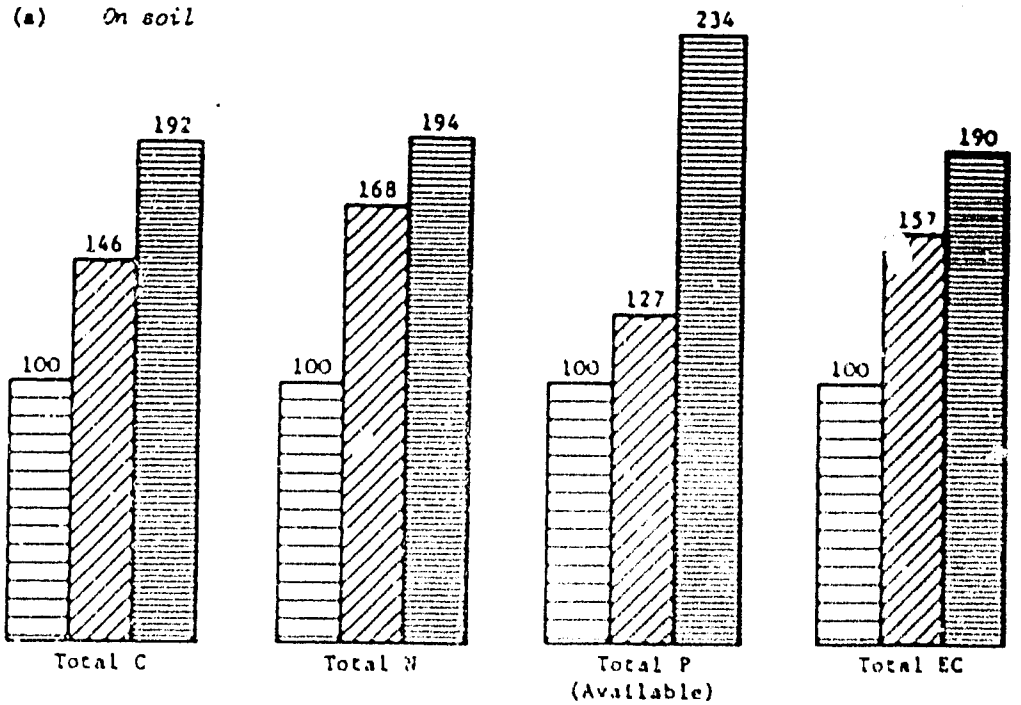


Alley-cropping

Multi-storey

Fig. 6 : *Effect of* Acacia albida

(a) *On soil*



(b) *On yields*

(Millet and peanuts)

500 ± 200 kg/ha to 900 ± 200 kg/ha

Fig. 7 : *Nutrient availability in soils under trees (Prosopis cineraria)* in arid and semi-arid areas

ELEMENT		UNDER CANOPY	OPEN
C(%) :	0-30 cm	.37	.25
	31-60 cm	.11	.04
N(%) :	0-30 cm	.045	.038
	31-60 cm	.020	.010
P(mg/100g) :	0-30 cm	3.82	1.52
	31-60 cm	1.95	1.23
K(mg/100g) :	0-30 cm	12.20	7.52
	31-60 cm	9.31	6.36

Fig. 8: *Alley-cropping effect on maize yield*

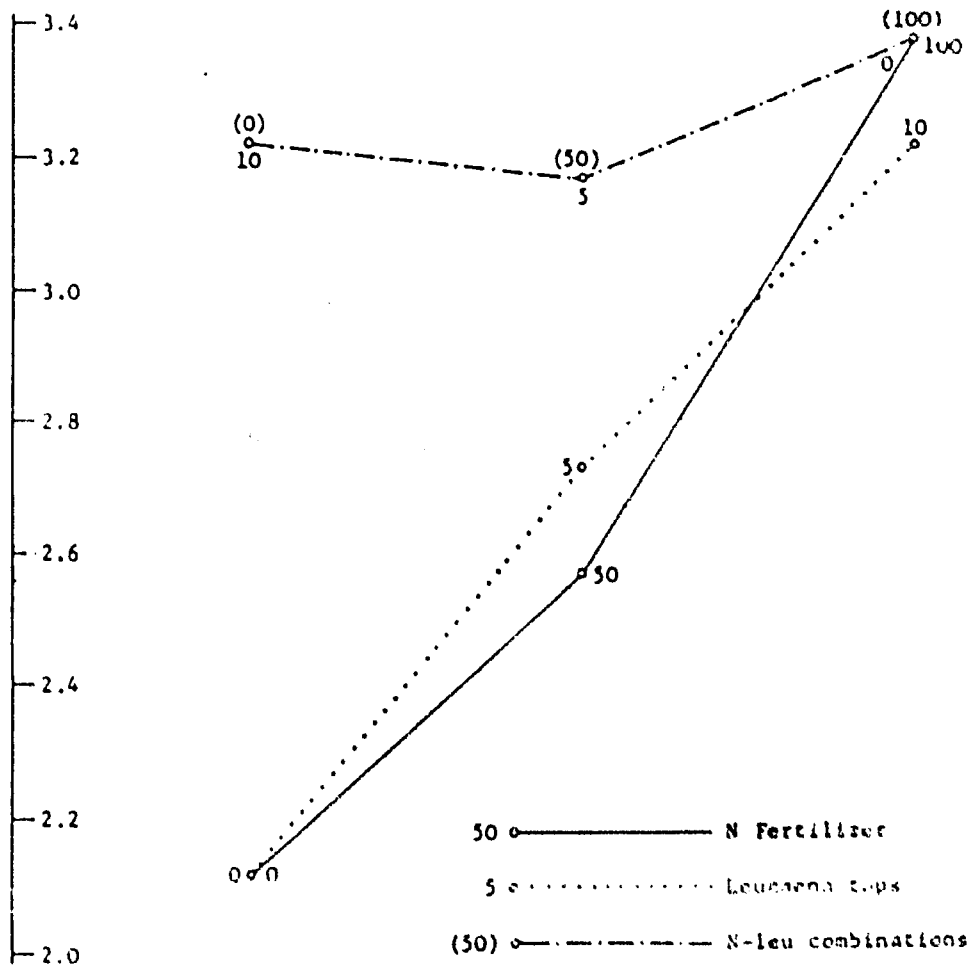


Fig. 9: *Silvi-pastoral systems*

Systems	Tree role			Interaction			Distribution	
	P	S		T	S		M	Z
Protein bank	✓	✓		✓				✓
Living fences		✓			✓			✓
Tree crop grazing	✓				✓		✓	

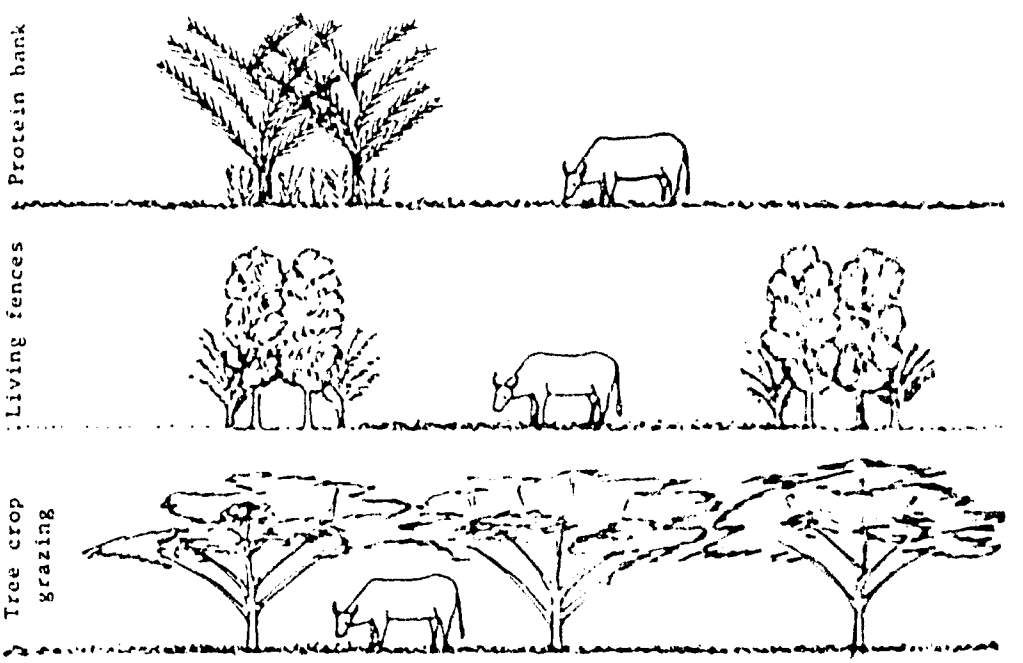


Table 1 shows the favourable effect of artificial windbreaks upon pasture production and live weight gained by animals during dry and rainy seasons in semi-arid zones. If the competition between woody and herbaceous components does not offset the advantage when natural (i.e. forest) barriers are used, such information would indicate the potential of "living fences" or just hedges.

Table 1 : Effect of shelter (windbreak)

PERIOD	Stocking RATE (Sh/ha)	SHELTER	DM Prod (Kg/ha/y)	LW (Kg)
	15	YES	370	43.5
		NO	205	40.5
DRY (3/65-10/66)	30	YES	117	32.0
		NO	61	26.3
	38	YES	68	27.5
		NO	34	25.4
	15	YES	1920	50.5
		NO	993	49.5
RAINY (11/66-9/68)	30	YES	730	44.5
		NO	343	37.5
	38	YES	339	40.0
		NO	163	32.5

Data in Tables 2 and 3 show that, under certain circumstances, trees would not impair, and might even improve, production of herbaceous vegetation growing underneath, both in humid and semi-arid zones. This would indicate a potential for silvo-pastoral systems of the "pasture with trees" type.

Table 2 : Effect of tree density on grass growth

DENSITY	DRY MASS (G/M^2)	LIGHT INTENSITY	SOIL T° (°C)
Closed canopy	276	3.9	23.1
Open canopy	447	5.8	24.6
Open grassland	302	15.8	30.2

Low fertility soil

Trees : *Brachystegia spiciformis*
Julbernardia globiflora

Grass : *Panicum maximum*

Table 3 : Pasture production under leguminous and non-leguminous trees (Average of five replicates)

SP.	DRY MATTER (G/M^2)	SOIL N (%) 0.20 cm	20-40 cm
Erythrina poeppigiana (L)	639	.35	.15
Phitecolobium saman (L)	720	.38	.18
Gliricidia sepium (L)	639	.32	.18
Cordia alliodora (N-L)	752	.25	.15
Control	750	.28	.16

Data in Table 4 would suggest that the production and utilization of a herbaceous component growing underneath trees would not affect the yield of these components in the system, in this case, tree crops.

Table 4 : Grazing under coconuts (tree density : 100/2)

HERBACEOUS LAYER	CARRYING CAPACITY (ANIM./HA)	TREE CROP PRODUCTION (NUTS/HA)
Weeds (control)	-	82.8
Native pasture	.77	72.7
Pangola grass	.87	75.1
Guinea grass	1.67	83.2

3.3 Agro-silvo-pastoral systems combine food crops with "productive" (timber, food or fodder) and/or "service" trees and livestock, with or without pastures. Fig. 10 indicates some conceptual systems of this type and their possible "classification". Fig. 11 is a schematic representation of an integrated pig production system developed in Ecuador.

The proposed systems represent several biophysical hypotheses about alternative systems including woody components in land management. If they are substantiated by research, they can be used as the basis for the generation of specific technologies.

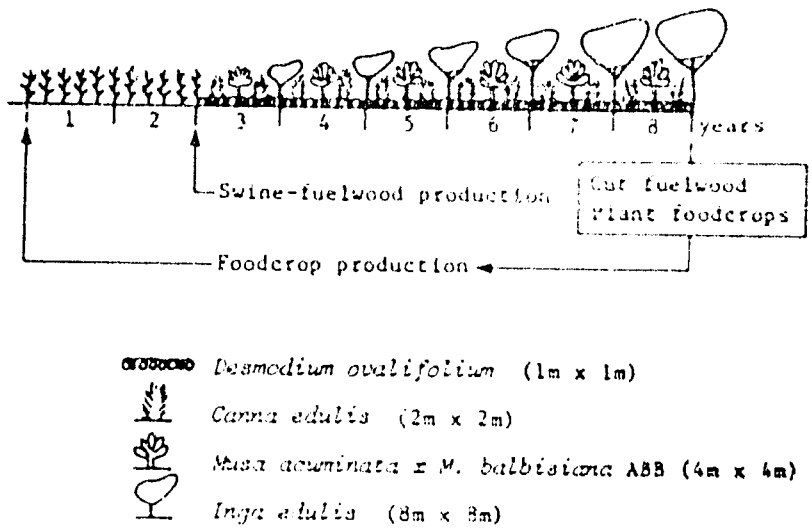
Fig. 10: *Agri-silvi-pastoral systems*

Systems	Tree role			Interaction			Distribution	
	P	S		T	S		M	Z
A - S ⟶ S - P	✓			✓	✓		✓	
Multi-storey	✓				✓		✓	

A - S → S - P

Multi-storey

Fig. 11: *Integrated foodcrop, swine and fuelwood production*



4. *Agroforestry, as an alternative technology*

As mentioned earlier, agroforestry systems represent an alternative for land management that can improve production in sustainable ways. Their adoption by the farmer would depend not only upon their potential to solve problems of a biophysical nature, but also upon their appropriateness for the circumstances surrounding the decision maker.

These circumstances would condition the characteristics of agroforestry technology to be generated. In this respect, the spectrum of conceptual systems mentioned before offers the possibility of following a pathway of intensification which would facilitate their adoption by requiring only gradual changes in existing practices.

THE USE OF AGROFORESTRY TO IMPROVE THE PRODUCTIVITY OF CONVERTED TROPICAL LAND

PREPARED FOR THE OFFICE OF TECHNOLOGY ASSESSMENT OF THE UNITED STATES CONGRESS

BY

DR. BJORN LUNDGREN
DIRECTOR, ICRAF

OCTOBER, 1982
ICRAF, NAIROBI

Abstract

Agroforestry is a collective name for land use systems and technologies where woody perennials are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components.

Applying this definition and scope it is obvious that agroforestry has for long times been in widespread use all over the tropical world, although under different names. There are several commercial, intermediate and subsistence agroforestry practices, some of which have attracted the systematic interest of agricultural and forestry experts, e.g. grazing under tree crops, taungya afforestation and shifting cultivation, but most of which have fallen outside the mandate areas of existing institutions. The realization that all these various practices has a common denominator in approach worth exploring and developing in a systematic way is recent.

The promise of the agroforestry approach to development of converted land lies in the fact that it has the potential of addressing some of the key ecological and socio-economic problems of such land, e.g. declining soil fertility, erosion, food and fuelwood scarcity, etc. By careful optimization of the positive interactions between woody components and crops/animals it should be possible to obtain a higher total, a more sustainable and a more diversified production from the land than is possible with "conventional" approaches. The systematic development of suitable "multi-purpose" trees/shrubs will be an essential component in strategies aiming to achieve this goal. There is a practically unmapped genetic potential for improving such species for soil improvement, fuelwood and fodder production, compatibility with and enhancement of crop production, microclimate improvement, etc. Similarly, there is unlimited scope for innovative and imaginative combinations of trees/shrubs and crops/animals.

The most serious constraints to the development of agroforestry to its full potential are institutional. Agroforestry falls between existing, well established disciplines at all levels - educational, ministerial, scientific, etc. - still requires an interdisciplinary approach and resources for its development. The trend today of agroforestry being regarded as a subdiscipline of forestry, and thus the sole responsibility of forestry institutions, is not satisfactory and will prevent its efficient development. Other constraints and problems include tree-"hostile" land tenure and legislation in many countries, extension services lacking necessary expertise to advice on integrated farming, farmers' reluctancy to adopt more complex and time-consuming management practices, etc.

Concerted and decisive actions will be required, both at international and national levels, if a systematic and efficient development and adoption of well conceived locally adapted agroforestry practices are to take place. In view of their importance as awareness-raisers, policy-makers and funders, international donor and development agencies must assume a lead role in this process, first of all by revising their own institutional handling of agroforestry. Increased financial support for development projects should not be considered an immediate priority but should await a more systematic assessment of the relevance and potential of agroforestry technologies to solve real problems in a farming systems context. Initiating and supporting a scientific screening and development of promising multi-purpose trees and shrubs are urgent priorities for international actions.

At national levels, actions need to be taken to remove tenurial and legal bottlenecks for permanent, integrated forms of land use, to upgrade extension services to cope with agroforestry systems, and to create educational, scientific and training frameworks that facilitate an interdisciplinary approach to land development.

The likely consequences of a systematic use of agroforestry technologies and systems to improve use of converted lands must be assessed in relation to the enormity of the problems addressed. It will be by far more difficult to instrument agroforestry development than, for example, the "green revolution", and it will take longer time. Still, if decisive actions are taken and substantially increased support is eventually given (i.e. when institutional and other bottlenecks are removed), it is likely that agroforestry technologies will have a significant positive impact on the use of converted and other lands on a 10 to 25 years' horizon.

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"The use of agroforestry to improve the productivity of converted tropical lands"

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INTRODUCTORY REMARKS

The problem area addressed by this review is very large. By far the most common cause of conversion of tropical forests is for obtaining agricultural land. This may be either in the form of more or less well organized settlement schemes (the transmigration schemes in Indonesia, the Amazon settlements along highways etc.), or as a gradual disintegration of stable shifting cultivation systems and an unorganized move into forest areas resulting from population pressure and land scarcity on adjacent land.

Seen on a reasonably long time scale, say a century, a very substantial proportion of land in the tropics which is now under permanent, semi-permanent and bush fallow forms of agriculture, or under various pastoral uses, was once under forest or woodland. They are, thus, in the true sense converted lands and equally relevant to this assessment as more recently converted land.

The increasing pressure on remaining tropical forests is to a large extent a result of the inadequacy of already converted land to provide a rapidly growing population with basic necessities of life. Problems of erosion, declining yields, desertification, droughts, and acute food and fuelwood shortages are increasing in the tropics and are mainly confined to converted lands.

There is little doubt that, seen on a global or regional scale, the medium and long-term sustenance of tropical forest resources depends much more on finding solutions to the land use problems of already converted land than it does on refining the use of remaining forest. This, of course, does not deny the fact that significant local, or even national, benefits can be obtained from improving forest management.

It goes without saying that the improvement of the use of converted lands, on a scale which significantly can off-set the pressure on tropical forest resources, is not a matter of finding a miracle technology. Quite apart from the enormity of the

problems, in terms of number of people involved and area affected, their complexity and local variations rule out any panaceal, global approach. What will be needed are carefully conceived, local strategies and plans, based on a full understanding of the complex interactions between social, economic, ecological and other factors.

This review deals with the agroforestry approach to land development and the potentials and constraints of this "technology" as a component of strategies to solve problems of using converted lands. It has been prepared under considerable time pressure and does not aspire to be a complete state-of-knowledge report on agroforestry.

However, by making use of the considerable experience and information built up at the International Council for Research in Agroforestry (ICRAF) over the five years since its inception, it has been possible to base this assessment on most of what has been written on and about agroforestry since the word and concept appeared as a focus of interest about a decade ago. It has not been possible, though, to systematically cover even a fraction of all information of direct and indirect relevance to a complete assessment of agroforestry which can be found in agricultural, forestry, social anthropological, rural economy, geographical, and other literature. Neither, of course, has there been time to obtain access to unpublished, up-dated results from on-going research and development projects on agroforestry through any questionnaire type of surveys.

A deliberate choice has been made not to overburden this report with subjectively chosen result data from various publications to drive this or that point. Instead, an attempt has been made to synthesize the conclusions from various sources as these are relevant to an assessment of the agroforestry technology to improve the productivity of converted tropical lands.

1. PRESENT KNOWLEDGE AND EXPERIENCE OF AGROFORESTRY

1.1 Definition and scope

"Agroforestry" as a term and concept has arrived and become firmly established in international development and rural science terminology in a surprisingly short time. It was not until the late 1960s and early 1970s that the word started to appear in publications, then mainly in forestry circles as a wider, collective name for all the various forms of "taungya" afforestation systems practised for a long time in many tropical countries (King, 1968). General text-books on tropical agriculture and farming systems from the 1970s do not even mention the word (e.g. Ruthenberg, 1980; Manshard, 1974). The final "break-through" of the concept came with the report of Bene et al. (1977).

Still, since 1977 at least a dozen international meetings (seminars, workshops, conferences, etc.) specifically focusing on agroforestry have been held; major UN conferences held during the last five years invariably mention the value of agroforestry in their resolutions and recommendations (e.g. "FAO World Forestry Congress", 1978, the "UN Desertification Conference", 1977, the "UN Conference on New and Renewable Energy Sources", 1981, and the recently concluded "UNEP Session of a Special Character", 1982); all principal donor agencies, both bilateral and multilateral, have recently taken up "agroforestry" in their lending and spending programmes; international and national institutions, journals, consultants, publications, etc., featuring agroforestry are mushrooming all over the world; etc.

There are probably many interrelated reasons for this explosive increase in interest - one no doubt being the built-in dynamics of "fashion" concepts. But there is much more to it than that - agroforestry is the first concrete concept that builds on a synthesis of much of the practical experience and scientific knowledge acquired

over the past decades in tropical agriculture, forestry, ecology, soil science and rural socio-economics. Our increased understanding of the tropical environments, both social and ecological, and the frequent disappointments and failures encountered when trying to implement "modern" agricultural and forestry technologies in ecologically sensitive and socio-economically complex situations have let to a realization that alternative approaches to land development must be given higher priority. It is, of course, not by chance that the increased international concern about deforestation, desertification, food and fuelwood shortages and other social and ecological problem complexes which originate in man's use and misuse of land resources coincides with the increased interest in agroforestry.

Then, what is agroforestry? Many definitions have been proposed, good and bad ones, wide and narrow ones, many, unfortunately, with subjective and presumptuous claims that agroforestry, by definition, is a more superior and successful approach to land development than anything else. It would not serve any purpose here to list a large number of definitions (for this, see for example Agroforestry Systems, 1982). One definition, as good as any, and with the advantage of being objective is:

"Agroforestry is a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components"

This definition outlines the broad boundaries of agroforestry and the typical characteristics of such systems:

- agroforestry normally involves two or more species of plants (or plants and animals), at least one of which is a woody perennial,

- an agroforestry system always has two or more "outputs",

- the "cycle" of an agroforestry system is always more than one year,

- even the simplest agroforestry system is more complex, ecologically (structurally and functionally) and economically than a monocropping system.

It is apparent that this definition of agroforestry encompasses many well-known land use systems practised since long times on converted lands in the tropics.

Traditonal shifting cultivation and bush fallow systems, for example, fall under this definition since the woody fallows are clearly a deliberate and important part of the system, interacting both ecologically and economically with the crops grown in the cultivation phases. Systems with natural fallows can, of course, be classified as "primitive" agroforestry since no deliberate choice and planting of woody species takes place.

Furthermore, all forms of "taungya" afforestation systems are included, as well as systems in which such well-known tree crops as rubber, oil palm, coconut, etc. are underplanted with other crops or pastures.

Natutally, more "typical" agroforestry systems, such as the home gardens of the wet tropics or the deliberate use of fodder trees and shrubs in the dry tropics are part of the concept.

The definition, and its implication in terms of what is included in it, brings out one very important point - agroforestry is only a new word, not a new practice. The novelty lies in the realization that all these different land use systems and practices, some of which have traditionally fallen into the field of horticulture, some into agriculture, some into forestry, and many of which have

not attracted any systematic attention at all, possess certain common features which hold great promise for land development in the tropics.

The word "agroforestry" is admittedly rather unfortunate in the sense that it linguistically evokes a notion of it being a subdivision of forestry (Stewart, 1981) rather than an integrated form of land use in a much wider sense. Similarly, the word creates some problems in the translation English-French-Spanish (see Combe & Budowski, 1979). However, the word agroforestry is now so firmly entrenched that there is no point in wasting energy and efforts on trying to find a "better" one.

1.2 Aims and potential role of agroforestry

The aim and rationale of agroforestry systems and technologies are to optimize positive interactions between components (trees/shrubs and crops/animals) and between these and the physical environment in order to obtain a higher total, a more diversified and/or a more sustainable production from available resources than is possible with other forms of land use under prevailing ecological and socio-economic conditions.

In order to understand the theoretical potential of agroforestry to fulfil these aims, it is useful to identify the distinct physical and social features of most converted tropical lands. Although these features are quite well known, and often repeated in technical literature, their implications in relation to land management are distressingly often ignored.

Soil conditions and climate show enormous variations within the tropical regions - soil age, origin and its physical and chemical properties vary as much in the tropics as they do in temperate regions. Likewise, annual rainfall spans from practically nil to well over 10,000 mm.

For much of the tropical world, and certainly for most converted lands, one permissible generalization can, however, be made - there is an inherently low land productivity potential. The reason for this is to be found in three environmental conditions which are typical for the tropics and which must be clearly understood when using tropical land:

- The first is the continuously *high temperatures* which, by definition, characterize the tropics. Although this promotes a high rate of photosynthesis, which is good, it also promotes high rates of negative biological, physical and chemical processes, such as decomposition and oxidation of organic matter, weathering of minerals, production of pest and diseases, and evaporation of moisture.

- The second, and most frequently ignored feature is the *high intensity of tropical rainfall*, meaning that daily intensity, the intensity of individual storms and the total amount of rain falling in heavy storms are considerably higher in tropical than they are in temperate regions (Jackson, 1977). It is, for example, estimated that about 40% of the rainfall received in most tropical locations (both dry and wet tropics) occur at intensities of at least 25 mm/h, which is considered as the threshold level at which rainfall becomes erosive. This should be compared with about 5% of rainfall of erosive nature in temperate regions.

- The third feature is the strong, sometimes extreme, *dependence on organic matter for fertility and structure maintenance of most tropical soils*. This, in combination with the fact that organic matter decomposition rates are five times higher in the tropics than in temperate regions, explains the rapid fertility and structure decline of tropical soils when organic matter, in the form of litter, mulch, or manure is not continuously added to the soil in adequate quantities.

An understanding of the dynamic interaction between these factors and between them and land management practices helps us to interpret much of the physical land use problems in the tropical developing world. For example,

- why shifting cultivation, when allowing sufficient fallow periods, can be a rather stable system;

- why permanent tree crops, such as oil palm, rubber and coconuts, can be successful on soils and in climates where any attempt to introduce continuous annual cropping fails;

- why erosion sooner or later becomes a problem in any land management system which leaves the soil bare at regular intervals, etc.

It also helps us to identify the two bearing principles for successful management of tropical lands, regardless of the level of capital input available, regardless of whether it is small-scale or large-scale enterprises, regardless of whether you produce crops, animals or trees, namely:

- *protect the soil against direct rain impact*, and
- *maintain soil organic matter levels.*

Understanding these two seemingly simple principles and realizing that land must, wherever possible, be managed to yield more and more to cope with a growing need of basic necessities, are the technical and social points of departure for the agroforestry approach to land use. Trees and shrubs possess many features that may help the land user to adhere to these principles.

The most apparent ecological potential for an agroforestry approach to land use thus exists in areas where soil fertility is low and mainly depends on soil organic matter, where erosion potential is high and where the incidence of surface soil desiccation is high.

On such "marginal" lands, which cover by far the largest areas of converted land in the tropics, the deliberate use of woody perennials may, if properly integrated in the land use systems, enhance both land productivity and sustainability. The less capital and technology inputs that are available, the more motivated theoretically is the use of trees and shrubs to enhance organic matter production, to maintain soil fertility, to reduce erosion and to create a more even micro-climate.

The potential for agroforestry is, however, by no means restricted to marginal lands. Some of the most successful small farmers' systems in the tropics are in fact found on high potential, fertile soils, where intensive agroforestry systems have proved their ability to economically support dense and growing population for generations (see below, section 1.4.).

A further potential for agroforestry, equally applicable on marginal and rich land, exists in socio-economic situations where land tenure and/or lack of rural infrastructure (communications, markets) and cash makes it vital for people to produce most of their basic needs of food, fodder, fuel, shelter etc., from a limited geographical area - in favourable cases their own land.

In conclusion, there is little doubt that an agroforestry approach to land development, i.e. a deliberate integration and use of trees and shrubs in the agricultural and pastoral landscapes to achieve certain protection and production benefits, is theoretically sound. The easily observed negative effects of devegetation and absence of trees and shrubs underline this. A conclusion like this does not, of course, imply that agroforestry approaches always have to be economically and socially feasible in concrete, practical problem situations.

1.3 Classification of agroforestry systems and technologies

Like with many new sciences in search of an identity, agroforestry has had its fair share of classification efforts (Combe & Budowski, 1979; King, 1979; Torres, 1979; Grainger, 1980; Vergara, 1981). It would lead too long to make a detailed review of all the proposed classification systems. The most commonly used criteria for differentiation of agroforestry systems are:

- *Physical structure:* particularly spatial arrangements of woody components in relation to crops (e.g. if trees are planted at regular spacements, in alleys, in patches, or in a haphazard way), and vertical stratification (e.g. if it is a two-storey or multi-storey system),

- *Temporal arrangement:* if crops/animals and trees are permanently mixed or rotated ("fallow" system), length of tree rotation,

- *Relative importance and role of components:* whether agri-silvicultural (i.e. aiming to establish tree plantations), silvo-pastoral (trees/shrubs supporting animal production), agro-silvo-pastoral (crops, trees and animals in mixture), or whether trees only serve protective/supportive roles for crop production.

- *Production aims/outputs from system:* whether food, wood, fodder or any other product dominates, or whether it is a multiple-output system,

- *Social and economic features:* whether large scale or small scale, commercial, subsistence or intermediate.

Some classification systems are based on one criteria only (e.g. King, 1979, on the role of components; Vergara, 1981, on temporal arrangements), others try to integrate various criteria in hierarchial systems (Combe & Budowski, 1979; Torres, 1979).

A good classification system should not only serve descriptive purposes but also provide a relevant and realistic framework for developing strategies and action plans for research and development of agroforestry land use. Most of the systems proposed so far fail to achieve this, even if many are of use in identifying research needs, which often is the background reason for their development.

In section 1.4 below, a brief review is made of present knowledge and experience of agroforestry under the headings: *Commercial*, *intermediate* and *subsistence* systems, i.e. a socio-economic criteria is used. Although this is rough, and certainly does not claim to be a well conceived "classification system", it is a suitable basis for discussing potentials and problems of further development and large-scale implementation of agroforestry, for estimating resource needs and, not least, for making an assessment of impact of national and international development efforts.

No specific classification exists of agroforestry "technologies". However, since much of the novelty of agroforestry as a field of systematic research and development lies in the introduction of trees and shrubs into the agricultural and pastoral lands, it is natural that most attention so far has focused on various aspects of the woody component. This, of course, is also a result of the fact that agroforestry up to now has mainly been promoted, and the thinking behind it developed, by people with a forestry, ecological or social/geographical background.

There are particularly three technology areas which have received attention:

- multi-purpose trees identification
- management of woody components
- arrangements for compatibility between woody and non-woody components.

Unfortunately, little attention has been paid by crop agronomists or agricultural economists to agroforestry technologies.

1.4 A review of agroforestry practices

1.4.1 General geographical overviews

The growing interest in agroforestry has resulted in a rapid increase over the last few years in the number of written (published and unpublished) accounts of agroforestry practices around the world. Although the word agroforestry is not mentioned in the major geographical works on tropical agricultural land use from the 1970s, e.g. Manshard (1974), Gourou (1980), or Ruthenberg (1980), these contain numerous descriptions of systems and practices which are distinctly agroforestry in the sense that woody perennials are deliberately integrated into cropping or animal raising systems.

Several geographical enumerations of agroforestry practices have been presented to various workshops, seminars etc. only in the last 3-4 years. A listing of agroforestry systems and practices around the tropical world was presented by Combe & Budowski (1979). Likewise, Nair (1982) has given a large number of examples of agroforestry practices around the developing tropical world.

There is a wealth of country and regional overviews of traditional agroforestry systems and practices from various parts of the tropics and sub-tropics. Budowski (1979) has, for example, described various practices in Central and South America. Special reviews of agroforestry from the Western hemisphere have been presented, for example, from tropical America (Weaver, 1979), the Andean region (Ampuero, 1979), the Brazilian Amazon (Galvao, 1979), Central America (Wilken, 1977) and Costa Rica (Budowski, 1981a).

A special review on agroforestry in francophone Africa was published by FAO (1981a). This overlaps partly with the several reviews on Sahelian agroforestry published over the last years, e.g. von Maydell

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(1979) and Seif el Din (1981). Traditional agroforestry practices in humid and sub-humid West Africa were described by Okigbo (1981), and more particularly for Nigeria by Iyamabo (1979) and IITA (1980). Poulsen (1981a) has reviewed agroforestry practices and potential in Malawi and also given several examples from all over tropical Africa (Poulsen, 1979).

Agroforestry practices in South East Asia have been described by Atmosoedaryo & Wijayakusumah (1979), and country reviews presented by Generalao (1982) for the Philippines and Ahmad (1982) for Malaysia. A detailed review, although with a strong bias towards forestry-based agroforestry practices (taungya), was recently published by FAO (1981b) for India and Sri Lanka.

Practically all these reviews on regional and country practices are superficial, descriptive (qualitative) accounts. Very rarely are there any quantitative data on number of people or area affected, let alone any in-depth studies on the ecological and economical advantages or disadvantages of the systems or practices described. They do show beyond doubt, however, that agroforestry in the sense we now use the word, is, and has for a long time been, practised in almost all parts of the tropical and sub-tropical developing world, both dry and wet, and that the variation in practices is enormous.

1.4.2 Commercial systems

The term "commercial system" is used here as a collective name for agroforestry land-use systems where the production of crops, often a single commodity, for sale is the predominant aim and rationale for the systems' development. Scale of operations is often medium to large and land ownership may be government, corporation or private. Labour is normally paid or otherwise contracted and does not, as a rule, permanently reside on the land used for the system. Subsistence food crop production may or may not be carried out on the land for a shorter or longer period in the

management cycle but is always sub-ordinate to the production of the commercial crop(s). These systems are normally, though not always, found on land which is either relatively more productive (more fertile soils, accessibility to permanent water, etc.) and/or with a better communication and market infrastructure than most land under small-scale subsistence farming.

Commercial agroforestry systems have been the object of systematic development efforts by horticultural, agricultural or silvicultural institutions - depending on what discipline the dominant crop traditionally "belongs" to - for a long time. One may distinguish three basic types of systems:

- commercial tree crops, such as rubber, oil palm, coconut and timber, permanently underplanted with food crops, other crops (spices), or forage crops/grazing animals,

- commercial shrub crops, e.g. coffee, tea, cacao, with an overstorey of shade trees, and

- rotational timber/food crop systems in which a short phase of food crop production is used as a silvicultural method to ensure establishment of the timber crop (various forms of "taungya").

Information about the first two types of systems is found in horticultural and agricultural literature and research reports from commodity-oriented institutions throughout the tropics. Although most of the major commercial tree/shrub cash crops are still grown under monoculture on large to very large holdings, with the possible exception of coconuts, there is a growing area being put under mixed agroforestry forms of use (Nair, 1981a; Watson, 1980 & 1981).

One particular form of commercial intercropping which has attracted much attention as a promising way of increasing total yield from the land is grazing cattle under tree crops. Improved forage grasses

and legumes are planted under the trees, and depending on the cost-benefit ratio of the tree crop respectively animal component, spacing of the trees may be modified to allow better ground pasture development. Such grazing is very common under coconuts in the South East Asia/Oceania region and has been thoroughly analyzed by Plucknett (1979).

Large-scale grazing under commercial pine plantations was also successfully introduced into the Jari Florestal project in the Brazilian Amazon (Briscoe, 1981). In Malaysia, grazing under rubber plantations is of growing importance (Wan Embong, 1977).

Another form of commercial silvo-pastoral system is to be found in the savannas of South America, where trees are planted to provide soil fertility and additional fodder, rather than a cash crop. In these systems, the animals are the dominant production goal. Much work is being done by CIAT to further develop silvo-pastoral systems for the acid savanna soils (see, for example, many articles in Sanchez & Tergas, 1979, as well as reports from CIAT's "Beef and pasture programme".)

Planting other crops under coconuts is a common practice in India and Sri Lanka (Nair, 1981a). Although coconut, with its normally light canopy (except in the early middle age of a plantation), is the most suitable tree crop to combine with other uses, there is also a growing interest in developing suitable combinations with rubber and oil palm. Tchoume (1981) has, for example, estimated that 100,000 hectares of oil palm plantations in the Ivory Coast would be suited to intercropping with cocoa and cassava in the early stage of the palm rotation.

Coffee and tea are not agronomically suited for intercropping when grown on a large scale. The use of shade trees has traditionally been by planting rows of tall-growing trees, the final use of which has been of very marginal interest in the total management. The use

of low, fast-growing shade trees, such as *Gliricidia* which can be cut back annually to produce valuable fuelwood or sticks/poles, is increasing, e.g. in Sri Lanka. Although there is little potential to integrate food crop production in entirely commercial shrub-crop systems, these crops, particularly coffee, forms the economic backbone in many intermediate and subsistence systems of land use (see below).

A very large proportion of the commercial timber and pulp-wood plantations in the tropics has been established through the "taungya" system, by which the farmers/forest labourers are allowed to grow their subsistence crops for a few years in the land preparation and early plantation phases in exchange for weeding and care of the young trees. The wide-spread use of this system and the many local variations that exist (King, 1968), are clear indications of its silvicultural success. It can indeed be argued that the present interest in agroforestry to a large extent owes its origin to the success of this agri-silvicultural system. The economic and ecological compatibility between timber trees and food crops grown in partially overlapping rotation has shown that agriculture and forestry can be integrated on the same piece of land.

The potential for further qualitative improvement of commercial agroforestry systems must be considered to be substantial. Specialized research and extension institutes are often available to lead the innovation efforts on development of new intercrops and crop (animal) combinations, agronomic and silvicultural management methods, etc. Infrastructure, in terms of communications and markets, is normally well developed and can in most cases probably easily absorb a diversified output from the systems. Organization and management are often such that innovations and changes can be efficiently implemented.

However, even if the increased use of commercial, commodity-oriented land use systems for agroforestry combinations may be theoretically

attractive, its quantitative and practical potential for substantially alleviating land problems, is limited. The total area under such systems, or potentially available for them, is very small seen on a global basis. The area under perennial agricultural tree/shrub crops occupy only about 8% of total arable area in developing countries today (Nair, 1981a). Out of these c. 25 million hectares (Spears, 1979), only a minor part is used for intercropping or grazing, mainly 6 million hectares under coconut. It has been estimated that between now and the year 2000, a further 2 million hectares of perennial agricultural tree crop plantations could be established without running into serious marketing problems (Spears, 1979). Commercial considerations will continue to govern the management of these crops, and it is only when it is clearly economically profitable or otherwise advantageous that agroforestry combinations will be introduced. The argument that tree crop land should at any price be brought under combined cash and subsistence use only to absorb people from overpopulated, degrading land will not impress private land owners or governments depending on cash crop export earnings.

The situation is different with regard to timber plantation land. Most, if not all, commercial forests are government-owned in developing countries. Taungya afforestation is a well established agro-silvicultural practice which, with rather small changes in relative rotation length of food respectively timber crop and spacing of trees, could accommodate a considerably increased food production and population than at present. This could be achieved without jeopardizing timber production. Forest plantations are often stituated in areas close to both natural forests and converted lands, i.e. very strategical in relation to the problems addressed by this review.

Also here, however, the quantitative potential is rather limited. Only few countries and regions have substantial forest plantation areas which can ease the pressure on forest and converted land.

The current planting rate is only 700,000 ha/year in the entire developing world (World Bank/FAO, 1981). If we assume that half of this area is suitable and attractive (ecologically and economically) for rotational food cropping and that the cropping period can increase from present 2-3 years to 5 years, we are still only talking about a total area of 1,5-2 million hectares throughout the developing world, which can support people in commercial timber plantations.

1.4.3 Intermediate systems

"Intermediate" agroforestry systems (i.e. intermediate between commercial and subsistence) are arbitrarily defined here as land use systems in which small to medium size farmers use land for combined production of perennial cash crops and subsistence crops and where the cash crop forms the economic back-bone of the system. They are normally characterized by reasonably safe tenurial rights for the farmer - ownership of land or long-term lease/tenancy arrangements. Farmers reside and work themselves on the land and may supplement labour need by paid temporary labour. Infrastructure in terms of roads and markets are often, but not always, well developed. Extension services, credit facilities and moderate capital inputs are mostly available, at least to a larger extent than for more typical subsistence farmers and pastoralists. Some systems falling in this group come very close to purely commercial systems, distinguished mainly through holding size and the fact that land is used by farmers. Other systems come close to subsistence systems to which there is no clear boundary.

There are many examples throughout the tropics of this type of small-holder intermediate land use systems where commercial tree or shrub crops are interplanted with food crops or pastures. Several systems are described in both general literature on tropical agriculture (e.g. Ruthenberg, 1980) and, more particularly, in special overviews of agroforestry or tree crop systems, e.g. Douglas & Hart (1980), Watson (1980 & 1981) and Nair (1981a).

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Coffee forms the economic basis for many integrated land use systems, particularly on fertile soils in tropical uplands. In the East African highlands, multi-storey production is common with coffee mixed with bananas, beans and shaded by timber trees such as *Albizia* and *Grevillea*. The most intensive land use of this type is found on the slopes of Kilimanjaro and Mt. Meru in Northern Tanzania (Poulsen, 1979). Similarly, coffee forms the backbone of small-holder agriculture in Costa Rica, where it is grown under the shade of both timber trees (*Cordia alliodora*) and multi-purpose trees (*Erythrina spp.*) (Budowski, 1979 & 1981a).

Another important "base" crop in tropical small-holder agroforestry is coconut. Underplanting coconuts with food crops (tubers, maize), spices and/or pastures are common practices in the wetter parts of Sri Lanka and India as well as in South East Asia and the Pacific regions (Nair, 1979; Nair & Varghese, 1980).

Oil palm and cocoa are commonly intercropped in West Africa, particularly in Nigeria (Lagemann, 1977) and Ghana. In Malaysia, the potential for grazing under small-holder rubber plantations is considerable (Wan Embong & Abraham, 1976). Small-holder tea plantations in Sri Lanka often use *Gliricidia* as low shade trees on which pepper climbs (Tran van Nao, 1981).

One system which, at least in its previous intact form, ought to be considered in the "intermediate" category, is the "gum arabicum" gardens of Sudan. Before the price of "gum arabicum" sank as a result of the development of artificial substitutes and before population pressure increased in the "gum" belt, the rotation system of *Acacia senegal* (7-12 years) and *millet* (2-5 years) flourished and gave a good cash income to farmers (Seif el Din, 1981). Not only did the *Acacia* trees give a good cash income, but also fodder, fuel, shade and restoration of soil fertility. The extent of this system today and the relative importance of the gum production is such that it is more to be regarded as a subsistence system.

An interesting agroforestry approach is where large commercial companies enter into contracts with small and medium-scale farmers to produce the companies' raw-material need on their farms. The most well-known case is the PICOP model in the Philippines, where small farmers grow short-rotation *Albizia falcataria* on their farms to supply pulpwood to PICOP's mills (Pollisco, 1979; FAO, 1979; Veracion, 1980). A similar approach is used by the British-American Tobacco Company (BAT) in Kenya, where farmers grow both tobacco and the fuelwood needed for its curing on their land together with their own food crops.

A growing interest is being shown in the tropics, often through foreign-assisted development projects, to increase the use of various fruit trees among small farmers and to develop already existing but often low-yielding orchards combined with grazing or underplanting of food crops. The most common fruit trees used are various citrus, avocado, mango, papaya, jackfruit and cashew nut.

There are probably many more interesting systems of this kind throughout the tropics, but the examples mentioned above suffice to show that these intermediate cash/subsistence agroforestry practices are very common. It is even true to say that most of the promotion of the agroforestry approach to land use has been done by pointing at successful land use practices of this type.

Although it is definitely clear that there exists a large potential for qualitative improvement of these systems, one must also keep in mind that most of the economically and ecologically successful examples are found in relatively seen more favourable areas (fertile soils, good communications, existing marketing infrastructure, etc.). It would be unrealistic to think that there is scope for a considerable expansion of permanent cash crops into less favourable areas, where infrastructure and markets are under-developed, where land tenure is uncertain or where the environment imposes serious restrictions on intensive land use.

Still, the potential and scope that exist for improvement and expansion of this type of system are large enough to motivate a considerable resource allocation in research and development. New ventures, such as commercial fuelwood production by small farmers, may have a large potential even in rather inhospitable areas (Morgan, 1980; Moss & Morgan, 1981). The scope for improving already existing systems through introduction of better varieties of tree crops/fruit trees and compatible food crops is very large.

In summary, intermediate cash/subsistence systems have a considerable potential for qualitative improvements where they already exist, and a moderate potential for wider applications in new areas.

1.4.4 Subsistence systems

Subsistence agroforestry systems are those where the use of the land is directed towards satisfying basic needs of food, fuel, shelter etc. Cash crops, including sale of surplus production of food or meat, may well be part of these systems, but are not so important that they alone can support the land user.

A large variety of such systems exists, practised by a substantial portion of the population of the developing world, from pastoralists in semi-arid areas to shifting cultivators in the rain forest regions. Areas in which these systems are practised are often characterized by more or less serious constraints, ecological and/or socio-economical. Infertile soils, erosion hazard and/or drought problems are major physical limitations prevalent in these areas. Insecure land tenure, too small holdings in relation to carrying capacity, lack of infrastructure, capital and extension services, and lack of education (and thereby ability to absorb innovations) are some common socio-economic constraints.

By far the most widespread agroforestry "system" in this group is the multitude of shifting cultivation and bush fallow practices found throughout the tropical world. The deliberate use of woody fallows to restore soil fertility and, in some cases to provide additional products and incomes (fuel, medicines, gums, building material animal protein, etc.) clearly classify shifting cultivation as agroforestry systems according to the definition given in section 1.1. It would lead too far here to go into the rich and easily accessible literature on shifting cultivation. It suffices to say that one of the greatest challenges facing "agroforesters" today is to find new and improved forms of land use for most of the 36 million sq. km and 250 million people (FAO, 1974) under more or less rapidly degrading traditional shifting cultivation today.

Apart from shifting cultivation, which in its tradional forms can be regarded as "primitive" agroforestry in the sense that none or very little deliberate management is applied to the woody fallow, the tropics abound with more or less sophisticated systems and practices where subsistence farmers use trees and shrubs to obtain higher total, more diversified and/or more sustainable production from their land. Many such systems are described in the regional surveys mentioned in section 1.4.1.

One of the most well-known and studied forms of permanent, traditional agroforestry are the "home gardens" of S.E. Asia. They are characterized by a multi-storey mixture of a large number of species of trees, shrubs, climbers, palms, tubers, etc. and often with animals (pigs and poultry) to supplement food. In West Java only, there are 240 thousand hectares under home gardens, and in the whole of Indonesia 2 million hectares (Atmosoedaryo & Wijayakusumah, 1979). An excellent, recent publication on the home gardens, or "village forest gardens" in West Java is found in Bompard et al. (1980). Several articles dealing with various agronomic, ecological and sociological aspects of this system in Indonesia have been published.

e.g. Anderson (1980), Abdoellah & Isnawan (1980), Wiersum (1980 & 1981) and Tran van Nao (1981), just to mention a few. Similar land use systems are practised in many humid tropical regions, for example in Sri Lanka where the traditional "Kandy forest gardens" are at present the focus for systematic development efforts. Several other agroforestry systems exist in Asia, many of them integrating rice production with use of trees for windbreaks, boundary demarcation, fuelwood production etc. (Hatch, 1980; ben Salem & Tran van Nao, 1981).

The Indian subcontinent is probably the area in the developing world where most active, government-supported interest has been shown in agroforestry over the past decades. Many of the ICAR institutes in India have programmes for development of traditional and new agroforestry systems and technologies. In the semi-arid areas of the country, institutes such as CAZRI and IGFRI are doing a lot of work on silvopastoral systems. CAZRI's work on developing the traditional use of *Prosopis cineraria* as a fodder and fuel tree in the grazing lands has been going on for 20 years (CAZRI, 1981; Shankarnarayan, 1981a; Ahuja, 1981). Another area of the subcontinent where agroforestry is given a lot of attention is the Himalayan slopes, both in India (Srivastava, 1979) and in Nepal (Manandhar, 1979).

In the Sahelian region of Africa, people have traditionally made extensive use of trees, both in farming systems and in pastoral systems (von Maydell, 1978 & 1979; Ahmed, 1979). It is particularly species of *Acacia* that are used, e.g. *A. albida* and *A. senegal*. Due to over-grazing, population increase, fuelwood cutting and drought, many Sahelian traditional agroforestry and silvopastoral systems are no longer sufficient to support people. Further development of traditional practices in combination with new ideas and technologies are required if the Sahel shall stand a chance to break out of its trend of rapid environmental degradation. Extensive use of trees and shrubs, both for fuelwood production, erosion prevention and as integral parts of farming and grazing systems, is an undisputed necessity for the area.

Subsistence agroforestry practices are also common in the wet zones of West Africa where several indigenous tree species as well as tree crops such as oil palm and cocoa are used in mixture with food crops and as supplementary cash earners (Lagemann, 1977; Getahun *et al.*, 1981). In the highlands of East Africa, coffee is often integrated with food crops such as bananas and maize. Although, where coffee is important, these systems are more justifiably classified as "intermediate", there is no clear boundary between subsistence and commercial practices. The Meru people of Mt. Kenya cultivate a local tree (*Catha edulis*), which yields a highly priced stimulant, khat, together with their subsistence crops (Bernard, 1972).

There is a growing number of examples of successful development projects where agroforestry principles are practised. In Rwanda, a project based partly on traditional practices and partly on innovative thinking, integrates trees and shrubs for fodder, erosion control, fuel, fallow, boundary demarcations, etc. with subsistence food crops in an apparently highly successful way in steep terrain with a high population density (Behmel & Neumann, 1981; Zeuner, 1981).

Other subsistence agroforestry practices are described by Bene *et al.* (1977), Ruthenberg (1980), although not under the name agroforestry, and in FAO (1979).

It is practically impossible to make a qualified estimate about the area involved and number of people practising subsistence agroforestry in the tropics today. National land use surveys, where they exist, quite obviously do not distinguish between agroforestry and other forms of land use.

More interesting for this assessment would have been to obtain an estimate of the areas and number of people for which agroforestry has an apparent potential to improve subsistence farming. With

the present lack of systematic knowledge on the economic and ecological potential of agroforestry in different situations, also this, however, is impracticable. Some ideas about the magnitude of the problems involved can be obtained from figures presented in section 5.1.

It is quite clear that the problem of introducing improved subsistence land use practices through agroforestry to an extent which will have a significant positive influence on tropical deforestation, food and fuel production, erosion and flood control, etc., is of an entirely different magnitude than that of improving commercial and intermediate agroforestry systems. We are talking about hundreds of millions of people spread over a substantial part of the tropics, often in areas and situations with serious physical and socio-economic constraints to development. Even if the theoretical potential for improving subsistence farming on infertile soils, on erodible slopes and in semi-arid areas through a careful introduction of trees and shrubs, is high, the practical problems are enormous. Still, it is in these areas where the urgency for improving land use is greatest, where something must be done in the decades ahead and environmental disaster shall be avoided.

1.4.5 Special agroforestry technologies

Whereas reports and work on agroforestry land use *systems* are mainly descriptive and qualitative in nature there is a very rapidly growing body of more or less quantitative information on various agroforestry *technologies*. The major focus of interest is in the tree/shrub component, e.g. potential trees for agroforestry, their uses, management, soil relations, effects on crops and animals, etc. It is quite natural, but somewhat unfortunate, that the interest has almost entirely been on the tree component of existing and potential agroforestry systems (cf. section 1.3, page 11-12).

In forestry and horticulture interest is normally concentrated on trees and shrubs yielding a single product, e.g. timber, pulp, fruit, latex, etc. Naturally, such trees may also be of considerable interest in many agroforestry situations (cf. sections 1.4.2 and 1.4.3). However, since the major attraction and potential of agroforestry approaches to land development exist in areas with physical limitations to intensive arable farming and/or with socio-economic constraints on large scale commercial land use, interest on trees for agroforestry has focused on species which may serve more than one purpose. It may be species producing more than one basic need, e.g. both fuelwood and fodder, or species combining production of utilities with soil protection or amelioration effects.

Such "multi-purpose" trees, although used in many traditional societies and farming systems, have not, with a few exceptions, until recently attracted any systematic attention by agricultural and forestry research and development institutions. Many of the most interesting species have even been considered as serious "weeds". Most of them being neither conventional "forest" nor "horticulture" crops, still lack an institutional "home" in the rigidly disciplinary national and international research and development infrastructures. In spite of this, there has been a very marked increase in the interest on multi-purpose trees in the last few years.

One of the most clear evidences of this interest is the flood of publications and reports on multi-purpose or agroforestry trees and other woody species - species or genus monographs, bibliographies, lists of species for specific uses or ecological regions, etc. A "classical" in this context, although the first edition appeared as late as 1976, is Douglas A Kart's (1980, 2nd ed.) global account of "forest farming" practices, in which the authors describe numerous traditional and potential uses of tree crops for production of food, fodder and other non-wood utilities. The general

potential for development of tree crops for agroforestry has also been dealt with by Grainger & Esbenshade (1978).

Because of the versatility of many genera and species in the legume family they have attracted particular attention (Felker & Bandurski, 1979; Raintree, 1981). Soil fertility improving features, through the ability of legumes to fix atmospheric nitrogen, in combination with leaves and pods of both fodder and food value, fuelwood of good quality, and different species adapted to an amazingly wide range of ecological conditions, explain the particular interest in legumes. One species, *Leucaena leucocephala*, stands out in much literature on agroforestry. It can rightly be argued that this extremely versatile Central American legume, long since spread all over the tropics, has been a major contributing argument in the advancement of agroforestry (see for example, National Academy of Sciences, 1977; Arellano, 1978; Brewbaker & Hutton, 1979; Blom, 1981).

Many remarkable multipurpose species with proven potential for agroforestry situations - most of them has been in long use among traditional farmers and pastoralists - are found in the genera *Acacia* and *Prosopis*. The habit of *Acacia albida* in the Sahel to be in leaf during the dry season and shed the foliage in the rainy (crop growing) season, its deep root system enabling it to grow in very dry areas, the fodder and fuel produced and the micro-site enrichment favouring crop growth, all add up to make this one of the most "typical" agroforestry species (Felker, 1978). There are at least a dozen other *Acacias*, ranging from species adapted to humid conditions (*A. auriculiformis*) to those thriving on the driest margins of human habitation (*A. senegal*, *A. tortilis*, *A. nilotica* and others), of interest to agroforestry situations.

In the deserts of the Indian subcontinent, *Prosopis cineraria* (Khejri), with the same remarkable phenology as *Acacia albida* in the Sahel, is a very important economic component in the dry farming and pastoral systems (Mann & Saxena, 1980; Saxena 1981; Leakey & Last, 1980).

Other "agroforestry" *Prosopis* species include *P. pallida*, "Kiawe" on Hawaii (Eshenshade, 1980), *P. juliflora*, *P. tamarugo* and *P. chilensis*. Excellent genus monographs exist, e.g. Felker (1979) and Burkart (1976), as well as separately published bibliographies (Pedersen & Grainger, 1981).

Other legume trees and shrubs often mentioned in literature, and indeed used in traditional farming/pastoralist societies as well as in recent development projects, include *Ceratonia siliqua*, "carob" in the Mediterranean region (Winer, 1980) and South Africa, *Sesbania grandiflora* and *Albizia falcata* in humid Asia, *Tamarindus indica*, "tamarind", in semi-arid India and Africa, *Gleditsia triacanthos*, "honey locust", in cooler sub-tropical and warm temperate regions, *Cordeauxia edulis*, "Yeheb-nut", on the Saharan fringes, *Gliricidia sepium* in Central America and humid Asia, and many others.

Several non-legume multi-purpose species are equally interesting, either because of their general versatility, their adaptability to less favourable sites or because they yield a particularly valuable product beside their "normal" uses and features. A good example of the last type is *Simmondsia chinensis*, "jojoba", from the N. Mexican and S. USA deserts. The almost explosive interest in this previously little-known species is because of the very valuable oil, similar to sperm whale oil, contained in its seed. This, in combination with its adaptation to severe aridity and its value as a browse plant, make it one of the most interesting agroforestry crop plants for arid regions (Brooks, 1978; Hogan, 1979).

The "saltbush" genus *Atriplex*, is potentially very valuable for silvo-pastoral systems in arid lands and on saline soils (Goodin, 1979). One of the most versatile and valuable tree species for semi-arid regions is *Azadirachta indica*, the "neem" tree, originating in the dry zones of Asia, and long since established in the savanna zones of Africa. An excellent timber (it is of the mahogany family, *Meliaceae*), it survives extreme droughts, produce an excellent fuel-wood, is a very good shade tree and wind break, produces tannins, insect repellent and fuel/lubricant oil (Radwanski, 1977). Other

interesting non-legume genera containing multi-purpose species, include *Casuarina*, *Eucalyptus*, *Tamarix*, *Zizyphus*, and several others.

One group of plants, often overlooked in discussions and literature on agroforestry are the woody perennial grasses, the bamboo. In the proceedings from an IDRC-sponsored workshop on bamboo more than 75 different uses of various species were listed from S.E. Asia only (Lessard & Chouinard, 1980).

Lists of suitable agroforestry species for particular geographic/ecological regions or for particular uses abound today. Some are contained in books on related subjects, others are contained in development project feasibility studies, still others are based on surveys, questionnaires, etc. Few, unfortunately, but naturally in view of the recent interest in multi-purpose trees, are based on original trials or quantified experience - many are probably only compiled from other lists. One therefore has to realize that much of the recommendations on suitable species, their uses and management, are best guesses only which require certification trials before being implemented on a large scale.

Two publications are particularly useful as information sources on trees for the tropical and sub-tropical regions in general: Webb et al. (1980) and National Academy of Sciences (1980).

Although the first one, based on the considerable experience of the Commonwealth Forestry Institute, deals mainly with wood-producing species (for timber, pulp, fuel, etc.) many of the 120 species described are truly multi-purpose. The second one gives as detailed recommendations as possible on 60 different "firewood" species, but since the criteria in selecting these species have been to include species with more than just good fuel characteristics, the book is an excellent agroforestry handbook.

An impressive book on tree species for various uses in the Sahel has been written by von Maydell (1981). It is based on almost ten years' of intensive field study of promising indigenous, naturalized and

introduced trees and shrubs, and carries detailed descriptions of habitat, uses and, as far as is known, management of 107 species, as well as excellent photos for identifications.

Other regional lists of suitable or potentially suitable agroforestry species are found, for example, in Mann (1981) for arid and semi-arid India and Okafor (1981) for Southern Nigeria. The latter author (Okafor, 1980a & 1980b) and Getahun (1981) have inventoried potentially valuable food and fodder trees already used by farmers in the Nigerian forest and savanna zones. Together they list over 50 species worth systematic investigation and development. Agroforestry in Indian and Nepalese Himalayas has been strongly promoted over the last years and there are innumerable reports and recommendations on suitable species for fuel, fodder, erorion protection, etc. (see for example Panday, 1975; Srivastava, 1979; Kessler, 1981). Potentially economic species in the S.E. Asian forests were discussed by Whitmore (1980). A recent review on local uses of non-wood tree and shrub products in Africa (Poulsen, 1981b) mentions several interesting speices which have attracted very little systematic attention but which have a considerable potential in agroforestry.

One non-wood use of trees and shrubs that has been relatively seen more and longer studied is the fodder/browse aspect. Since this work has mainly been carried out by animal husbandry and range management institutions, it has, to a certain extent, escaped the attention of "agroforesters". It is, however, enough to study some major texts on forage crops (e.g. Skerman, 1977), read through a review on shrubs and trees in range management (e.g. Le Houérou, 1978), or to have a look at any detailed study on browse species (e.g. Touzeau, 1973), to realize that the species dealt with are largely the same as the multipurpose trees and shrubs recently "discovered" in agroforestry.

In view of this, it is not surprising that there is far more quantitative data available on management, use and effects of multi-purpose trees as fodder producers and pasture improvers than from other fields (see, for example, Das 1961; ILCA 1981; Le Houérou *et al.* 1982).

On the other hand there is surprisingly little hard data on the effects of agroforestry species on soils, surprising in view of the weight given to the soil improvement/erosion prevention arguments in the

promotion of multi-purpose trees. This does not mean there is nothing, and it does not throw any doubt on the correctness of the basic assumption that the right trees and shrubs planted and managed in the right way will improve soil conditions and prevent, or reduce, erosion. It is simply another indication of how recent the interest in agroforestry and multi-purpose trees is. Some reviews and discussion papers, mainly based on deductions from work done in agriculture and, to a lesser extent, forestry have been written, e.g. Sanchez (1979) on fertility aspects, Tejwani (1979) on physical soil conservation, and Nair (1981b) on soil productivity aspects of agroforestry in general.

Some detailed studies are available on soil influences and effects on the growth of interplanted crops e.g. in Felker (1978) for *Acacia albida*, and in Shankarnarayan (1981b) and Aggarwal (1980) for *Prosopis cineraria*, *Acacia nilotica* and *Prosopis juliflora* and in Felker *et al.* (1980) on *Prosopis*. The work done at IITA in Nigeria on "alley-cropping", i.e. growing alternate rows of maize and *Leucaena leucocephala* on infertile soils using the tree as green manure by cutting it back regularly and putting the leaves on the maize soil, has shown that it is indeed possible to maintain maize productivity for several years by using soil-improving multi-purpose trees (Wilson & Kang, 1980; Kang *et al.* 1980 & 1981). The use of multi-purpose trees as component technologies in farming systems for other purposes than fodder production and soil improvement has been reviewed and/or studied, e.g. wind breaks by Kunkle (1978) and Bognetteau-Verlinden (1980), as live fences by Budowski (1979) and Saner (1979), and, of course, as fuel-wood (National Academy of Sciences, 1980; Moss & Morgan, 1981).

During the last five years, finally, a large number of research projects have been initiated, mainly at University Forest Departments and Forest Research Institutes, studying the long term economic and ecological productivity of agroforestry combinations of various trees, planted at different spacements, and a food crop, often used as a "test" crop for quantifying the competitive or soil improving influences of the tree. None of these studies have reached a stage when relevant conclusions can be drawn from them (other than on initial

survival and growth of the trees). Unfortunately, there are, as far as is known to the present authors no research projects where different agricultural crops are tested under similar tree cover.

2. SUMMARY OF POTENTIALS AND CONSTRAINTS

Based on an assessment of information and experience available it is possible to make a first tentative summing up of the potentials and constraints of agroforestry systems and technologies to improve the productivity of converted tropical land.

The potentials of agroforestry can be assessed from three different angles - from a general and theoretical point of view, from the point of view of technology potential, and, finally, the adaptability of agroforestry technologies into farming systems.

- In general terms, the idea and approach of agroforestry, i.e. the deliberate introduction of woody perennials into many tropical systems, are theoretically sound. Erosive rains, organic matter dependent soil fertility, an increasing fuelwood scarcity and a lack of cash and infrastructure among the vast majority of tropical land users, are some of the most relevant ecological and socio-economic arguements for tree integration into farming and pastoral areas (Bene *et al.*, 1977; Eckholm, 1979; FAO, 1981c; World Bank/FAO 1981). An indirect argument in favour of the agroforestry approach to land use is the all too easily observed productivity decline and land problems that almost invariably follow removal of permanent vegetation cover (be it forest, woodland or planted trees). It is also increasingly realized by many agronomists that the only feasible, long term approach to the development for some key tropical areas, e.g. the rainforest zone of Amazonas, are tree-based land use systems, either horticultural crops, forestry or agroforestry (Alvim, 1979).

- Another general factor that positively affects the potential of agroforestry to have an impact is the interest and enthusiasm the approach has aroused in both national and, particularly, international development and technical organizations. Although enthusiasm still far outweighs knowledge and experience on how

to realize the potential of agroforestry, there is no doubt that the psychological foundation, including preparedness to allocate substantial resources, for a major agroforestry development thrust is there. Many development banks, e.g. the World Bank, the Asian Development Bank and, recently, the Inter-American Development Bank, UN agencies such as FAO, UNESCO and UNEP, and most major bilateral aid agencies, all give high priority to rural tree planting, including agroforestry, in their policies today. Some also support large field programmes in various tropical countries.

- The most striking potential of agroforestry lies in the practically unexplored field of genetic improvement of the multipurpose species which are of interest. In agriculture, horticulture and forestry, systematic and determined efforts on improving desired characteristics in crops through selection and breeding have achieved remarkable results. The "green revolution", a major part of which has been the development of improved varieties of rice, maize and wheat, is probably the most widely known example. No less spectacular results have been obtained in forestry and horticulture. Palmberg (1981), for example, reports on *Eucalyptus camaldulensis*: 'The results from 32 sites in 18 countries showed that the potential gain in productivity which can be achieved simply by selection of the best-adapted provenances for prevailing environmental condition, could amount to several hundred percent'. Likewise, the average yield of rubber has increased 17-fold in a century as a result of breeding and improved management (Nair, 1981a).

There is no scientific reason why selection and breeding for improving features desirable in agroforestry, such as fodder and fuel quantity and quality, rooting characteristics and phenology favourable to interplanting with annual crops, nitrogen-fixation, pest resistance, drought resistance, etc., could not result in similar successes. Indeed, the very few efforts that have been made on systematic improvement proves the point. For

example, the "sorting out" of provenances, sub-species, varieties, etc. of *Leucaena leucocephala* has resulted in a situation where it is now possible to obtain seed meeting particular requirements, e.g. growth habit. Even more exciting is the apparently highly successful work on "breeding out" the two major disadvantages of *Leucaena*, its high mimosine-content and its intolerance of acid soils, going on at CIAT (Hutton, 1981).

In Nigeria, work with indigenous forest fruit/food producing trees has resulted in the establishment of seed orchards vegetatively reproduced from trees selected for their early fruiting age and low fruiting height (Okafor, 1981).

The potential gains of systematic breeding of agroforestry species has been emphasized by the World Bank which has declared it a priority interest in supporting this work (World Bank, 1981a). A thorough discussion on the potentials and problems of genetic improvement of tree species for, among other purposes, agroforestry is found in Burley (1979).

- Another potential of agroforestry lies in the almost unlimited scope that exists for innovative and imaginative development of new technology packages. The alley-cropping work at IITA, refered to in the previous section (page 31), is one good example of how unconventional thinking has resulted in an "agroforestry solution" to the problem of declining soil fertility and crop production. Introduction of shade tolerant forage grasses and legumes under pine plantations has increased land productivity substantially in some cases e.g. in the Jari project in Amazonas (Briscoe, 1981). The wide scope that exists for addressing particular land productivity problems, e.g. soil erosion, organic matter and fertility, drought, seasonal fodder shortages, fuel and building pole needs, etc., by combining trees and shrubs with desired characteristics in suitable spatial or temporal arrangements with annual crops and/or animals, is a great challenge to research and development organizations.

- It is more difficult to assess the potential for agroforestry systems or technologies to be adopted on a large scale by farmers and pastoralists. If, however, the relevant land use problems have been identified in dialogue with the concerned land users, and an ecologically, economically and socially well adapted agroforestry "solution" is demonstrated to be feasible, there is no reason to believe that agroforestry will not be adopted. The crucial thing is to find locally acceptable solutions to problems which are perceived and realized by the farmers. A "diagnostic and design"-methodology to enable research and development agencies to do this is being developed at ICRAF at present (Raintree, 1982).

Unfortunately, considerable resources seem to be wasted on irrelevant, though no doubt scientifically interesting, research on agroforestry around the tropics today. Sophisticated trials on the best spacement of trees over crops are, for example, not particularly relevant if it is highly doubtful whether farmers will be interested in that particular tree species. Similarly, if an economic feasibility study of an "agroforestry system" is based on on-station research using a food "test" crop which is not used in the area, then people are not likely to adopt the system no matter how superior the internal rate of return happens to be.

One factor which always will facilitate the adoption of new technologies by farmers is when early cash returns can be demonstrated. The situation today with a rapidly spreading fuelwood shortage and, as a result of it, an increasing commercialization (Morgan, 1980) of firewood and charcoal, may well turn out to be a blessing in disguise from the point of view of eventual adoption of better land use. If fast-growing fuelwood species, which also have, for example, soil-improving qualities, are "marketed" as a cash-crop, the adoption process may be very simple. It will, of course, still be up to development and extension services to demonstrate the best location and management of the trees in the farm to obtain the optimum multiple benefit from them.

The constraints and problems encountered in the development and adoption of agroforestry systems and technologies are many and certainly not easily solved. They may be usefully summarized and briefly discussed under the headings: general, development and implementation constraints. Several authors have discussed the problems of agroforestry and this summary, although arranged in a slightly different way, is mainly based on review and discussion papers by Adeyoju (1981), Andriesse (1978), Arnold (1982), Budowski (1981b), Burley (1980), Catterson (1981) and Openshaw & Morris (1979).

- Among the most obvious general constraints to a significant contribution of agroforestry in increasing productivity of converted tropical lands is the very magnitude of the problem addressed. We are talking about hundreds of millions of farmers and landless people spread over vast expanses of tropical lands. Physical as well as socio-economic limitations to rational land use are legio. Rapid population growth, unsafe land tenure, erosion, droughts, floods, declining soil fertility, lack of infrastructure, political instability, illiteracy, and other development problems often characterize those vast areas where agroforestry approaches to land use have a potential role to play. It is therefore obvious that agroforestry development can never be seen in isolation from general social and physical development problems.

- The development of agroforestry systems and techniques requires, at many levels and stages, an integrated and multidisciplinary approach. This obviously creates many obstacle and problems. Education at technical and professional levels is almost everywhere along traditional disciplinary lines, i.e. forestry, agriculture, animal husbandry, etc. Similarly, research institutions are normally mandated to work on strictly discipline-oriented problems. Even where "systems research programmes" are being undertaken, they are often, and understandably, strongly biased towards the discipline of the institute where they are based.

At government and administrative levels, rigid boundaries are normally maintained between departments dealing with different aspects of land use (forestry, agriculture, livestock, etc.), boundaries often being strengthened by increasing competition for scarce development resources. In many, probably most, tropical developing countries, forestry and agriculture are under different ministries with the latter normally being the big and important ministry with respect to land management, but with the former charged with responsibility for agroforestry (i.e. in the few cases where any formal agroforestry programme exist).

Land legislation and supervision of laws often reflect the administrative division with separate laws governing "forest" land and "agricultural" land. Some countries have laws making all trees government property, including planted ones. It goes without saying that such laws efficiently prevent success of any attempt to convince farmers to plant trees.

With regard to international agencies, e.g. UN-bodies, development banks, bilateral aid agencies, etc., most of which strongly promote the ideas of agroforestry and of an integrated approach to land development, traditional disciplinary boundaries still impose severe constraints. Agroforestry is often, as in the case of national institutions, considered as a branch of forestry, or even "environmental conservation", which means that resources for its promotion and development are allocated via forest divisions or departments. This, unfortunately, means that international research and development funds for agroforestry are relatively seen very limited, i.e. limited in relation to the substantial funds chanelled through more prestigeous agricultural divisions.

- Implementing agroforestry on a large scale in rural areas will run into many problems, e.g. how to reach farmers with information, advice and services, how to convince farmers to adopt new land use

practices and abandon old ones, and, finally, for the farmers to overcome management constraints. Reaching farmers is a problem of extension. This is relatively easy in well established and relatively prosperous agricultural areas where physical and administrative infrastructure is well developed. It is considerably more difficult in the vast expanses of marginal, converted lands where the need for agroforestry solutions to land problems is greatent. Lack of roads, lack of funds, and extension services not competent to deal with integrated land development problems (they are discipline oriented as well as their "mother" ministries) impose serious restrictions in this respect.

Even if farmers are reached they need to be convinced about the benefits of new technologies. It may be relatively easy to introduce new and "better" species or to make farmers adopt marginal improvements in management practices in areas where trees are already an integrated part of the land management systems. It is considerably more difficult where managed trees and shrubs are novelties. The time between planting a tree and achieving measurable benefits from it involves risks that farmers with small means may not be prepared to take. Similarly, it will be difficult to convince land users to make long term investments where land tenure is uncertain. Social and cultural attitudes and beliefs may locally pose serious constraints. It is certainly worthwhile for development and extension personnel to closely analyse the background of such attitudes, since they may well have a very rational background. People's negative attitude towards trees in tse-tse fly infested areas is a point in case.

- Finally, there are many down-to-earth management constraints to overcome before functioning agroforestry systems can be implemented. Raising plants, establishing, protecting and managing them, require skills which have to be learnt by farmers. Water availability for nurseries, protection of young plants

against domestic animals, increased time needed in managing more than one production component, etc., will in many cases require additional resources (both labour and capital) which may be outside the ability of many poor farmers. Credit and aid schemes will have to ensure that such constraints in the establishment phase of agroforestry system are overcome.

The rest of this report will discuss aims of agroforestry development and recommended actions to overcome constraints and realize the potential of agroforestry to make a significant contribution in increasing productivity converted lands.

3. OBJECTIVES AND NEEDS FOR AGROFORESTRY DEVELOPMENT

3.1 General aims

The adoption of agroforestry systems and practices is not an aim in itself. It should rather be seen as a promising potential means of achieving general economic and ecological development aims at various levels.

a) At the level of the individual land user, family or village, the aim is to introduce socially and ecologically site-adapted, sustainable land use practices which will be able to provide a growing number of people with basic necessities (food, fodder, fuel, shelter), or cash to purchase basic necessities, and with a surplus production to enable fulfilment of social and economic aspirations above a mere subsistence.

b) At a regional level, the introduction and significant adoption of agroforestry land use practices will contribute to the aims of halting deforestation and desertification, checking hydrological imbalances and erosion, and gradually alleviate regional food and fuelwood shortages.

c) At the national level, agroforestry adoption will contribute to the aims of achieving self-sufficiency in food and energy production, of reducing rural poverty, and of achieving more equal

development between intensively farmed areas (e.g. alluvial plains) and more marginal uplands (including most converted lands).

General aims like the ones formulated above can of course be considered utopian, unrealistic and, at any rate, too general to provide any clear action guidelines. They are, however, important at national and international policy-making level to clarify questions such as:

- what problems are we addressing?
- where does "agroforestry" fit into general and specific development priority identification?
- what type and magnitude of resources should be allocated to "agroforestry"?

It is essential, when seen in relation to such questions, to emphasize that the major general aim of agroforestry development is always the creation of productive farming systems and practices, able to supply an increasing and sustainable output of basic necessities, including cash. There has been an unfortunate tendency to put primary emphasis on the resource conservation aim of agroforestry, which probably has resulted in an underestimate of the potential production role of integrated farming systems. Maintaining soil fertility, preventing erosion, creating a better microclimate and other environment-enhancing roles of the tree/shrub component primarily serve the purpose of sustaining production over a longer period of time than is possible without woody perennials.

3.2 Specific objectives and needs

For agroforestry to significantly contribute to the fulfilment of the general aims stated above some specific objectives must be set up and needs satisfied:

a) Agroforestry as a concept and discipline must be accepted and fully integrated into existing institutional frameworks at all

relevant levels (educational, scientific, ministerial, etc.), both nationally and internationally.

The present situation of agroforestry either floating around as an idea enthusiastically promoted by individual "believers" without an institutional home and position, or of agroforestry being adopted and jealously garded against outside interference by forestry institutions, which rarely have got the range of competences needed to develop the full potential of integrated land use systems and technologies, is not satisfactory. Not only is there a risk of a gradual loss of interest when talk is not followed by action, or, worse even, when raised expectations are followed by misguided and unsuccessful actions, but there is almost certainly going to be problems to secure funds and resources required for large scale development and implementation of agroforestry. After all, even if a Minister of Finance or an international donor is convinced about the potential of agroforestry, they will hesitate to allocate substantial resources for its development when there is no institutional framework to ensure its implementation.

b) Another primary objective must be to systematically collect and evaluate existing knowledge and experience which are relevant to agroforestry development. Such "base-line" knowledge is required for identifying research and development priorities at local, regional, national and international levels.

Most of the information that exists on agroforestry is, as stated before, qualitative in nature. There is a strong need to obtain quantitative information on which to base further development. Much resources are being wasted at present on *ad hoc* and trial-and-error approaches, both in research and field implementation. Due to the urgency of finding solutions to the land use problems of converted lands and the time scale necessarily involved in testing and verifying the feasibility of agroforestry technologies and systems, it is essential that only technologies with a high probability of success are brought to large scale field implementation. Identifying such relevant

technologies require a solid base-line knowledge and an interdisciplinary approach.

c) The last and most important objective will be to ensure adoption of agroforestry practices on such a large scale that significant economic and ecological benefits are achieved.

This objective must be fulfilled at a national level. Apart from satisfying the first two objectives, i.e. the integration of agroforestry into existing infrastructures and the establishment of a base-line technical knowledge on which to base research and development priorities, it will necessarily involve many other actions and decisions. These include:

- ensuring that sufficient resources, both in terms of funds and trained man-power, are available for research, development and extension,

- analysing and, if necessary, revise land use legislation so that no legal constraints (e.g. government "ownership" of trees) prevents the adoption of agroforestry practices, and,

- creating necessary incentive for farmers to adopt practices which will often involve initial risks and delayed returns on investments, e.g. by ensuring tenurial safety of land, provision of credits, and removal of economic constraints such as controlled prices of fuelwood and charcoal set so low as to make any investment in tree planting for the purpose of producing commercial fuelwood completely uninteresting.

4. OUTLINE OF ACTIONS NEEDED

4.1 General

It should be stated first of all that it is quite impossible to quantify, in monetary or any other measurable terms, the actions needed at international and national levels in order to realize the potential of agroforestry in the development of converted lands. Agroforestry is in an early stage as a field of systematic exploration and development and the quantitative knowledge on costs and benefits, both economic and ecological, of agroforestry systems and technologies is weak. It is thus not possible to make statements of the type: "if so and so many 100's of millions of dollars are invested in this or that agroforestry technology it will increase food production by X percent and reduce erosion by Y percent in the developing world over the coming decade".

What can be done is to outline the type of actions needed and to assess their urgency and relative importance. Generally speaking, the actions should fulfil the objectives and satisfy the needs spelled out in Chapter 3 above. In outlining desired actions it is tempting to get lost in whishful thinking. Some points to keep in mind in order to remain in contact with reality are:

- recommendations on agroforestry "actions", or rather the implementation of such recommendations, can never be seen in isolation from the larger social, economic, political and ecological relations and development contexts.

- agroforestry developments will need long-term, consistent efforts at all levels, and must not be considered a "fashion" which can be disposed of in favour of a new fashion in five or ten years.

- we must get away from the "miracle panacea" stamp that all too often is visible in the promotion of agroforestry and establish realistic expectations and awareness of potentials and constraints of agroforestry.

- although it may be desirable, it is not feasible to think of globally coordinated actions, yielding quick results, as a realistic basis for recommended actions on agroforestry developments.

4.2 Action needed at international level

4.2.1 Institutional

International institutions are here taken to mean all multi-lateral and bi-lateral agencies involved in funding and implementing development activities in the tropics, international scientific bodies and institutions, training and education institutions, private foundations, international non-governmental organizations, etc.

From an awareness-making point of view, in relation to agroforestry, the most important international institutions are the development banks, particularly the World Bank, the UN bodies, notably FAO, UNESCO, UNDP, the major Western donor agencies, e.g. USAID, GTZ, CIDA, OECD, EC, ODA and others, plus some major foundations such as the Ford and Rockefeller Foundations and the OPEC fund. The importance of these bodies is not only through their role as major direct funders of international development, but also, and probably as vital, their role as international policy-makers. If, say, the World Bank, FAO and USAID strongly feature agroforestry (or any other approach or technology) in their policies and priorities, it is bound to have a profound influence not only on other international bodies but also at national levels.

There is little hope for new ideas and approaches to land development to achieve any significant impact if the major international bodies do not support them. The "green revolution" in agriculture and the major development of industrial wood plantations based on fast-growing exotic trees are good examples where determined international support to innovations in land use have led to significant results. As mentioned before in this report, agroforestry is increasingly being promoted and supported by international agencies (cf. p.3). Super-

ficically, and judging from the frequency with which the word "agroforestry" is being mentioned in reports, resolutions, project documents, etc., the situation may indeed seem satisfactory.

However, it is not! The main reason for this is that agroforestry is institutionally being squezed into existing, rigid disciplinary boxes as a sub-discipline of forestry. The development of improved varieties of, and irrigation/fertilizer practices for, rice can certainly best be developed by traditional agricultural institutions. Likewise, the improvement of pine plantations or tropical high forest management are the undisputed fields of conventional forestry experts. Agroforestry, seen as an approach to land development by which the use of trees and agricultural crops are integrated to optimize use of land and other resources can not be developed to its full potential if the entire responsibility will rest solely on forestry institutions.

Without in any way underrating the importance of the determined efforts made by the World Bank, FAO and other international bodies in the field of agroforestry, it is still doubtful whether these will have any major impact on the use of converted lands if there is not a radical rethinking in the organizations about the nature and potential role of agroforestry. Some examples:

- Agroforestry is strongly promoted by the World Bank, but mainly in its "*Forest* Sector Policy Paper" (World Bank, 1978).

- Agroforestry development support is incorporated into the "*Forestry* for rural communities" programme of the FAO *Forest* Department.

- Agroforestry has been identified as a priority research field in tropical *Forestry* in a joint World Bank/FAO (1981) report prepared for the International Union of *Forestry* Research Organizations's (IUFRO) conference in Kyoto, Japan in 1981.

- When the same paper was presented to the "Sixth Session of the FAO committee on *Forestry*" in May 1982, the following initial words were used when summarizing the section on agroforestry:

"To achieve the integration of social with productive and protection objectives, integrated *forest management* needs to involve a holistic approach to the use of *forest land* and *forest resources* (FAO, 1982).

- Similarly, when the International Council for Research in Agroforestry (ICRAF) was created in 1978, it was the result of an IDRC-sponsored study to identify the major priority area in tropical *forestry* research (Rene *et al*. 1977).

- ICRAF was not admitted to the Consultative Group on International Agricultural Research (CGIAR) on the grounds that *forestry* was not in the mandate of the CG-institutes.

- Two of the most important recent reports on how to tackle the problems of agricultural production in the developing countries, reports that will have far-reaching implications on the international communities' funding priorities, viz. "Agriculture: toward 2000" (FAO, 1981d) and "Accelerated development in sub-Saharan Africa - an agenda for action" (World Bank, 1981b), do not mention agroforestry at all, nor the approach as such under any other name.

Examples like these point at a fundamental institutional constraint in the present treatment of agroforestry which can be very coarsely summarized thus:

"Agroforestry is institutionally considered a sub-division of forestry. Forestry institutions deal with forestry and forest land. The major potential of agroforestry lies in the integration of trees into agricultural and pastoral lands. The development of these lands is the mandate of agricultural institutions. Agricultural institutions are not mandated to deal with agroforestry".

This may appear to be a naive and exaggerated summary of the situation and it is likely that it will be strongly disputed by many people involved in agroforestry developments. Unfortunately, however, it is a very accurate description of the situation prevailing today. Before this situation is revised among the major

policy-forming and innovation-promoting international agencies there is little hope that any truly integrated approaches to land development will be institutionally feasible at national levels (although there are indeed exceptions - some national efforts are far ahead of international "trends" in this respect).

Thus, action is needed among international institutions involved in the support of tropical land development to overcome their internal institutional constraints in dealing with integrated land development. *A thorough rethinking and revision on the level at which traditional disciplines are split into policy-making and budgetary units is needed.*

4.2.2 Research and technology generation

There are probably few fields in which there is such a high potential for substantial pay-offs on investments in research as there is in agroforestry. Systematic research for generating suitable technologies incorporating woody perennials in agricultural land use practices is not even in its infancy, it is in a pre-natal state.

The eventual generation and field validation of ecologically, economically and socially adapted and adoptable technologies must ultimately rest on local institutions. There is, however, a wide variety of actions and activities related to research and technology generation where the international community, in the form of donors, UN-agencies, developed country institutions, etc., could and should participate actively. These include:

- Financial support to national and regional developing country research institutions, either in the form of conventional project support in a wide sense, or as a more systematic effort to aid in capacity - or institution building. Included in this category is also "twinning" arrangements between research institutions in developed and developing countries, the cost of which is often met by aid agencies of the developed country.

- Technology generation problems of wider applicability, and research requiring large and sophisticated resources which is neither possible nor motivated to carry out on a national level, are often suitable for international efforts, both funding - and implementation wise. These reasons were behind the formation of the network of international agricultural research institutes in the CGIAR-system, in which the individual institutes are mandated to work on technology generation in specific ecological zones which cover many developing countries and/or with specific crops of major global or regional importance, e.g. the semi-arid tropics, the humid tropics, rice, maize, beans etc.

- Man-power development for research and technology generation, either in the form of full under-graduate or post-graduate schemes for students from developing countries, or in the form of shorter training courses addressing specialized technologies or problems, e.g. numerous courses arranged by FAO's various departments, the individual CG-institutes, or sponsored by bilateral donor agencies.

In agriculture and, to lesser extent, forestry international support is already considerable through these channels. In addition, very important direct research on tropical agriculture and forestry is carried out by specialized institutions in developed countries, not least through the old "colonial" research and development institutions in France, Great Britain and The Netherlands. The budget for research of direct relevance to tropical land use of the French GERDAT-institutes (e.g. IRAT, CTFT and others) and ORSTOM is, for example, larger than the total budget of all the CG-institutes taken together. Similarly, substantial work is carried out by various Commonwealth institutions, e.g. CFI in Oxford and CSIRO in Australia, the Tropical Products Institute in U.K., and the Royal Tropical Institute in Amsterdam.

International support for, and activities in, agroforestry research and technology generation is growing but is still very modest in absolute terms. The institutional factors discussed above also impose constraints in this field - who should support agroforestry research?; who should receive support?; and who should identify relevant priority research and technology subjects?, etc.

In a recent report (World Bank/FAO, 1981) it was estimated that the total multi-lateral support for *forestry* research in developing is probably less than US $10 million per year - and this *includes* research support for agroforestry, social forestry, fuelwood, etc. This can be compared with the support for the CG-institutes alone which amounts to something like US $120 millions per year. To this should be added direct multi-lateral and bilateral support to agricultural research carried out by national institutions in developing countries in order to arrive at comparable figures. It is probably not a bad guess to say that international financial support for research in tropical agriculture, forestry and agroforestry respectively relates something like 200:10:1. If anything, this underestimates the relative magnitude of agricultural research support.

This last point also indicates a fundamental difference that exists in the attitudes towards research in international agriculture and forestry institutions (or departments) - whereas there is a clear recognition of the importance and benefit of research in agriculture, the attitude in forestry donor circles is cool, to say the least. It is not uncommon to hear views like "research does not pay", "it takes too long time to yield result", or "we give priority to development projects, not research" (as if these were contradictory options!), from surprisingly senior people in bilateral and multi-lateral donor organizations. As long as international funding of agroforestry research and technology generation is channelled through donor *forestry* departments there is thus little hope that significant funds will be made available.

One recent development which may be an eye-opener in this respect is the global fuelwood crisis, the magnitude and urgency of which has only just been quantified. The World Bank (1980a and b, 1981a) has emphasized the importance of research into ways of increasing fuelwood production and stresses the untapped potential of genetic improvement of fuelwood species. If, through systematic research efforts, it would be possible to raise yield of fuelwood plantations by 10% (which is a very modest aim indeed!) this could reduce by at least US $2,500 million(!) the investment needed to establish additional fuelwood resources to meet the demand in developing countries by the year 2000 (World Bank/FAO, 1981). When it eventually is realized that the only feasible approach to achieve the level of fuelwood production required is through large scale integration of wood growing on farms (and not through Forest Department or commercial fuelwood plantations), i.e. through agroforestry approaches, this may lead to increased priority and funds given to agroforestry research.

A few international institutions and programmes deal specifically with research in agroforestry or technologies directly relevant to agroforestry. The International Council for Research in Agroforestry (ICRAF) in Nairobi, Kenya, is the only international institution with a direct mandate to work globally on agroforestry. The main foci of ICRAF's work, which is funded mainly by a number of bilateral donor agencies, are information assessment and dissemination, training of research and development personnel, and development of research methods for use by technology-generating institutions in developing countries.

Other institututions of an international character involved in agroforestry-related technology research or information and training for research, include:

- the International Tree Crop Institutes (U.K., U.S.A. and Australia)
- the Nitrogen-fixing Tree Association (Hawaii, U.S.A.)

- the National Academy of Sciences (U.S.A.), (on fuelwood and legume tree species),
- the Commonwealth Forestry Institute of U.K. (information, research and training),
- the East-West Centre (Hawaii, U.S.A.)
- the United Nations University (arranging workshops on agroforestry),
- some components of the UNESCO/MAB research programme,
- projects based on some national developed country universities, e.g. the University of Arizona's office of Arid Lands Studies, Wageningen Agricultural University (The Netherlands), Universities of Hamburg and Freiburg (Federal Republic of Germany), University of Montpellier (France), and a few others.
- some of the CG-institutes are engaged in specific technology research which is of an agroforestry nature, e.g. IITA in Nigeria on alley cropping (*Leucaena*-maize) and CIAT in Colombia (*Leucaena* acid-soil-tolerance and mimosine content),
- FAO's "Panel of Experts on Forest Gene Resources" works on data collection and assessment of information on "arboreal species for the improvement of rural living", particularly in arid/semiarid areas, together with IBPGR.

Although this list may seem impressive, it is not likely that the total volume of this work (i.e work directly related to agroforestry) exceeds US $10 million per year in budgetary terms.

It would seem tempting to conclude this section by stating that the action needed is basically to increase international funding for research in agroforestry. This will certainly have to be done if the full potential of agroforestry approaches and technologies shall be developed, but it must be preceded by clear identification of research priorities and of the institutional infrastructure in which research and technology generation should best take place. It would be a serious waste of resources if considerably increased funds were uncritically made available to all institutions (national

or international) declaring an interest in conducting "agroforestry" research. Although many existing, disciplinary research institutions, both in forestry and agriculture, as well as in other fields, certainly have got a capacity to study and develop various technology *components* of direct or indirect interest to agroforestry, few have got the interdisciplinary capacity and resources needed to develop agroforestry *systems*.

Thus, at the present stage, the priority actions needed at an international level for support and promotion of agroforestry research and technology generation are:

- promote research into component technology development of an undisputed value and potential, e.g. identification and improvement of multi-purpose tree/shrub species,

- urgent priority must be given to support research and development of multi-purpose tree/shrub germplasm in a systematic and scientifically acceptable manner - the present situation, with an almost totally uncontrolled collection and distribution of seed for various development projects is rapidly developing into a global "genetic mess",

- support the build-up of international and regional data information centres on agroforestry for use by national institutions interested in agroforestry systems and technology,

- give priority to the development of training and education programmes with an integrated view on land development,

- when support is given to technology-generating research on agroforestry systems, make sure that relevant proposals, and institutions with a capacity to implement long-term, interdisciplinary programmes, are supported,

- give initial priority to the development of methodologies aiming at defining and quantifying promising agroforestry

technologies for integration in farming systems (cf. Raintree, 1982 and Lagemann & Heuveldop, 1982).

Support for building institutions capable of conducting full-scale local research and technology generation in agroforestry should be an international priority as soon as the internal disciplinary constraints towards integrated land development are resolved within the international institutions themselves.

4.2.3 Financial support

Many of the major international donors and development banks are today providing, or plan to provide, substantial loans and/or grants for development projects focusing on rural forestry, fuelwood plantations, social forestry, agroforestry and other related activities. A major shift in emphasis towards this sector and away from the traditional forestry sector (plantations and industries) is clearly visible today. Out of a total of US $500 million of World Bank loan for the forestry sector in 1978-81, not less than 60% was for rural/environmental forestry (World Bank/FAO, 1981). Similarly, the percentage of FAO's total forestry activities that goes to rural community level forestry (see Catterson, 1981, and Tran van Mao, 1981) will increase from 5% in 1978/79 to a planned 25% in 1982/83 (World Bank/FAO, 1981). In a recent World Bank policy report on renewable energy resources in developing countries (World Bank, 1980b) it was proposed that the planned lending for fuelwood plantation establishment in 1981-85 of US $425 million should be increased to US $1,100 million which would be required to achieve a proposed target of establishing a total of 1 million hectares in 50 countries. Also the Asian Development Bank has considerable and increasing programme in rural forestry.

Several bilateral donor agencies are likewise significantly increasing their support for rural forestry, in which agroforestry invariably is included. Among the most active in this field are USAID, SIDA of Sweden, CIDA of Canada, West Germany, through GTZ and other agencies, the Dutch Ministry for Development Cooperation, the Swiss Development Corporation, and a few others.

Taken together, the external aid for rural forestry is considerable today, and it is rapidly increasing, particularly as a result of the fuelwood crisis in developing countries (FAO, 1981). However, partly because of the institutional constraints pointed out several times in this report, a very small proportion of these aid funds goes into agroforestry development projects in the sense of integration of multipurpose trees or other woody perennials into farming systems. By far the largest share of funds are channelled through donor forest departments to national forest departments for establishment of conventional woodlots on Government or communal lands. There is certainly nothing wrong in this approach when the aim is to reforest denuded slopes for catchment improvement or to establish a fuelwood supply for urban and rural population centres. It does not, however, adequately address the major problems facing the individual small and medium size users of converted, or other, tropical lands, namely the declining productivity of farm land and the domestic wood requirements for farmers in areas where no elaborate infrastructure exists for communal establishment, management and distribution of wood (or where cash for purchase of Government or commercially produced wood is not available). The former condition exists on most converted land, the latter probably on a major part of it.

The situation today, with a rapid, almost exponential, growth in international funds available for "rural/environmental forestry" development projects, has led in many countries to a saturation of the receptive capacity of aid in the forestry sector. Small, understaffed forest departments, often with a low "status" in national bureaucratic hierarchies, are asked to implement aid projects on "rural forestry" which are not seldom larger than thier total annual budgets. "Counterpart" and support staff requirements for the implementation of such projects, which of course are far too tempting, status- and financial-wise, to turn down, often seriously jeopardize traditional "core" activities of the departments, e.g. silvicultural management of natural or planted forests for industrial wood production, protection of vital catchment forests, etc. The result is not seldom that neither traditional activities nor the new rural forestry activities are satisfactorily implemented.

Another aspect of the often weak institutional capacity to receive project aid in rural forestry is the problem of efficiently spreading experience from internationally supported projects to a wider area and larger number of people if this has to rely upon the same national institutions receiving the original aid. Once support is discontinued it is highly doubtful whether any significant programmes based on national funding will take over the development initiated through the internationally funded project if the approach of this was "departmental". Similarly, it may be rather uncertain whether rural forestry projects based on strongly supported and subsidized communal efforts of tree planting will "catch on" and receive long term local support in areas where communal efforts do not have a very strong cultural background once project supported subsidies and incentives are not there.

These observations should be seen in relation to the fact that almost regardless of the level of international support, this will only marginally be able to alleviate or solve the problems addressed in quantitative, global terms. The importance of internationally financed development lies mainly in the innovative and demonstration values of projects. If they do not "catch on" locally they will be a drop in the ocean from a quantitative point of view. A point in case is the previously mentioned World Bank proposal to increase the bank's lending for fuelwood plantation establishment from a planned level of US $425 million to US $1,100 million in the period 1981-85. Even if the higher level were to be approved and implemented with full success it would still only cover a few percent of the need for <u>increased</u> fuelwood resources required to meet the demands of developing countries in the coming two decades.

What actions then are needed at the level of international funding for agroforestry development? The situation today is characterized by an enthusiasm and willingness among donors to provide funds which are two steps before both the knowledge and experience of how to carry out agroforestry projects on the one hand and the capacity of national institutions to receive the aid and follow it up on the other. Therefore, it may seem appropriate to recommend the following actions:

- identify more clearly national institutional capacities and constraints of receiving financial aid for implementing large scale development projects in "agroforestry" - should it be channelled through forestry or agricultural departments, or should an inter-departmental solution be sought (and if so, how)?

- allow a considerable part of financial support for agroforestry projects to go into project preparation: identification of relevant problems, identification of optimum technologies for solving identified problems (e.g. soil erosion, fuelwood supply, dry season feeding, etc.), and, if necessary, into research and trial to test technologies to be used in large scale implementation projects (all too often, for example, a tree species is used to solve a problem for which it is not suitable, simply because it happens to be the most readily available seed source).

- when institutional optimization (both at donor and recipient levels!) is assured, when relevant problems and technologies to solve them have been identified, and the latter seem feasible from a technical and social implementation point of view, then, but first then(!), should considerable funds be allocated to agroforestry development projects.

- financial support for agroforestry projects should go to activities with a convincing demonstration value where technologies and incentive structures (higher farm productivity, higher levels of cash income, etc.) are such that the probability of large scale adoption of project technologies is high and reasonably guaranteed.

4.3 Actions needed at national and regional levels

4.3.1 Institutional

If it is difficult to outline specific actions needed at international level to promote and realize the potential of agroforestry approaches to improve the productivity of converted lands, it is

virtually impossible to do it at a "general", national level. Although it is convenient in political rhetorics to talk about "developing countries" as a homogenous entity, or in science and land development to talk about "tropical and subtropical regions", there is little sense in trying to formulate generally applicable, concrete guidelines for national action for these entities. Countries such as India, Mali and Venezuela have practically nothing more in common than the facts that their GNP per capita all fall below an arbitrarily set limit, and that the minimum temperatures of the coldest months are all above a similarly set limit.

Therefore, short of goint into a country-by-country account of what institutional (and other) actions are needed, it is only possible here to briefly outline some general action requirements which are applicable to most nations in the developing, tropical/subtropical world.

Looking first at institutional infrastructures and frameworks (in administration, development, education, research and extension), the same constraints operating at international levels as a result of rigid disciplinary boundaries often also prevent efficient development of integrated land use at national levels. Several ministries and departments, normally competing for scarce or almost non-existent development resources, are often involved in partly overlapping and rarely coordinated development and extension activities related to the use of land resources. Not only are agriculture and forestry normally separated at ministerial level, but also livestock, water, energy, environment, etc., have their own ministries or departments. No doubt, this division may be well motivated for certain types and levels of activities but it creates problems and confusion when it comes down to the final, and most important(!), level, namely to advice and guide the farmer on the best use of his land resources.

There is no immediate, generally applicable solution to this problem, simply because it takes different forms in different countries. However, it is quite safe to say that in order to efficiently develop and disseminate agroforestry technologies and systems the following action will be required in most countries:

- a through review of institutional responsibilities for land development at farmers' level with an aim of achieving an institutional structure which will guarantee an optimization and synthesis of disciplinary development resources and knowledge at a level before it reaches the individual farmer or land user.

4.3.2 Legal and economic

As pointed out before in this review (cf. p. 37 and p. 42), institutional conditions and lack of technical knowledge are not the only, and often not even the most serious, constraints imposed on long term development and adoption of agroforestry technologies and systems. Political and social constraints may often make the most sound technical proposals on land development virtually impossible to implement. For example, no matter how motivated is tree integration into agricultural or pastoral lands, it will not succeed in situations where a system of short term, insecure leases of use of land is prevalent, where trees automatically become the property of the government, or where non-restricted communal grazing rights exist. Neither will it be possible to achieve large-scale surplus production of fuelwood as a cash crop by farmers, where controlled prices, aiming at protecting the interests of urban minorities and non-land using elites, are set so low that it does not pay to grow trees. There are many other similar examples of where political, legal and socio-economic conditions prevent agroforestry (and other) developments. Again, however, the situation differs vastly not only between countries but also between regions within countries, and it is meaningless to try to be too detailed in outlining what actions are needed.

Any government, though, which has a sincere intention to achieve more sustainable and productive land use practices through large scale popular adoption of tree planting and integration of trees into farming systems must take the step from political show-pieces such as "tree planting days", to actions which remove existing constraints and introduce efficient incentives. These may include:

- review land use legislation with the aim of removing legal

bottlenecks for integration of trees into farmland,

- review and identify constraints in land tenurial systems brought about by both written and customary laws as well as by social and demographic developments since the time when laws and customs were originally developed, and,

- create economic incentives for tree planting by farmers, or (more often probably) remove disincentives.

4.3.3 Research and education

The problems of development-oriented research in developing countries are well-known and have been the focus of many recent meetings and publications, e.g. FAO (1981e) and Daniels & Nestel (1981) for agricultural research, di Castri & Hadley (1979 & 1980) on scientific bottlenecks to natural resources development, and World Bank/FAO (1981) for forestry (including agroforestry) research.

In very general terms, the major constraints in most countries to efficient research for developing technologies for better land use are:

- lack of critical mass of adequately and relevantly trained scientists,

- inadequate funding, particularly operational, non-recurrent funds (in many countries, total research budgets may give an erroneous impression of being substantial whereas in fact they only go to salaries and other recurrent expenditures)

- as a result of the above, there is often a marked lack of continuity in research, which is particularly serious in land use research involving trees,

- research priorities are normally set within rigid traditional disciplinary boundaries, which, in combination with lack of staff and funds, creates a situation where innovative and inter-

disciplinary research approaches are rarely given any room.

At the same time as these constraints are apparent, the urgent need to significantly strengthen national research capabilities and programmes is becoming more and more obvious. This applies to traditional agricultural and forestry research as well as to new fields such as fuelwood energy and integrated landuse research. As previously mentioned, this need has recently been acknowledged by most of the big international donor and development agencies (FAO 1981d; World Bank 1981a and b; World Bank/FAO, 1981). At the time of writing this report (mid-1982) it is known that some major initiatives, involving the large donors, are in the being which appear to aim for considerable strengthening of national research efforts in the fields of agriculture and fuelwood.

Agroforestry as a field of systematic research at national level suffers not only from the constraints typical of traditional agriculture and forestry research, but also, and more severely, from the very facts that there are neither any "agroforestry" scientists, nor any scientific institutions focusing on integrated land use systems and agroforestry technology packages.

The work that is carried out is, with a few exceptions, done at disciplinary research institutes by scientists who have a strong bias towards either agriculture, forestry or social sciences. It should immediately be stressed, however, that the need is not for creating a cadre of "agroforestry" scientists, staffing separate "agroforestry" research institutes. What is needed in order to initiate and implement research aiming at developing locally adapted and adoptable systems and technologies are the following actions:

- establish, as an initial step, inter-institutional working groups, committees, etc. (either formal or informal) with the aim of reviewing constraints and problems of addressing inter-disciplinary research on integrated land use systems,

- inventory and assess the role of trees/shrubs in traditional farming systems in the country,

- identify what land use problems could, and ought to, be addressed by an agroforestry approach and assess the potential for developing traditional technologies, or for adapting international experience, through research to solve the problems,

- identify areas suitable for regional research cooperation (e.g. multipurpose tree germplasm exploration and development) and establish regional collaborative programmes where possible (if well conceived, such programmes will easily attract international funding),

- reassess medium-and higher level education in land use subjects with an aim of eventually creating a system which ensures a basic level of joint understanding and knowledge of the ecological and socio-economic bases for land use among students, with specialization into commercial forestry, cash crop agriculture, integrated subsistence land use, etc., coming at a later stage.

4.3.4 Extension and training

Extension services and training of farmers are key areas to the successful introduction and widespread adoption of any new technology or improvement of landuse practices. No matter how interesting and promising technologies developed on a research station are, and no matter how successful a limited "development project" is, they will only remain unfulfiled promises or drops in the ocean if there is no efficient network of disseminating them to a large number of "end-users".

This applies in principle to any agricultural or forestry "innovation". In the case of agroforestry technologies, involving tree/shrub introductions into farming lands, the problems are normally considerably greater. Not only are the "conventional" problems of existing agricultural or forestry extension services prevalent - lack of staff, low attractiveness of extension work, lack of supporting facilities (transport, demonstration material, etc.) - but there are also

additional problems specifically related to agroforestry extension, e.g.:

- lack of extension staff with an adequate training for advicing on integrated land-use systems and technologies involving mixtures of trees, crops and animals,

- in most cases there is no established network of on-farm demonstration plots on agroforestry technologies,

- because of this and the time involved in demonstrating to farmers the benefits of agroforestry, consistent extension efforts will be required with good back-up services in terms of plant supply, training of farmers in the best management of trees to obtain optimum benefits, frequent visits by extension staff to monitor development on farms, etc.

- the difficulty of obtaining goood and certified seed of multipurpose tree species for mass distribution to farmers is a major problem for agroforestry extension (unfortunately in many cases local collections by unqualified personnel is restored to which will most likely result in the distribution and use of deficient, or at any rate sub-optimal, germplasm),

- many of the areas where agroforestry will have a major role to play are often lacking in infrastructure, people are spread over vast expanses of land, illiteracy will be common among small subsistence farmers, etc., all adding to the problems of reaching a sufficient number of people to obtain significant impact of agroforestry extension.

In order to overcome these problems and establish an efficient agroforestry extension and training service most developing countries will need to take significant actions, e.g:

- review the suitability of existing extension services in agriculture, forestry, animal husbandry, etc., for integrated land - use systems and technologies, with an aim of either merging then

or to create an institutional structure that ascertains a close cooperation between them,

- training of extension staff at technician and professional levels, should be reviewed with an aim of creating a joint basis of knowledge on trees, crops, animals and their interactions, before specialization takes place,

- a general upgrading of the "status" of extension work is required (not only applicable to agroforestry),

- sufficient resources must be set aside for transport, establishment and maintenance of on-farm demonstration plots, development of facilities for training of farmers, facilities for propagating multi-purpose trees, development of A/V - information material, etc.,

- close and mutually interactive relations must be established between research and extension (again a generally valid condition but particularly so in relation to "new" agroforestry technologies),

- a strong government back-up of extension efforts in the initial stages of promoting and spreading agroforestry technologies, e.g. in the form of credits, creation of economic incentives, etc., to overcome farmers' reservation to tree integration on their farms, before the technologies prove their value (i.e. after trees/shrubs have become old enough to yield the expected benefits).

5. LIKELY CONSEQUENCES

5.1 The scene

What impact can be expected if the desired actions outlined in Chapter 4 are implemented? This is almost impossible to forecast in absolute, quantitative terms. Agroforestry as a systematic approach to land development has not yet been tried on a scale which allows any firm conclusions to be drawn on its potential economic

and ecological influence on a regional or national level. One thing is clear however - if the conclusion is drawn that agroforestry is a potential and feasible approach to large scale alleviation of the problems of declining food and fodder production, fuelwood shortages, desertification and deforestation, etc., an approach to be pursued vigorously together with "coventional" approaches and strategies such as increasing land under irrigation, improving crops, establishing departmental and communal fuelwood plantations, etc., then very substantial resources must be set aside to implement the actions outlined in Chapter 4 over the coming decades.

Although global and regional statistics on problems often breed despair and does not provide any guidelines for local actions, it is useful in the context of a conceptual report to be aware of the scene for which we paint different impact scenarios. Many of the figures and conditions quoted below do not entirely coincide with converted lands but there is no doubt a considerable overlap.

The number of people and the area involved will of course depend on where one sets the limits of converted land or land in which agroforestry development should be given priority. The World Bank (1981), for example, estimated that about 200 million people live within or on the margins of remaining tropical forests. These people are naturally to a very large extent the same as the 250 million (7% of mankind) estimated by FAO (1974) to practice shifting cultivation on a land area of approximately 36 million sq. km.

Arid and semi-arid lands cover 37% of the earth's land surface and is inhabited by nearly 400 million people (World Bank/FAO, 1981). It has furthermore been estimated (United Nations, 1978) that 19% (30 million sq. km.) of the earth's land surface is threatened with desertification due to overgrazing and devegetation caused by man.

King (1979), trying to assess the area of fragile ecosystems in the tropics, which basically are the infertile rainforest zones and the arid and semi-arid lands, concludes that 49 million sq.km. (65% of the land in the tropics) with 630 million people (35% of the popula-

tion in the tropics) living on them, have got either serious fertility, drought or erosion problems which limits their potential for conventional agriculture.

These figures establish a kind of minimum framework in which agroforestry developments will be desirable. It should be strongly emphasized, however, that the agroforestry approach to land development may have a much higher economic potential in areas which do not have serious limitations, but for the "marginal" or fragile lands it is probably one of the few feasible approaches to improving productivity and sustainability.

The fuelwood problem in developing countries has only recently been quantified. Figures on magnitudes and trends are of such an alarming character that most international agencies have given urgent priority to the problem. In the Sahelian region of Africa, for example, firewood need will be more than double from 16 million m^3 in 1975 to 33.5 million m^3 in 2000, necessitating an annual planting rate of between 150,000 to 300,000 hectares (Club du Sahel-CILSS, 1978). Similarly, in a special study of 15 developing countries (FAO, 1981d) it was found that the present rate of fuelwood plantation establishment of 63,500 hectares per annum would have to be increased by more than 10 times to 670,000 hectares per year if a shortage shall be avoided in year 2000.

For sub-Saharan Africa, the estimated fuelwood need in 2000 will be 280 million m^3 (World Bank, 1981b). In order to meet this need, 19 million hectares of fuelwood plantations will have to be established (which is 100 times more than exists today!). Annual planting will have to increase more than 20-fold (!) from 70,000 hectares per year to 1.5 million hectares. Looking at the developing world *in toto*, it has been estimated that if drastic measures are not taken, 3,000 million people will face an acute shortage or deficit of fuelwood in the year 2000 (FAO, 1981f). "Drastic measures", expressed in conventional terms of area of fuelwood plantation, means that 50 million(!) hectares of new fuelwood plantations will have to be established between now and the end of the century to ensure a reasonable degree of self sufficiency (World Bank/FAO, 1981). It does not take much calculations and reflection to realize that this

can not be achieved with an approach relying on donor assisted projects (the cost of conventional establishment of 50 million hectares is in the region of US $50,000 million), or on existing forest authorities in developing countries (who today have the capacity to achieve a planting target which is only 5-10% of the need). Only through large scale voluntary adoption of tree planting by farmers and rural populations is there any theoretical hope of meeting the needs.

Finally, to complete this rough, piece-meal quantification of the scene, some figures on the food production problem in developing countries. The previously quoted FAO report (FAO, 1981d) summarizes the whole range of problems of developing country agriculture and food production and outlines some major strategies to solve them. In the two decades 1960-1980, 38 out of 90 developing countries achieved less than 2% per annum increase in food production which is less than population increase and, consequently, a decreasing per capita production of food. In order to reduce undernourishment in Africa, the hardest hit region, annual food production has to increase from 1.8% per annum to c. 4% per annum between 1980 and 2000. To achieve this, very substantial external aid and national resources must go into development of intensified and improved agricultural practices.

Although it is obvious that the most dramatic, statistical improvements can be achieved through expanded use of irrigation, fertilizers, better crop varities on high potential land, chemical and other ways of reducing pest/disease and post-harvest losses, etc., it is also apparent that for large areas in the tropical developing world these approaches will be infeasible or only partially relevant. Where water is not available, where it is outside the economic reach of poor farmers to use fertilizers, where drought, declining soil fertility and erosion are the major limiting factors, etc., other approaches must be given priority. As the world and human societies, both at national and international levels, function today (and will probably always function!) it will be of little consolation to a subsistence farmer trying to eke out a livelihood from his farm in semi-arid Africa if new irrigation developments in Pakistan increases, in

a statistical sense, the average per capita food production in the developing world. Or, for that matter, to a resettlement scheme farmer in the Amazon or on Borneo, if coffee farmers increase their cash incomes in Southern Brazil or a high-yielding rice variety proves successful on Java.

The problem, thus is not whether the food production problem of developing countries should be solved by giving priority to irrigation development or to agroforestry, for example, but to realize that solutions and approaches must be location-specific and not "statistical". If population increase continues as today, the total production of food in developing countires will have to increase 5-fold by the year 2055. To achieve this and to avoid widespread local famines, it must be accepted that a multitude of locally adapted strategies and approaches to land use improvement have to be given support. Increasing productivity and sustainability of food and total output from marginal and other lands through carefully conceived introduction of woody perennials into farming and pastoral land is one strategy that should be pursued.

5.2 Low input scenario

Any assessment of the likely impact of various input levels for agroforestry development will necessarily be speculative and based on arbitrarily set criteria for what constitutes "low" or "high" inputs.

Low input is here basically seen as a an extrapolation and continuation of present trends. This scenario will be characterised by:

- a continued general interest at international and national levels in "agroforestry" but no real break-through in the realization that the potential of agroforestry lies in the introduction of trees and shrubs into agricultural land, and not in the introduction of food crops into forest land,

- a continued and moderately increasing level of international

funding for agroforestry projects in the true sense, and possibly a rapidly increased level of funding for "fuelwood" projects,

- as a result of the increased level of national and international funding for renewable wood energy approaches, it is likely that the coming decade will see some significant break-throughs on research and development of fuelwood species, many of which will be of direct relevance to agroforestry,

- the institutional constraints preventing efficient agroforestry development will continue which means there will not be any major, determined efforts to develop, through systematic, long-term and interdisciplinary efforts, truly integrated land use systems (i.e. land use research will continue to be "forestry" or "agriculture" oriented, and development projects will continue to be judged by short-term disciplinary criteria, such as number of seedlings or hectares planted, or increased yield of this or that crop, rather than by long-term total productivity and sustainability of integrated land use systems).

There is little doubt that this scenario will result in some local successes:

- some projects and activities on "social forestry", "village forestry" etc., which contain components of agroforestry, will certainly achieve their goals and have a multiplier effect in terms of wider adoption by farmers, particularly if technologies used are "farmer friendly" and the incentive systems are well conceived,

- similarly, there is little doubt that more sophisticated farmers and land users will adopt agroforestry component technologies with an easily demonstrable profitability, particularly in commercial and intermediate types of land use systems,

- the worsening fuelwood crisis will in many areas lead to a spontaneous planting of trees by farmers, which, if properly supported by development agencies (both national and international) in the form of provision of improved seed and advice on establishment

and management techniques, may well turn out to be the most significant "agroforestry" developments - with the present disciplinary approach, it will however not result in a large scale optimization of the multiple benefits which could be achieved by increased tree planting by farmers,

- there will be an increasing awareness among foresters and in forestry organizations about the usefulness and relevance of integrated land use systems, but, as long as this awareness is not shared by agricultural counterparts, it will not result in any significant actions,

- in some developing countries where there is a strong political backing for agroforestry, afforestation, soil conservation through tree planing, etc., and where substantial international support for these activities are available, e.g. India, Kenya, the Philippines and a few others, there is a clear chance that the effects of agroforestry developments (in a wide sense) will indeed positively affect national statistics on fuelwood production, erosion prevention, rangeland productivity, deforestation, etc.

However, in the vast majority of developing countires, and regions within countries, an extrapolation of present trends of agroforestry developments will not result in any significant improvements for the large number of small subsistence farmers and land users inhabiting converted lands. It will not matter much on a global scale how many 10's or 100's of millions of dollars are provided by international donors, if there is not an accompanying change of approach to development of converted land. In spite of the probable limited and local successes outline above, there will continue to be, as today, an *ad hoc* and trial-and-error approach which will result in much wasted resources through socially or technically ill-conceived "disciplinary" projects.

5.3 High input scenario

A high input scenario would basically be one where the actions outlined in Chapter 4 are implemented in a determined way at both international and national levels. It will entail not only, or even mainly, a substantial eventual increase in funding and resource allocation for "agroforestry", but more importantly, a thorough revision of and subsquent removal of, institutional constraints preventing efficient development of integrated land use systems and technologies.

Research, development, dissemination and adoption by farmers of agroforestry technologies and systems will be a much more difficult and complicated process to instrument than, for example, the "green revolution". This was basically achieved by a determined international effort to develop, through on-station research, genetically improved varieties of three-four essential food crops and management packages to go with the new "miracle" crops, often packages composed of high inputs in terms of fertilizers, irrigation, pesticides and tillage. Statistically, the "green revolution" has been a local success in terms of increased national or regional production of some key crops (e.g. rice and maize). However, problems related to the limited adaption and adoption of high input technologies in small subsistence farmers' environments has resulted in many international agricultural research centres (e.g. IRRI and CIMMYT) establishing "farming systems programmes" to study ways and means of overcoming social, economic and technical constraints of introducing the "green revolution" to a wider group of farmers.

Even with determined efforts to implement the required actions, the consequences of agroforestry developments will thus not be rapid and measurable in a short-term. The most favourable interpretation of what is realistic to achieve through a high input scenanrio would be:

- on a 3 to 5 years' horizon it would be possible to collate and assess existing national and international experience of traditional agroforestry technologies, and identify promising tech-

nologies for further development (projects to do this are already underway at ICRAF),

- on a similar time horizon, a revision and certification of institutional constraints could be made at international donor institution levels, but only to a limited degree on national levels,

- identification and initial development of promising agroforestry technologies, such as the exploration, germplasm collection and systematic evaluation of interesting multipurpose tree species; further development, refinement and farm validation of technologies such as alley cropping, improved fallows, live fences, mulch production with tree species, fodder production, etc., all mainly through continued and strengthened efforts by already existing international and national research programmes, e.g. at IITA, CIAT, CAZRI and other ICAR-institutes in India, CATIE, various institutions working on *Leucaena*, *Prosopis* and other nitrogen-fixing trees, etc. (cf. page 50),

- since research is one of the few fields where it is not entirely unrealistic to achieve a significant degree of international cooperation (cf. CGIAR), it would also be expected that in 5 years' time coordinated plans and strategies for international support of research for development of agroforestry *systems* and *relevant* technologies have been elaborated; this would involve considerations and decisions such as:

  . how to establish priorities for agroforestry/system generation;
  . what are the institutional and disciplinary requirements for efficient research on agroforestry;
  . should a coordinated international thrust on agroforestry research be through existing CGIAR-institutes (by amending their mandates and increasing their disciplinary capacities), through existing regional and national institutions (in which case a thorough and critical evaluation must be done on how to strengthen their capacities to cope with research on integrated land use), or through setting up a new network of "agroforestry" institutes;

. how to set up efficient international and regional information and training facilities to support agroforestry research and development activities;

- also on a 3-5 year basis, a high input scenario would see a critical and coordinated evaluation of the experience gained from on-going development projects on agroforestry, village forestry, social forestry, fuelwood planting, etc., the outcome of which should be a considerably increased capacity at international and national levels to identify both appropriate technologies that address relevant problems and approaches on how to achieve their wide-spread adoption by land users.

- on a 5-10 year basis, research on and experience of promising agroforestry technologies will have reached a stage of field/farm validation; facilities for mass-propagation of improved seed sources of multipurpose trees/shrubs of undisputed value will be established; agroforestry systems research will be well underway.

- at the national level many developing countries will have reviewed their training syllabi and development and extension services to produce staff and institutions able to cope with integrated land development; in a few countries this will be through national initiatives, but in most it will probably be through international initiatives and support.

- considerably increased international funding and national development resources should at this stage (5 to 10 years from now) be set aside for agroforestry field developments (in a wide sense). It will not be a matter of increasing the forest development budgets by, say, 50%, but, rather the magnitudes will have to be of the order of 25-50% (depending on region and country) of the total development funds for agriculture, forestry, livestock, water catchments and other land developments.

Still, even a high input scenario like the one outlined here will only result in significant improvements if technologies and systems demonstrated to be viable and profitable to farmers in "projects"

will catch on and become adopted on a larger scale, either spontaneously or through the support of local extension services. It would be unrealistic to think that improved or new agroforestry technologies developed and disseminated through determined, high input national and international efforts, will result in improvements to farmers and alleviation of problems which are measurable on national, regional or global scales within a matter of a few years. However, with a high input scenario, consistently pursued and supported, it could be expected that within 10 to 25 years, measurable improvements of the use of converted and other lands could be achieved.

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AGROFORESTRY - DEVELOPING A NEW RESEARCH DISCIPLINE

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INTRODUCTION

Is there really a place for yet another research discipline? I believe there is, on two main counts. The first, and more pragmatic is that any new amalgam of research ideas needs to be positively encouraged and identified as such, whether it springs from entirely original concepts and practices or not. This is especially so when the component research disciplines, in this case of agriculture and forestry, have established themselves almost as separate entities. The second is that a positive thrust towards the multiple use of land through agroforestry techniques generates a definite need to appraise and re-assemble our research tactics, so as to take into account the increased complexities in space and time which have to be dealt with in such systems. We might add, also, that we have to enquire whether our methods of evaluating the outputs of agroforestry systems, in terms of the multiple products and benefits which can accrue, are up to the job.

To this extent, then, agroforestry research is a "new" discipline. Of course, it will borrow and adapt existing well tried methods absolutely familiar to researchers in agriculture, forestry, ecology, biology and so on.

COMPLEXITY OF AGROFORESTRY SYSTEMS

Very few existing agroforestry systems have been studied critically and so far, many still await even broad description. Most agroforestry systems have arisen through the enterprise of indigenous rural communities who have, themselves, evolved them. Whether it is a home garden in Indonesia, a multi-storeyed mixture of trees and agricultural crops in Central America, or a silvo-pastoral system of fodder shrubs and grasses in the Sahel, suggestions for changing the inputs in terms of spatial arrangements, the temporal sequences of crops, or the very plant components themselves are unlikely, in many cases, to be used on measurement data because we have so few to work with.

A scientist faced with the challenge of identifying bottlenecks in many agroforestry systems, and of initiating investigations concerning

these, will often find a morass of variables to handle, and an acute problem of sampling to face.

It is not difficult to see why. Picture a system consisting of just one multipurpose woody species (say, *Leucaena leucocephala*) being grown for both fodder and fuelwood, together with sorghum or maize and a grain legume such as cowpeas or field beans. We need to optimize not only a choice of products in relation to the time scale in which they should be available to the farmer, but also maximize the nitrogen fixing capacities of the shrub; as well as soil and water conservation and shelter-conferring benefits. These benefits will have to be balanced against the water and nutrient economies of the various crop components, which will all occupy land for different periods and have a whole range of alternative spatial arrangements and management operations (time of planting, cultivation, fertilizer applications etc). Such a relatively simple agroforestry system is one which most research workers are not, as yet, familiar with handling.

THE VALUE OF WOODY PERENNIAL SPECIES

An agroforestry system is intended to be sustainable. That is it is supposed to lead to land improvement rather than degradation while at the same time, presumably, avoiding an increase in weediness and a build up of pests and diseases. Can merely adding trees and shrubs into a land use system achieve this?

Certainly, in many ecological regions the fertility status of the top layers of the soil can be improved by planting trees or shrubs (Kellman, 1979). These can change the soil fertility status both horizontally and vertically in an exploitable way, without necessarily increasing the total fertility of the system - although, if legumes are used they may, perhaps, by fixing atmospheric nitrogen achieve this too. In general terms, land can often be made more productive and less liable to degradation under woody perennial species because such a plant cover makes it less "leaky" for nutrients, light and water as compared with seasonal crops.

The challenge in agroforestry research is to discover to what extent less than a full cover of trees or shrubs can achieve these desirable effects, whilst allowing the land between to be used concurrently for growing seasonal crops or grasses, and at the same time increasing productivity, at least in the long term. What is making this idea more feasible now is a host of woody perennial species - the so called multipurpose trees - which can usefully fit into such systems and provide a range of products and/or benefits which the farmer wants (e.g. Burley, 1979).

The place which trees or shrubs may play in affecting pest build up is certainly a very complex one where, again, we unfortunately have very few data.

EXPLOITING HETEROGENEITY

Plant components in agroforestry systems can be arranged as completely intimate mixtures, or in small zones within the same unit of land. There are likely to be many more opportunities for mixed cropping arrangements in a "rich" environment which intrinsically supports a large biomass, but zonal schemes may be more realistic for semi-arid regions. Also where plant species, or species mixtures, are zoned the overall management may become simpler. The possible permutations in geometry of agroforestry systems is very large but these two general approaches seem to be a starting point.

Whichever is chosen, mixtures or zones, there is a chance to take advantage of environmental heterogeneity. Much of temperate agriculture and forestry has been aimed at specialisation (homogeneity), which utilises the benefits in output that can accrue through the relative ease with which various inputs can be added and, management processes manipulated, so as to optimise such systems. However, heterogeneity or variability is a fundamental feature of our environment. From among all this apparent disorder we have developed highly skilled ways of handling sample data in order to try to contain variability so as to understand the main features of it. However, users of land in the tropics invariably exploit heterogeneity, both in space and time. For example, a small farmer will often arrange his crops to take advantage of the varied pattern of soil fertility across his plot; also he may use sequential plantings to obtain the best growth opportunities, or to avoid pest infestations as far as possible.

Agroforestry systems of land-use, by incorporating plant species of very diverse economic life span and phenology, and with different spatial requirements, provide a better than usual choice of combinations which can share the environmental riches available.

AGROFORESTRY IS FOR EVERYONE

Agroforestry has often been spoken of as particularly suitable for fragile ecosystems - an estimated 2.5×10^9 ha in the tropics. These include desert fringes, mountain slopes, some cultivated and some not, as well as large tracts of tropical forests. The latter are disappearing at, supposedly, around 1 percent a year, and are mostly being converted into non-sustainable agricultural systems (Myers, 1980).

There are, in addition, more than 1×10^9 ha of currently used arable land in the tropics, much of which we know is undergoing an insidious decline in fertility. One way to overcome this is to increase the level of inputs, such is fertilizers, and to improve soil management practices. Although this might be an ultimate goal for achieving the highest possible productivity (de Wit, 1979), an immediate concern is now to make the best use of what is locally available in order to satisfy the needs of the rural population for

food and fuelwood etc. agroforestry systems may well then be beneficial for these lands too.

No system produces something for nothing, but to maximize the use of environmental resources and to reduce losses would seem to make good sense. It is for this reason that we most often hear about agroforestry as being applicable to low input systems. It is, however, illogical *not* to consider it as a valid alternative to any other land use system, at any level of inputs, and to evaluate the possibilities accordingly.

SOME PROBLEMS UNDERLYING AGROFORESTRY RESEARCH

These can be only briefly sketched in here. Initially, at least, we are unlikely to have the luxury of experimenting with entire land use systems, although those with much experience will have, at least, a conceptual appreciation of what it is they are handling. Thus, field experiments will be concerned with sub-systems and with systems components, also their interactions, the magnitude of which will certainly be highly location-specific.

Our knowledge of the plant components in any agroforestry system may be at quite different levels. For example, the agricultural crop will usually be well studied, often with a wide range of selected germplasm to choose from. The trees of shrubs - particularly if these are new-introduced multipurpose species - will be much less well explored.

There are also a host of differences in handling seasonal crops and woody perennial ones - biologically and management-wise. For example, in their juvenile stage, woody perennials will most often be "dominated" plants when grown in a mixed cropping situation with a seasonal or with grasses. This situation is reversed after a few years as the trees mature. Many seasonal agricultural crops are highly selected, self-pollinated and genetically homozygous. Woody perennial species are often cross-pollinated and highly heterozygous. The annual productivity of woody perennials often depends on what has happened to them in the previous season (e.g. "biennial bearing"), and it can even be influenced by what occurred in their early stages of growth. Yet again, woody perennials tend, more than seasonal crops, to build up their problems as the years go by, especially with regard to pest management. The land and soil preparation required for seasonal crops and woody perennials is another obvious difference, as are the very different harvesting problems.

If we are going to mix seasonal and woody perennial crops with such diverse characteristics, then compromises in management will be needed which will almost inevitably make the system more complex to handle.

RESEARCH TACTICS

Once we have evaluated the systems we are dealing with, and have

identified problems that require investigation, how do we set about formulating a research programme? Clearly there is a vast accumulation of working material which forms the basis for thinking about the management of land under any kinds of plant or plant/animal associations. However, not all of it is in a form appropriate to the extended time frame and complex spatial arrangements which we find in agroforestry systems. Purely heuristic approaches are not to be despised, but a new set of sound field research tactics needs to be worked out if resources are not to be squandered.

Table 1 outlines the different phases and stages of a research programme for studying plants for agroforestry systems and indicates the type of field approach which might be suitable for each. Both mature and juvenile phases of trees need to be taken into account.

It may be possible to utilize existing woody plant stands and associations (survey and simulation techniques), and this might be an advantage. Otherwise field experiments will start with newly-planted woody species, bearing in mind that it may take many years before these reach their mature phase (conventional fully-randomised or randomised block designs, or systematic designs may be useful here). What has been barely-explored to date is the relative cost/effectiveness of these different approaches with regard to agroforestry.

Simulation (Oldeman, 1980) starts with an accurate description of the architecture and aging structures of existing vegetation, and identifies opportunities of replacing specific components with more productive ones. Sampling of existing mature trees or stands, around which appropriate agricultural crops can be introduced, can be used with appropriate multivariate analysis techniques to look at the crop-environment interactions. Ecologists have been using such methods for many decades to discover facts about the association of different plant species in natural stands.

Conventional randomised block layouts are widely used in agriculture and in forestry research but, with the many variables and levels involved in agroforestry tree/crop mixtures, the space they would occupy could become inordinately large. In these circumstances they are of low efficiency with regard to space utilization because of the need for internal guard rows; but they are robust designs.

Systematically designs use very little land and can facilitate the rapid return of information regarding plant responses to a few treatment variables covering a very wide range of levels for each. In particular they are valuable in examining a major variable, that of changes in plant population. Such designs could be simplified so as to use them "on farm", combining farmer evaluation plus a more detailed sampling of results by trained field teams.

There is no doubt that all these are useful field methods but just

which need to be used in any particular set of agroforestry circumstances has to be given careful thought, depending on the objectives of a particular experiment and the phase of the investigation which has been reached. Because of the time scales and costs involved in agroforestry research there is certainly a need to set limited objectives.

EVALUATION AND ADOPTION

Evaluation of agroforestry systems poses the same kind of problems which are intrinsic to the evaluation of any multiple-enterprise system. But the complexity of agroforestry systems, and especially their extended time scales, pose special problems.

Often rather little is known about why farmers grow trees (other than specific agricultural tree crops), what they hope to get from them and how they allocate resources to improve this part of their system. "Convenience" as well as "Risk" (Zandstra *et al.*, 1979) can influence decision making and adoption, and these are matters which are often largely speculative at present. Techniques such as linear programming may often be inadequate to encompass the dynamic changes inherent with time, and it is difficult to handle the large number of components, restraints and alternative output goals.

The results of field research in agroforestry should be presented in a form which will help offer clear choices to the land user. To give one example, a complex multifactorial field experiment in which the results are given only as mean effects may have under-emphasized the results obtained between the highest and lowest sets of treatments. If the treatments and levels represent a series of management inputs then the farmer needs to be able to judge what he is likely to get back if he invests in them at any chosen level. In such a situation the experiment may have been better planned so as to obtain as valid a comparison as possible between separate input steps, and/or the treatment range rather than the mean (Huxley, 1981).

Generally, even where land tenure is secure, farmers in the tropics are more prepared to invest their resources, or at least a bigger proportion of them, in short-term gains rather than long-term benefits. Where a community effort is required the matter is often made even more intractable. If land users are not already planting trees and shrubs, a general call to do so may well fall on deaf ears. This has often been a problem in promoting fuelwood lots, or the planting of browse shrubs.

The simultaneous use of land so as to combine agricultural crops with trees and shrubs may be a solution to this problem, because the procedures for planting the woody perennials can be carried "on the back" of those for sowing the short term crop. Certainly the socio-economic implications of agroforestry are a rich field for

study (Openshaw and Morris, 1980).

AGROFORESTRY EDUCATION

If there is to be a major change in our approach to integrate land-use (the solution to which may or may not be agroforestry in any particular situation) where are the planners, researchers and technical practitioners to come from? Scientific research is fundamentally analytical, and its pursuit is largely a devisive activity. Education on the other hand, has to be integrative from the outset, and particularly so if the recipient is to become a productive participant in handling land-use systems (Huxley, 1976a, b). The challenge here is to devise much more appropriate and relevant education programmes, because it is doubtful whether merely adding yet one more subject ("agroforestry") to the curriculum will serve other than to over-burden already crowded courses and programmes (Huxley, 1980).

THE CHANGING SCENE

Three major changes have occured in our approach to the development of land in the tropics over the last decade or so: intercropping has become a reputable study; minimum/zero tillage with mulch farming has been shown to offset, or even reverse the declining soil fertility which occurs under continued cultivation in the wet tropics: and its potential for semi-arid regions also looks promising. Finally, and more recently, agroforestry as a system of land-use has aroused considerable interest.

The possibilities of combining all three approaches to improve and develop productive and sustainable land use systems in the tropics is enormous. But it will need some rather broad-minded practitioners backed by equally adaptable researchers, to explore the wide range of possibilities open to us.

Any "new" discipline must move rapidly from the descriptive to the experiment and developmental, and it must take care to avail itself of all existing information, data and new ideas. Deciding on the most appropriate and efficient experimental approaches for the various phases of investigation is an early priority.

Table 1

Stages in the execution of plant research for agroforestry land use systems. A general appreciation of the type of system, or systems, being dealt with is assumed. If sylvo-pastoral systems are involved then animal research (mentioned specifically here only in stage 2(D) would follow a parallel course.

	OBJECTIVE	TYPE OF EXPERIMENT	TYPE OF LAYOUT	TIME SCALE
Stage 1	A. Determine if the plant species are adapted and select those which establish and grow well	Screening trials for: a) establishment and b) adaptation - providing minimum managment such as fertilizer for the planting hole and/or minimum irrigation at planting.	Replications of: well spaced- plants and close-placed plants (hedgerows)	5-6 years
	B. To determine species phenology and the influence of management on growth of the single plant	Single-tree plots, fully randomized and plants subjected to a range of different simple management treatments	Fully randomized	5 - 6 years
	C. Appraisal of environment-related factors which affect growth and yield of different species growing in natural or suitably-modified associations	Survey of plant associations and environmental characteristics on a seasonal basis	Multivariate techniques	Over 1 - 3 years
Stage 2	D. Management trials on plots containing groups of plants of any one species a) without animals so as to optimize productivity and b) with animals, if appropriate i.e. if the species have a browse function and so as to investigate the plant-animal interactions	These would be especially to establish the interaction of spacing and management treatments (note that feeding trials with animals kept separately could be carried out if sufficient material is available from this type of experiment or any of the proceeding ones)	a) Parallel row designs or factorial experiments with fixed/variable interrow populations b) Randomized blocks with plots arranged to facilitate grazing or very simple systematic designs for farmer evaluation trials	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

OBJECTIVE	TYPE OF EXPERIMENT	TYPE OF LAYOUT	TIME SCALE
E. To test under full-scale trials a selection of viable alternative components or sub-systems based on the information from proceeding experiments A-D - also to include economic assessement such as labour, costs, etc. etc.	Large plot investigations using only highly selected treatment combinations	Randomized block layouts with or without internal guards and with provision for thinning of the woody component/s	1 - 15 years
F. Evaluation of complete systems	Large area investigation to appraise a combination of technical, ecological, social and economic factors	Replication difficult	Very long term

TABLE 1: Different phases and Stages of field research for studying plants in agroforestry systems.

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WOODY PLANTS AND LAND USE

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INTRODUCTION

Woody perennial species (trees, shrubs, palms, vines) produce a multitude of products and they may often have functions which are concerned with soil improvement, climatic amelioration, or amenity and aesthetic purposes. So, of course, do non-woody plants. Indeed, annual or seasonal plants which also form ligneous tissues can similarly be used for fuel, construction materials and paper or board making, for example.

There are, however, some characteristics of trees/shrubs etc. which must determine the ways these are utilized in land use systems, which strongly affect the choice of whether or not they are included, or used at all, and thus what overall type of system is under consideration (agricultural/horticultural, forestry and agroforestry). These have been listed in the Appendix and they are all the outcome, in one way or another, of a woody perennial habit.

Some of the technical characteristics listed can, depending on the social and economic considerations, be considered advantageous or not depending on particular circumstances. In any case, planting trees for any purpose is a relatively long-term, less-flexible investment (in terms

of cash or labour) than any seasonal cropping programme for land use; because of their long land-occupancy choice of site and soil preparation are more critical, and woody perennials tend to accumulate pest problems to an even greater extent than seasonal crops, for which a break in rotation can often be made.

SOIL IMPROVEMENT CHARACTERISTICS

One major and positive aspect of tree/shrub growing is the capacity which such plants have for soil improvement. This is because of the nutrient cycling processes which occur and, in part, the mechanical and physical effects which trees/shrubs can have on soil (stabilization, reduction of soil surface temperature and other physical effects of a perennial plant structure over the soil surface).

Woody perennial species can, therefore, maintain or enhance the sustainability of land use systems. The extent to which they do this over time depends on a number of factors: the climate and soil, the species of tree or shrub, their number, arrangement and management. Also the amount of plant materials removed from the site and of fertilizers and/or mulch materials brought in.

High input/low output systems (in terms of nutrients and biomass) e.g. coffee farming and many fruit, nut, spice tree crops systems can be highly sustainable or improving. But so can low input/low output systems, such as conventional natural forestry, as long as harvests are extended over long periods. Plantation forestry, however, using fast-growing species can be soil degrading (Chijioke, 1980) as are many relatively low-input/high-output agricultural systems (wattle, sisal), and a great many low input/low output tropical agricultural systems which involve inadequate soil management techniques.

Trees and shrubs may often be deeper rooting than plants in the

herbaceous layer, but this is not always the case. Their rooting can also be very extensive (e.g. Olive, Sawaf, et al., 1978). However, the location of the most active region of uptake of plant nutrients is often fairly close to the trunk, although this can change seasonally (Huxley, Patel, Kabaara and Mitchell, 1974; I.A.E.A, 1975), and only a relatively small proportion of nutrients are likely to be taken up from depth. Nevertheless, in terms of total nutrients in the system as a whole this small fraction is probably highly significant over time where the offtake of biomass is restricted. Depending on plant population and arrangement, the more extensive root system of trees/shrubs can make the system less "leaky" for plant nutrients.

An actual assessment of the potential sustainability of a system depends on the interaction of a great many variables (Table 1). We have information about the effects of some of these but, clearly, there is a great deal still to be learnt about others. Ultimately, a relatively simple methodology for studying the outcome in a site-specific way for agroforestry systems is needed.

PRODUCTIVITY/SUSTAINABILITY

The potential of trees/shrubs for improving the sustainability of land use systems has to reconciled with requirements for productivity. Where we are dealing with single product outputs (fruits, seeds, timber, leaves) this can be assessed using conventional economic methods. For multiple output/long time scale systems there are, as yet, no satisfactorily established means of approaching this. Linear programming techniques, for example, may help to ascertain what major features are contained in the problem but they do not provide us with adequate means to evaluate it (Dykstra, 1981). Other approaches are now being tried (Ethrington, pers. comm.)

For agroforestry systems which are concerned with multipurpose trees on farm lands the situation can be at least outlined by considering the response surfaces generated with time for both the productivity and sustainability of any system where a replacement series of the tree species and agricultural crop are involved. Such an approach is a first approximation which can be used for both biological and economic evaluation (Huxley, 1981).

TREE CROPS - SOME MAJOR DEVELOPMENTS IN THE LAST DECADE

Agriculture

In agriculture one of the most interesting developments with tree crops in recent years has been a change to highly intensified close-spaced systems of growing trees. It has occurred in both temperate and tropical crops (e.g. Huxley, 1974; A.R. East Malling Research Station, UK., 1974 on; Mitchell, 1975). This progressive step, which can shift potential production to a greatly improved level, has come about through a better understanding of the physiology of woody perennials which has enabled us to maintain the fruiting capacity per unit volume of small trees, while exploiting the greater production per unit area of land which occurs at higher plant populations than were generally used before.

Another significant change of attitude has been the acceptance among scientists of the value and validity of intercropping as a means not only of satisfying risk and management requirements, but to increase biological productivity (e.g. Willey, 1979 a,b). As tropical farmers in many parts of the world commonly intercrop trees, shrubs and vines with herbaceous seasonal crop plants the need to understand the plant-to-plant interactions at the tree/crop interface is clearly of value if we are to improve both the management and design of such systems (Huxley, 1980; Cannell, 1981).

A major agricultural development in both temperate, and now tropical regions has been a change in approach to soil management. Zero or minimum tillage systems these days form a valid, and in many cases much more rational way, of maintaining productivity and sustainability than hitherto. In fact, in tropical regions, minimum tillage has always been an integral part of the soil management approach of many peasant farmers, and recent scientific studies have confirmed its value if combined with plant residue or mulching techniques, for both the wet and semi-arid tropics (UK. Commonwealth Secretariat, 1979; Lal, 1979).

From what has just been stated above about intercropping it is clear that we need to reappraise our soil management practices in relation to tree-growing. At the same time bearing in mind that only shallow or zonal-cultivation techniques have often been applied to such crops.

Forestry

The change from exploiting natural forests in various ways (including shifting cultivation, which is a form of agroforestry) has, according to resources, incorporated an increasing level of activity towards man-made plantations composed of single or a relatively few tree species. The biological aspects of growing timber in this way are fairly well understood (Cannell, 1979). There is however, a major area of relevant study concerning the sustainability of plantation systems which requires careful evaluation (Sanchez, 1979; Chijioke, 1980 and Lundgren, 1980).

Genetic improvement of forestry species has been a feature of progress, and most countries have seen the inclusion of a range of new, productive, well-adapted timber species for plantation forestry in the last decade or so. (e.g. Webb, Wood and Smith, 1980).

Perhaps the greatest and most significant change has, however, been in the whole approach to forestry through an acceptance that trees have many functions and outputs other than provision of roundwood timber. The forest policy of Kenya is an excellent example. As with most developing countries Kenya's population is not only increasing rapidly (over 4% per annum) but by far the larger part of the population relies on fuelwood or charcoal for cooking and heating. Land is under considerable pressure for crop production. Yet until quite recently the forest policy in Kenya was conservationist and timber-production oriented (O'Keefe, Weiner and Wisner, 1981). The growing and obvious need for fuelwood has now engendered an entirely new approach, which also encompasses the possibilities for providing many other kinds of forest products. Such new programmes are being promoted throughout the world as "Social" or "Community" forestry (Bene, Beall and Cote, 1977; FAO, 1978; World Bank and FAO, 1981; IUFRO, 1981).

Agroforestry

The provision of a village woodlot under a community forestry programme is probably best considered as "micro-forestry" as, basically, it depends on the same type of resource-base as does conventional forestry (allocated land, shared or hired labour, similar nursery techniques, and the same fast-growing tree species). Agroforestry systems are concerned with a more intimate arrangement of trees and crops, often on the farmers' land itself, so that the resource base and the kinds of tree/shrubs species used, are likely to be very different.

There are many kinds of agroforestry systems which have evolved throughout the world as the logical outcome of the land users' choice of plants which will fulfill his needs for multiple outputs (Chandler and Spurgeon, 1980). What they all have in common is an association

of trees and crops (or grasses) and , hence, multiple outputs from the same unit of land.

In order to understand and improve these systems, or to devise new ones, it is necessary, therefore, to know about the interactions between the plant components, both for the short-term aspects of productivity and the longer-term ones of sustainability. We want, also, to have a clear-cut diagnostic for comparing all these forms of land use (agriculture, forestry, agroforestry). It is in this context that the potentials and restraints of different types of systems have to be fully understood, and the role of the tree in overcoming these restraints evaluated.

One of ICRAF's main tasks is to develop the appropriate methodologies for doing this (Steppler and Raintree, 1981), but we still need a great deal more detailed knowledge about tree-crop-environment interactions to enable us to achieve practical improvements (Huxley, 1981b).

Depending on whether the tree-crop interaction is favourable or otherwise, the layout of agroforestry systems can be arranged so as to maximize or minimize the interfaces. The maximal amount of interface can be achieved through some form of mixed cropping, and the minimum in a zonal system. The latter may also be chosen in order to simplify management procedures. For example, 'Alley cropping' with *Leucaena leucocephala* and maize is one form of zonal agroforestry, (Raintree, 1980).

A consequence of interest in both community forestry, and agroforestry has been the exciting number of potentially useful species of trees and shrubs which have been reviewed and which now appear to be extremely promising components in a range of different systems. Some have been predicated for particular purposes (e.g. browse, International Livestock Centre for Africa, 1980; fuelwood, National Acadamy of

Sciences, 1981) but, in fact, many of these species are multipurpose, providing animal fodder, fuelwood, building materials, medical products, dyes, and so on. They can also be used for woody mulch material.

One major difference they have as compared with most of the better known timber species (*Eucalyptus*, *Pinus* etc.) is that their form and growth habits are much better suited to crop associations, and to management techniques which will maintain their productivity whilst reducing competitive attributes.

A key area of research now is to evaluate these species as widely as possible and to extend our search for more. As many of them are leguminous the added possibilities for nitrogen fixation make them of especial interest in land use systems, even those where fertilizers are used, because of the present-day need to reduce the cost of such inputs.

Special uses of trees

Falling into both rangeland management and agroforestry (sylvo-pastoral) systems the use of browse shrubs and fodder trees is now seen as a key way of supplementing animal feed. Woody perennials have often been viewed, in the past, as being detrimental in grasslands. While it is true that *grass* production may be reduced, overall production of total fodder, or protein, may not. Furthermore, the phenological responses of trees and shrubs can be different, sometimes very different, from that of the ground vegetation. Hence, they can extend the supply of available feed materials into unfavourable seasons in a very significant way. There is now considerable interest in using trees and shrubs in this way although there are many problems in increasing the tree cover in arid and semi-arid regions, especially where there are occupied mainly by nomadic pastoralists rather than by settled inhabitants.

Another 'special use' area for trees and shrubs of all kinds is to assist in the rehabilitation of degraded areas. Such 'fragile environments' as mountain ecosystems, desert fringes, tropical acid savannas and areas where deforestation has resulted in impoverished and weedy soils. In some cases re-afforestation may be the solution. But in others it is not, because of the population pressure and the need for food production. In these cases, some form of agroforestry may be appropriate and the choice of tree or shrub species could include a mixture of these which will provide not only conventional fruit crops but species which will supply fuelwood, fodder, building materials and other products (including honey).

Finally, a most important consideration in many land use systems around the world, and especially in the tropics, is the use of trees or shrubs for soil and water conservation, as well as for windbreaks and shelter. The technical aspects of using plants as windbreaks are largely well-identified (with the exception of water-use considerations, which can be especially important in arid regions). There is still much to be learnt, however, about how best to use trees for soil and water conservation in the tropics. The wider issues of the effects on the hydrological cycle of complete tree cover, as compared with other forms of plant cover, or bare soil has certainly been looked into (Pereira, 1979). Although some information is available (Tejwani, 1979; Wenner, 1980; Thomas, 1981) what is much less well-defined is the best way to utilize a less than full cover of trees, such as one will find in many agroforestry systems. Complete intact rows of trees along soil conservation terraces may present few problems, although there is a need to explore the most suitable species in terms of productivity, their interactive characteristics with crop plants, and their water use (Zeuner, 1981). Mixed cropping systems present

more difficulties, and the form and nature of agroforestry systems of this kind need to take into account the effects of the trees on soil and water conservation if their potentials for benefit in these respects are to be realized.

CONCLUSIONS

Trees and shrubs have many roles to play in improved land use systems - especially in the tropics. The recent changes in attitudes in agriculture and forestry, as well as the appreciation that agroforestry systems are of considerable relevance to sound land use in many situations, means that we have to re-appraise the range of woody species we might use, as well as the management systems which we may wish to subject them to. In many situations well-tried soil crop systems, providing a single product are, of course, essential and still amenable to considerable further conventional refinement through improvements in germplasm, nutrition, pest control, and a range of management factors. The possibilities for changing forestry enterprises so as to provide more widely for the well-being of the rural inhabitants, or of modifying agriculture so as to include some possibilities for the farmers themselves to offset their own fuel-wood needs could undoubtedly be fruitful.

A more direct and positive approach is also needed to look at the role of trees for all kinds of purposes in agroforestry land use systems. This requires a rapid re-appraisal of existing technologies and the development of methodologies for evaluating and comparing different schemes with a view both to optimizing production, and at the same time attaining sustainability. The latter is particularly important because so many tropical arable systems are undergoing a slow but insidious decline in soil fertility. If mixed tree/crop agroforestry can be encouraged, using

the capacity of trees and shrubs to make the systems less "leaky", then the benefits can be great indeed.

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Table 1 (Cont.)

Nutrient (Fertility)Status of Soil in 5 (10,15,20) years time

$$= N\left(\left([A'(A)]_{t_1}-[A'(A)]_{t_0}\right)\ \left([B'(B)]_{t_1}-[B'(B)]_{t_0}\right)\ \left([C'(C)]_{t_1}-[C'(C)]_{t_0}\right)\right)$$

N is the current nutrient (fertility) status of the soil.

A'(A) B'(B) C'(C) represent the groups of factors categorized above.

t_0 = present time and t_1 5 years hence (t_2, t_3, t_4, could be incremental 5-year periods).

TABLE 1

LIST OF FACTORS AFFECTING NUTRIENT STATUS OF THE SYSTEM

		Natural		Man-Manipulated
ENVIRONMENT	(A)	Soil characteristics Topography Climate (Rainfall)	(A^1)	Soil management practices Soil conservation practices Water conservation practices
PLANT	(B)	Characteristics of species used in systems	(B^1)	
		- Growth (habit/rate) - Rooting characteristics		Plant management
		- Potential useful biomass		Harvesting Programme and techniques
		- Nutrient content of plants		Fertilizer practices
		- Canopy effects (on temperature, throughfall		Training/pruning/(harvesting of leaves/wood)
SYSTEM CHARACTERISTICS	(C)	Space Layout and arrangement of plant species (positions and dimensions)	(C^1)	Management efficiency
		Time Cropping sequences, Crop succession and land occupancy		Timeliness
		(Consequences of hetrogeneity in space and time)		

Nutrient Budget (N) = Accumulated inputs (soil and plant biomass) - Accumulated losses

(but processes are not linear with time and soilfertility status does not depend only on soil nutrient status).

APPENDIX

CHARACTERISTICS OF WOODY PERENNIALS WHICH INFLUENCE LAND USE DECISIONS*

A. TIME/SPACE CONSIDERATIONS

1. Length of (economic) life cycle

Affects many issues for both high and low economic input land use systems.

a) Restricts flexibility of management plans

b) Restricts responses to changing market or other economic conditions.

c) Investment is long-term

d) Returns in early years are small or non-existent

e) Certainty of land tenure is very important (Perennials sometimes affect this)

f) Restricts associated crop plants (if any) to those that are compatible.

g) Accumulates pest problems

h) Benefits of a permanent plant establishment have to be considered (eg. effects of soil, shelter etc.)

i) Possible risk of periods of climatic or man-made adversities need to be considered e.g. likelihood of drought, hurricanes, fire etc.

2. Size and form

a) Must relate to available space, where this is small, or plants must be managed to keep them small yet productive.

b) Must relate to the land user's ability to handle and utilize (and so as to be made available to animals, if appropriate); special equipment may be needed.

c) Considerations of "preference"

d) Problems of climate have to be considered (high winds, hail, salt-spray etc.)

e) Management can involve heavier "costs"

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* See also Huxley, P.A. 1981. Some characteristics of trees to be considered in agroforestry. Poster paper presented at the Consultative Meeting on Plant Research and Agroforestry 8-15 April, Nairobi, ICRAF, Nairobi.

3. General

a) Sometimes involves a greater degree of skill (management and labour inputs than with seasonal plants)

b) Ability to keep animals away can be important - especially at the planting-out/early growth stages.

c) Need for especial care and management in early stages has to be considered.

d) Water availability in dry areas can be important for seedlings and establishment.

e) Marketing of some tree/shrub products may be less well established and/or stage life of product (fruit) is short

f) Total outlay (money, labout, skills) can be higher than with seasonal crops.

B. MANAGEMENT UNCERTAINTIES

a) Variability of genotype	-	Heterozygosity caused by many tropical tree/shrub species being outcrossing.
b) Availability of seed	-	For less well-known multipurpose tree/shrub species.
c) Seed germination problems	-	Few remain in major crop plants (eliminated through selection) but various forms of germination regulation (hard-seeds, specific requirements) and short-term viability need to be looked out for.
d) Lack of knowledge about adaptability for specific sites	-	Well established for crop plant varieties and fruit and forest tree species. Detailed information still needed for many multipurpose and functional trees/shrubs.
e) Seedling/young plant management	-	Requirements for shade, protection, nutrients, effective innoculation (legumes), training, pests and diseases planting out requirements (including land preparation) - unknown to any extent for many of the 'new' species.
f) Responses to management in mature phase		Efficiency of different types of plant management in optimizing yield and length of economic production period. - again, these are not known for species of recent interest, in most cases.

2.2 PRACTICAL EXERCISES

- AGROFORESTRY FIELD TRIP TO KIAMBU DISTRICT
  (Peter Huxley and Fred Owino)

AGROFORESTRY FIELD TRIP TO KIAMBU DISTRICT

- Approx. 75Km

This short tour takes us through some of the most fertile areas in Kenya and traverses a wide range of land-use systems. We go from Nairobi (altitude 1660m, rainfall 1200m p.a.) to above Limuru (Uplands) reaching an altitude of 2240m rainfall 2100mm p.a.).

Below Nairobi to the South and East (see Machakos District Tour) there is less rainfall and, for example on the Thika Road, are some old sisal estates, many now turned into cooperative ranches. Above this zone the coffee starts, reaching its most productive around Kiambu (altitude 1750m). The soils in this part are Kikuyu Red Loams derived from weathered phonolite (a massive lava flow) and in most parts, they are very deep and fertile (see Coffee soils in Kenya and Their Characteristics etc "by A. Mehlich, Coff. Res. Found. A.R. 1966/67 1963). In some parts of this area, particularly in sheltered valleys, intensive banana/maize cultivation is prevalent, also with maize/beans and "sukuma wiki", a collard-type brassica which stands repeated leaf harvesting.

Further up the altitude range (and consequently with higher rainfall and more acid soils) one comes across dairy enterprises followed by tea. At the top of this altitude range there is forestry (including plantations of, mostly, Pinus radiata and Cupressus lusitanica) with sheep grazing on the grassy areas between (a typical grass here is Pennisetum clandestinum "Kikuyu grass" which is very deep rooted and provides good grazing).

The Tour

We start by leaving Nairobi City along the Limuru (Uplands) road, joining

it at Muthaiga where we pass through a segment of the Karura Forest. The indigenous species here include:-

Croton megalocarpus, Brachylaena hutchinsii, Albizzia gummifera, Teclea trichocarpa among the dominant forest species while the undergrowth is composed predominantly of Clausena anistum and the refuge Lantana camara.

Of particular interest are the remnants of the montane sclerophyllous forest which covered the whole of this area prior to farm settlement. Further on, we will see remnant signs of the original montane rain forest in the scattered single trees of Podocarpus gracilior, Olea africana and Polyscias kikuyuensia. Some areas here also been set down to Plantations of:- Juniperus procera (an indigenous gymnosperm which yields to plantation management) Cupressus lusitanica and Eucalyptus saligna.

STOP 1 Crossing the bridge after passing through indigenous forest, we can pull off the road a little higher up and view the plantation of Cupressus lusitanica (LH). We then continue uphill very soon reaching a coffee estate (RH) with large

STOP 2 mature trees of Acrocarpus fraxinifolius on the right side of the road, and Jacaranda mimosaefolia on the left. This is well-kept, unshaded coffee typical of the carefully-managed crop which produces some of the highest quality product in the world.

STOP 3 Further up the road we have an opportunity to stop to view the general landscape (to the right). Trees form an integral part of the land surface. Population per Km^2 will be around 300-400 persons (note the many dwellings). Trees are being used in hedgerows, for shade and environmental benefits, in fuelwood lots, and there are also some timber trees, including a few indigenous species remaining from the forest. In general, farm size is smaller here (about 3-5 hectares?) than on the return route we shall take.

where large tea estates, dairy farms and coffee estates will be seen.

Apart from introduced species, mainly used for fuelwood or timber (e.g. Cupressus, Pinus, Grevillea etc.) Two of the 9 species of indigenous Croton are common here. Croton macrostachys (from 650 - 2200m) and C. megalocarpus a large tree, similarly widespread, which can be dominant in the upper-storey in places.

Leaving this place we continue up. Occasional fruit trees to be seen in farms are mangoes and guavas, but it is too high to grow papaya successfully here. Further up we shall see pears, peaches and plums. Note various types of hedgerows. Several species are used, always ones easily propagated. Cupressus lusitanica again (frequently some plants are allowed to grow tall and all the lower branches are lopped for fuel). Kai apple (Aberia caffra), Croton spp. Buddleia polystachya, Crassocephalum mannii (this is commonly used as "toilet paper"). Cassia siamea is sometimes grown in hedges and cut for poles.

You will see maize (usually maize/beans intercropped) right up to the highest altitude, even though it grows very short and takes a long time to mature.

STOP 4 (Above Rosslyn School) At this altitude the landuse is beginning to change to dairying and fuelwood lots. Note the large number of trees of different species left among the grazing land (RH) But further up these good pastures are being turned-in for cultivating crops (LH). Black Wattle (Acacia mearnsii) can be seen planted in wood-lots (also grown for its bark), but in many places it has seeded and spread to waste patches. Note relatively large plantation of pears to the left (middle distance).

To the right hand side of the road we pass a large tea plantation (looking rather patchy), unshaded but with *Hakea saligna* used as a windbreak.

We then proceed right along a road into Limuru town. Immediately on the left after the turn is a wattle plantation.

We proceed through Limuru and take a new tarmac road past Uplands. On this route we shall see various examples of plantation forestry on the Lari Escarpment. The original land-use in this region up to the early '60s involved clearcutting the indigenous montane forest and replacement with fast-growing exotic tree species (mainly *Cupressus lusitanica*, *Pinus patula*, *P. radiata* and *Eucalyptus saligna*) in large plantations on government-owned land. Since the mid '60s much of this forest has been excised for human settlements either on an individual basis or as co-operatives.

You will see on your way a 15-year old *Cupressus lusitanica* plantation marked for thinning. You will also see the performance of *Eucalyptus paniculata* on a flat water-logged site.

STOP 5 We stop at the "look-out-point" to discuss the plantations. Also there is a fine view over the Rift Valley and the sharp gradation in rainfall to the semi-arid plains is obvious - with consequent changes in vegetation. What prospects are there for agroforestry in the drier parts below us?

Trees obviously play an important role in most areas that we have seen on this route. Are they always the most productive and/or the best suited species however? In many cases the land-user seems to have given some thought to tree/shrub arrangement - but are these optimal?

The return route will be through a similar transect but illustrating larger farm sizes. Note the well-grown tea (RH) with the original "shade" trees (Grevillea robusta) ring-barked and killed. Other tea plantations can be seen (far left). Further down the hill we pass through Arabica coffee plantations - shaded here - and then back into the banana/maize zone. And so to return to Nairobi - Note that there are some large plots of land adjacent to the road here, with well kept hedges and decorative trees/shrubs, this being an area which was well-settled in the past with some large houses close to the road.

The final entry into Nairobi is back through the Karura Forest again.

Dr. Peter Huxley
I.C.R.A.F.

Dr. F. Owino
NAIROBI UNIVERSITY

APRIL 1981

2.3 SUPPLEMENTARY MATERIALS

- PROJECT PROPOSAL FOR AGROFORESTRY SYSTEMS INVENTORY
  (P.K. NAIR)
- GLOBAL INVENTORY OF AGROFORESTRY SYSTEMS: DATA COLLECTION GUIDELINES
- ICRAF FIELD STATION
  (P.K. NAIR)
- THE ENVIRONMENTAL BASIS OF AGROFORESTRY
  (ANTHONY YOUNG)
- THE ROLE OF WOODY PERENNIALS IN ANIMAL AGROFORESTRY
  (FILEMON TORRES)
- THE USE OF ECONOMICS IN AGROFORESTRY
  (DIRK HOEKSTRA)
- LAYOUT OF ON-STATION AGROFORESTRY TRIALS
  (DENNIS WAMBUGU)
- A MULTIPURPOSE TREE DATABASE
- ICRAF'S PROGRAMME ON AGROFORESTRY TECHNOLOGY
- THE TREE/CROP INTERFACE

INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY (ICRAF)

PROJECT PROPOSAL FOR AGROFORESTRY SYSTEMS INVENTORY

Part of the Project Document submitted by ICRAF in August 1982 to the US Agency for International Development (USAID) for funding

(with updating as of November 1982)

Project leader: P.K.R. Nair

AGROFORESTRY SYSTEMS INVENTORY

1. Justification

Agroforestry is one of the oldest and widely practised land use systems, yet it is one of the scientifically least-studied ones. Therefore its potentials have little been realized: the system is operating far below its potential efficiency where it is currently practised, and it is not extended to other potentially desirable and feasible situations. In order to overcome these drawbacks, innovations have to be brought about in the traditional agroforestry systems. Such innovations are possible mainly through transformation and refinement of existing agroforestry land use systems, in order to make them more productive (of the basic needs) and protective (of the environment). The basic requirement in this process, therefore, is a knowledge of the existing agroforestry systems.

It is well recognized that agroforestry systems abound around the world. However, the information on such systems is limited mainly to descriptive and qualitative accounts. There is very little quatitative information on the structure and functioning of most of the systems. But such data are basic and essential for all activities aimed at improvements of the systems and also to extrapolate such systems to other potentially suitable locations.

It is only logical that ICRAF, the international agency with a mandate to promote and catalyze research for agroforestry development on a global scale, ventures to gather such information. Realizing the importance of the activity, ICRAF's Board of Trustees had identified this as a priority program for the Council right at its very inception.

2. Goal and Purpose

i) to assemble and catalogue the information on the functioning of

different agroforestry systems around the world;

ii) to evaluate the information scientifically in order to identify the weaknesses and constraints of the systems, as well as their potential for improvement and wider applicability;

iii) to identify research topics to overcome the constraints and improve the systems;

iv) to disseminate as much quantitative and descriptive information as possible on world-wide agroforestry practices for the eventual use of researchers and development workers; and

v) to establish an agroforestry systems register and data bank to record and update global statistics on trends in agroforestry.

3. Method

The project will consist of three major activities, viz., collection of all possible information, their evaluation, and their synthesis with input of scientific data from other sources, keeping in mind that the objective of the exercise is to have a comprehensive description of the existing systems rather than in-depth studies on any particular systems. Emphasis will also be given on the evolution and history of the system, i.e. changes with time, failures and breakdown of systems, effects of population pressure and fuelwood shortages on such systems, etc.

Collection

This is the primary and most elaborate task. This will be tackled by:

i) developing an operational framework - a checklist and other inventory data sheet - for collecting the data and recording the data according to this format;

ii) undertaking a region-wide situation review through mail survey, literature search and on-the-spot visits to fields and institutions

by competent individuals who are knowledgeable about local and regional agroforestry practices;

iii) conducting literature search to identify, assemble, and catalogue as much documentary materials as possible on such systems.

Evaluation

Evaluation of the data that are so obtained will be done to highlight the distinguishing characteristics and merits of the systems, diagnose their inherent weaknesses and operational constraints, and thus indicate methods for "repairing"/refining them. A primary evaluation could be done even while collecting the data. The services of an expert consultant for data collection and evaluation will be obtained.

Synthesis

The information that emanates from evaluation will be pooled together for each major geographical/ecological region. The systems from similar ecological regions are expected to be biologically similar, though sociologically not. An appraisal of such similarities and dissimilarities will not only indicate research priorities but also reveal the possibilities of adopting alternate approaches that are of proven value in similar situations elsewhere.

4. Output

An agroforestry Data Bank: a comprehensive compilation on agroforestry systems, their distribution, basic characteristics, functional weaknesses, operational constraints, possible ways of improving them, and sources of information. The Data Bank will also facilitate subsequent up-dating of global statistics on trends in agroforestry.

An Agroforestry Systems Register containing detailed and descriptive information on the catalogued systems, similarities and dissimilarities

of systems under identified ecological situations, and literature extracts and documentary materials resulting from mail and field survey activities; various publications will be brought out to disseminate the information so gathered.

Identification of potential methods to improve the systems, research needs and scope and approach for further investigations; this could lead to specific collaborative research/development projects in the future.

Indications on some specific technology components for further testing and evaluation at ICRAF's Field Station, Machakos and elsewhere.

5. Implementation Plan

Regions

Although the scope of the study is world-wide, it will, naturally, be confined to the developing countries where land use systems similar to agroforestry are practised. Moreover, the study will have to be limited to countries whose political systems permit free access to study personnel. Since the study area extends throughout the developing countries, it is necessary to have functional units. There could be two ways to establish such units: geographical and ecological. Although ecological grouping has some advantages, it will pose practical problems of great magnitude. Therefore the primary grouping has to be based on geographical considerations; within each geographical region, there could be ecological subdivisions.

The primary geographical regions are designated as follows in accordance with the grouping that has been adopted for ICRAF's Collaborative and Special Projects Programme

1. Southeast Asia
2. South Asia

3. Mediterranean

4. Sub-Saharan Africa

- East and Central Africa

- West Africa

5. American Tropics

Under each of these geographical regions, there will be:

a) ecological sub-divisions (humid lowland, arid and semi-arid, highlands); and

b) socio-economic stratification.

Personnel

The project will be based in Nairobi and coordinated by the project leader Dr. P.K.R. Nair, who is an ICRAF senior scientist (core staff). He will be assisted by consultant regional coordinators one each for each geographical region. The following individuals have been identified as regional co-ordinators:

SE Asia	-	Dr. J.C. Madamba Director, SEARCA, Los Banos, College, Laguna 3720, Philippines
South Asia	-	Dr. K.G. Tejwani Land Use Consultants (International) 25/31 Old Rajinder Nagar New Delhi 110 060 India
Mediterranean & The Middle East	-	Dr. M. Baumer Clos des trois pins 446 Combe caude F 34100, Montpellier, France
East and Central Africa & Humid West Africa	-	Dr. A. Getahun Energy/Development International P.O. Box 6[illegible] Nairobi, Kenya
Semi-arid and Arid West Africa		Prof. H.J. von Maydell World Forestry Institute Leuchnerstr. 91 2050 Hamburg 81 West Germany

American Tropics - Dr. C. Budowski
Head, RNR Program
CATIE
Turrialba, Costa Rica

In addition, a consultant has been identified to advise on data collection and evaluation procedure. He is: Prof. C.R.W. Spedding, Faculty of Agriculture and Horticulture, University of Reading, U.K.

The regional co-ordinators will organize the work utilizing their institutional/personal contacts within the region. Depending on the individual situations, the honoraria and fees for the regional co-ordinators will be given individually to the person concerned, or to the institution with which they are attached. Any specific work and names of persons, about which ICRAF comes to know concerning a region, will be brought to the attention of the respective regional co-ordinator.

The project leader, with the active support of other ICRAF staff and the regional co-ordinators will enlist the cooperation of individuals with extensive regional or national knowledge on agroforestry systems and liaise with relevant institutions having considerable field experience on land use systems (e.g. FAO, UNESCO's MAB program, etc.).

At the project headquarters in Kitale, a documentalist will handle the mail survey and literature search. Support staff will be recruited locally for secretarial, data analysis and other necessary assistance.

6. Schedule

6.1. Planning Phase

- identifying the regions/regional coordinators,
- suggesting a general classification of the agroforestry systems,
- developing a checklist and operational framework for collection of data;

- organizing a planning workshop of regional coordinators and ICRAF staff to discuss the operational framework and decide the regional action plan.

6.2. Survey/Data Collection Phase

- the regional coordinators travel to the respective regions and collect the data from all available sources and compile the information as envisaged;
- detailed case studies of specific systems within a region, as deemed necessary;
- the coordinator/other HQ staff travel to the regions for field-work and on-the-spot studies;
- literature review and mail survey continue from the HQ.

6.3. Evaluation Phase

The coordinator, the ICRAF staff, regional coordinators and consultants assemble at the headquarters for a mid-project appraisal, when progress to-date will be evaluated and further course of action decided. Methods of data evaluation will also be decided, following which the regional coordinators will undertake to evaluate the data, keeping in mind the objectives of the exercise. The document files (Systems Register and Data Bank) will be built up for each geographical region and/or ecological sub-divisions.

6.4. Final Compilation and Publication

This will be handled by the coordinator and the documentalist at the headquarters, the details could be decided in course of time in consultation with ICRAF staff and the regional coordinators.

6.5. Time Frame

Phase/Activity	Initiation	Duration
1. Planning (Regional coordinators' Workshop in Nairobi)	October 1982	Three months
2. Data collection	January 1983	One year
3. Evaluation (Mid-project appraisal Workshop in Nairobi)	January 1984 Jan-Feb 1984	Six months
4. Final compilation	July 1984	Ten months
5. Publication	To be ready by mid-1985	

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

GLOBAL INVENTORY OF AGROFORESTRY SYSTEMS

DATA COLLECTION GUIDELINES

I. GENERAL CONSIDERATIONS ON DATA COLLECTION

1. The scope of the exercise is to have a reconaissance, state-of-the-art, description of the existing agroforestry systems around the world. The data collection has, therefore, to be organized to fulfill this objective.

2. It is expected that professionals at various levels will be involved in the data collection exercise. But it is important that the surveyors have a reasonably acceptable level of understanding of the concepts and practices of land use systems in general and agroforestry in particular.

3. A definition of agroforestry that can be used for the purpose of data collection is: "Agroforestry is a collective name for land use systems in which woody perennials are deliberately grown on the same piece of land as agricultural crops and/or animals, either in some form of spatial arrangements or in sequence. In agroforestry systems, the woody component interacts ecologically and economically with the crop and/or animal components. Such interactions will take many different forms, both positive and negative, and they need not remain stable over time.

   The aim and rationale of most agroforestry systems are to optimize the positive interactions in order to obtain a higher total, a more diversified and/or a more sustainable production from the available resources than is possible with other forms of land use under prevailing ecological, technological and socio-economic conditions."

   The underlying principles and concepts of agroforestry rather than a definition per se should be the main consideration. Thus, a general criterion could be that any multiple land use system, in which woody

perennials constitute one of the discernible components by performing a clearly distinguishable function can be considered agroforestry for the purpose of this project. Here again, it is up to the technical discretion of the individuals who collect the data to set the limits and criteria to decide which of the practices can be included in this project.

4. The enclosed data collection format provides a general framework for the survey. It consists of three parts: the first one is intended to assemble general description of the area and other background information that are relevant to a description of dominant "agroforestry" systems and practices; the second deals with describing the structure, performance, dynamics, socio-economics and other operational features of the identified systems and practices in as much detail as possible with emphasis on quantitative data; and the third part aims at an analysis of the system in terms of its merits, constraints, weaknesses, extrapolability, potentials for improvements, research needs, etc. However, since the type of information to be gathered and the nature of questions to be addressed to accomplish the task will vary depending upon a number of local factors, the surveyors are free to deviate from the format as deemed necessary. The questionnaire may be considered as a purely explanatory guide to prepare an account of the system/practice that is being described.

5. The data collection format may appear to be rather exhaustive, and it may not be possible to get answers, especially in quantitative terms, to all questions that are posed. However, answers to all points may not be necessary to prepare an overview of the system.

6. A flexible procedure may be adopted also for classifying the systems. Several criteria could be used, for example: the role or function of woody perennials in such systems, proportion of land used by the woody components, type of output, level of management, temporal and spatial admixture pattern of components, etc. But the lack of a unified classification system should not be a major problem in the early data collection phase, and the strategy should be to collect all possible information on all types of agroforestry systems and practices that are currently being practised or tried.

7. The size of the basic data collection unit is yet another issue to be considered, if not resolved. Since the project's objective is to collect a comprehensive account of the systems, rather than aiming at in-depth studies or farm-to-farm surveys on any particular system or sub-system, it can be contended that the basic unit should be broad enough to substantiate the prevalence of the practice over a reasonable extent of area. Moreover, the boundaries of the system will also vary depending upon the question that is being addressed. For example, for the general description of the background information, the boundary will be the whole locality or area where the system is practised. On the other hand, for answering specific questions relating to an operational unit, the boundaries will refer to those of the farm or the field that constitutes such a basic unit. Again, the prudence and discretion of the persons who collect the data will be the major decisive factors in this respect.

8. The purpose of system descriptions is not necessarily to compare one system with another. Therefore the approach should be to give physical and quantitative data (to the extent possible) than to engage in comparative narrations.

II. DATA COLLECTION FORMAT

Part I

BACKGROUND INFORMATION

This refers to a locality or sub-region where agroforestry-type land use systems and practices are known to exist. A general account of the location may be given on the following aspects with a view to concentrating on agroforestry systems/practices and describing them in more detail as outlined in the later sections.

1.1. DESCRIPTION OF THE AREA/REGION

1.1.1. Geographic

Country

Province

District/Location

Altitude

Latitude(s)

Longitude(s)

Other description

1.1.2. Biophysical environment

1.1.2.1. Climatic

Rainfall pattern (intensity, quantity, distribution, etc.)

Temperature regimes

Other distinct climatic features

1.1.2.2. Edaphic

Soil types

Topographic patterns

1.1.2.3. Ecology

Climax vegetation

Distinct ecological features

1.2. LAND USE SYSTEMS

(Give general but brief descriptions of the major land use systems of the locality)

1.2.1. Agriculture

General situation (subsistence/commercial)

Major crops

Cropping systems

Livestock production system

1.2.2. Forestry

Natural forests

Plantation forestry

Social forestry

Farm forestry

1.2.3. Commercial Production Systems

1.2.4. Integrated Production Systems

1.3. AGROFORESTRY-TYPE SYSTEMS/PRACTICES

Give brief and general account of the currently practised land use systems and practices that have relevance to agroforestry; detailed description of the systems to be given in later sections.

Shifting cultivation

Taungya

Farm forestry

Smallholder plantation crop production systems

Tree integration on farmlands

Silvopastoral

Shelterbelts

Others

Part II

SYSTEM DESCRIPTION

This part may be completed separately for each of the major identified agroforestry-type landuse system/practice within each locality/sub-region.

NAME: Give an abstract or descriptive name of the system/practice.

2.1. ADDITIONAL BASELINE DATA

2.1.1. Environment

- Agro-ecological zone
- Special conditions of soil, topography, climate, etc. that facilitate or compel the land users to practice agroforestry
- Hydrological features
  (including seasonal waterlogging, watershed characteristics, etc.)
- Other distinguishing physical, environmental or ecological aspects by the influence of which the system/practice stands out in relation to other land use systems and practices in the locality.

2.1.2. Socio-Economic Characteristics

- Size of the management unit (range as well as mean)
- Area and number of people involved in/supported by the system/practice
- Land tenure system
- Demographic factors
  population density, land pressure (number of people or families per unit of cultivable land), migration patterns, sex ratio, etc.
- General level of farming/development activities
- Marketing facilities (Excellent/Good/Fair/Poor)
- Credit facilities (Excellent/Good/Fair/Poor)

- Roads and other infrastructure (remoteness of the area) (Excellent/Good/Fair/Poor)
- Cooperatives (Excellent/Good/Fair/Poor)
- Other special socio-economic features, if any

2.2. STRUCTURE OF THE SYSTEM

(This will essentially refer to the basic (representative) agroforestry unit - a farm or a field)

2.2.1. Biological Components of the System

2.2.1.1. Crops

- Species
- Varieties
- Their management aspects
- Number of crops per year
- Cropping pattern/rotation/mixture

2.2.1.2. Trees and other woody perennials

- Species, varieties
- Products
- Tree management
- Average life cycle of the tree as well as its production cycle within years/seasons.

2.2.1.3. Other plant species (including weeds) that are dominant or have a useful function.

2.2.1.4. Animals

- Type and role
- Number per farm/family
- Feeding pattern
- Other details

2.2.2. Arrangements of Components

in time)
) describe with the example of a farm/field
in space)

- Number of components per farm of average size
- Specific admixture pattern especially between trees and crops
- Management considerations in arrangement of components

2.2.3. Interactions

in time

in space

- Nature of interactions

  e.g. - direct (fodder trees for cattle)
  - cyclic (crop residues for cattle)
  - competitive (crops vs trees)
  - others

- Magnitude of interactions
- Easily recognizable interaction effects

2.3. SYSTEM FUNCTIONING

2.3.1. Resource Input and Utilization

2.3.1.1. Quantity

- Give a general account of the resources (land, labour, capital (?) and others) that are used - their nature, quantity, utilization aspects with respect to time within a year/seasons, etc.

2.3.1.2. Pattern

- Availability and supply pattern

- Bottlenecks in timely availability
- Effect of uneven availability (excess/shortage) on the functioning of the system

2.3.1.2. Sources of Inputs

- Source of seeds, fertilizers, etc.
- Inputs from outside the system (e.g. seeds, fertilizer, animals)
- Price data of inputs and source of information
- Power sources (animals/mechanical (tractor)

2.3.2. Production

2.3.2.1. Quantity

(quantities on the basis of average farm of given size)

- Agricultural commodities
- Fodder and other feeds for cattle
- Fuelwood (firewood/charcoal)
- Poles
- Timber
- Honey
- etc.

2.3.2.2. Pattern

- Seasonality of production
- Variability (season-to-season/year-to-year) of production
- Efficiency of production (input-output relationships for the scarcest resource?)
- Production for home consumption versus market economy (export)

2.3.3. Protective and Service Aspects of the System

- Soil management considerations

- Soil improvement (specific)
- Soil productivity maintenance (specific)
- Soil conservation (specific)
- Microclimate amelioration
    - windbreak/shelterbelt
    - shade
    - etc.
- Fencing
- Hydrological cycle/catchment area effect
- Other recognizable effects on farm/area basis
- How effective is the system in its protective/service function (qualitative assessment at this stage)

2.3.4. Socio-Economic Description

Obtain specific socio-economic data as much as possible on the basis of an average farm on a yearly basis wherever possible:

- Capital peaks/availability
- Labour peaks/availability
- Cash-flow (input/output)
- Family labour utilization pattern (male/female)
- Impact of technological inputs (improved seeds, fertili. rs, etc.)
- Special note on the specific type of land use practices adopted by women
- Relations between specific ethnic groups and particular agro-forestry practices

2.3.5. Overall Performance Assessment

At this stage, a comparative asssement may be made of the functioning of the particular system in relation to other land

use systems of the locality in terms of the production and protective/service role(s). It will be of particular significance to see what would be the condition of the management unit without the agroforestry component (which would be possible by comparison with similar units without agroforestry).

2.4. SYSTEM DYNAMICS

2.4.1. Rate of Growth/Shrinkage

Indicate the expansion/shrinkage of the system over time in terms of the area covered.

Reason for shrinkage (decline)/growth

- Demographic factors
- Technological advances
- Urbanization
- Social factors
- Other factors

2.4.2. Degradation of the System

- Case-history of the breakdown
- Main causal factors
  - Erosion problem
  - Soil fertility problem
  - Weed infestation
  - Overgrazing/desertification
  - Others

2.4.3. Improvement of the System

- Significant innovations for improvement of the system over the past few years

- Impact of modern technology
- Role of extension agencies
- Other organized governmental or such other assistance

2.4.4. System Sustainability

- Productivity pattern over time
- Impact of technological inputs on productivity
- Rate of change of land's capability to sustain production at a certain level
- Effect of the rate of production of one component on that of other component(s)
- Major determinant factors, the manipulation of which can affect the efficiency of the overall system.

2.4.5. Special Features of the System

- Highlight any outstanding features of the system/practice (e.g. specific management aspects that can cause reduction on inputs, association of particular ethnic groups/races with a system, notable success stories, etc.
- Indicate special aspects of the system/practice that warrant detailed follow-up study.

2.4.6. Data/Information Base

- Highlight any past/present/future research on the system/practice
- References to documents and other information sources on the system/practice
- List of institutions and resource persons or relevance to system
- Other information/data of significance

Part III

EVALUATION OF THE SYSTEM

Based on the information gathered thus far, a preliminary evaluation of the system could be attempted.

3.1. MERITS OF THE SYSTEM

Conspicuous advantages of the system in its productive and/or protective functions. Give comparative figures if available.

Indicate the value of the system in the specific socio-economic and ecological situations where it is currently practised.

3.2. WEAKNESSES

What are the salient points of weaknesses

- Climatic
- Ecological
- Biological
- Socio-economic
- Managerial
- Socio-political

What effect does each of these have on the system's performance

3.3. CONSTRAINTS

What are the major constraints in the operation of the system

- Inherent weaknesses mentioned above
- Input constraints
- Infrastructural problems including markets, roads, etc.
- etc.

3.4. POTENTIALS

Reasonable expectations on potential accomplishment under different

levels of input, ecological constraints, etc.

Potentials of non-monetary inputs (timely sowing, appropriate management system, judicious plant combinations, etc.)

Potentials for improvement in the performance of the system

Potentials for manipulating the system/components to solve specific problems and meet particular needs such as soil conservation, food production, silvopastoral production, etc.

3.5. EXTRAPOLABILITY

What is the extrapolobility rating of the system if it were to be tried in other areas with similar/dissimilar conditions, and what will be the degree of success under each?

What aspects of the system needs to be modified to make it widely extrapolable?

3.6. RESEARCH NEEDS

Indicate the general areas of research at the system and the component levels in order to refine the system to make it more productive, protective, widely adoptable and efficient.

SECTION 3 - A DIAGNOSTIC APPROACH TO THE DESIGN OF AGROFORESTRY SYSTEMS

3.1 MAIN NOTES

- Guidelines for Agroforestry Diagnosis and Design
- Resources for Agroforestry Diagnosis and Design

DIAGNOSTIC AND DESIGN METHODOLOGY MANUAL SERIES NO. 1

W O R K I N G P A P E R

N O.

6

GUIDELINES FOR AGROFORESTRY DIAGNOSIS AND DESIGN

DRAFT FOR COMMENT

AN INTRODUCTION TO THE ICRAF METHODOLOGY

INTERNATIONAL COUNCIL FOR RESEARCH IN AGROFORESTRY

November 1983

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ACKNOWLEDGEMENTS

The development of a Diagnostic and Design Methodology for agroforestry has been the subject of concerted effort at ICRAF for over two years. It began with the identification of the need in agroforestry for a quick and reliable means of identifying research and development priorities and with the adoption of a systems approach to agroforestry as one of the cornerstone's of ICRAF's institutional strategy (Steppler, 1981). It has continued in a prominent place in ICRAF's Programme of Work, as developed by ICRAF's Director, Dr. Bjorn Lundgren, and his staff.

The basic framework of the D&D approach was developed and tested by J.B. Raintree, Diagnostic and Design Methodology Project Leader and Systems Programme Coordinator, and Filemon Torres, Collaborative and Special Projects Programme Coordinator. Dirk Hoekstra, Dianne Rocheleau and Anthony Young contributed substantially to the further testing and elaboration of the methodology. The methodology is interdisciplinary in its development as well as its application. To date, the following ICRAF staff members, representing the disciplines indicated, have contributed in one form or another to the development, field testing or review of the D&D Methodology:

Peter G. von Carlowitz	Forester
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Filemon Torres	Range Management/Livestock Scientist
Anthony Young	Land Evaluation/Soil Scientist
Ester Zulberti	Education and Training Officer

Renko B. Vonk of Wageningen University, Louise E. Buck and Edward Alitsi of the Mazingira Institute, and Patrick J. Robinson of the Commonwealth Forestry Institute also contributed to the early development and testing of the methodology. ICRAF is also grateful to Cor Veer, Michael Collinson, Hubert Zanstra, Robert Chambers and Michael Stocking for comments on earlier drafts and working papers. Thanks are also due to Stella Muasya and Fredric Gitau for their tireless effort in the typing and production of the manuscript.

This draft of the *Guidelines* was written by J.B. Raintree and Anthony Young.

ABSTRACT

ICRAF has undertaken to develop an interdisciplinary Diagnostic and Design methodology for agroforestry, to assist agroforestry workers in identifying priorities for technology-generating research, based on designs for appropriate agroforestry technologies derived from a diagnosis of the needs and potentials of land use systems. After initial development and testing of the D&D methodology in more than twenty sites around the world over the past two years, ICRAF has produced these draft *Guidelines for Agroforestry Diagnosis and Design* and a companion volume entitled *Resources for Agroforestry Diagnosis and Design*. They are being published in working paper form in order to facilitate early dissemination and wider field testing of the evolving methodology and to elicit comments and suggestions for improvements to be incorporated into subsequent editions.

The present document provides an introduction to the Diagnostic and Design methodology, covering the logical framework of the methodology, an outline and description of the step-by-step procedures, a discussion of manpower requirements, the scale and timing of D&D activities, institutional considerations, etc. Although the emphasis is on the use of the D&D methodology at the formulation stage of agroforestry projects, the role of the continuing diagnosis and design process as part of the project's 'internal guidance system' is also discussed. For more detailed procedural guidelines and a variety of useful tools and materials, the reader is referred to the companion document.

HOW TO USE THESE GUIDELINES

Although this document is intended to possess a stand-alone capability as a source of basic guidelines for the diagnosis of land use problems and potentials and the design of appropriate agroforestry systems, it is also intended to be used in conjunction with the companion volume, *Resources for Agroforestry Diagnosis and Design* (ICRAF, 1983) and other methodological publications from ICRAF (e.g. Young, 1983; Hoekstra, 1983; Huxley, in press).

The *Guidelines* present an introduction to ICRAF's Diagnosis and Design Methodology, which outlines the logical framework of the D&D approach and presents the step-by-step procedures in minimal but sufficient detail for users who wish to make use of the basic framework while filling in the details themselves. The *Resources* contain a more detailed set of suggested guidelines and worksheets, along with a compendium of useful tools and materials, to aid in carrying out the procedures outlined in the *Guidelines*.

The D&D Methodology has been designed to fit a wide range of applications and must, therefore, be tailored to the resources and requirements of specific institutional settings and types of applications. While the basic methodological framework outlined in the *Guidelines* is quite generally applicable across a broad range of circumstances, not all of the considerations and procedures contained in the *Resources* will be applicable to every situation. The user must pick and choose and, in the final analysis, assemble his own adapted set of detailed procedures. For an overview of the D&D approach and a sense of what minimally should be included in an application of the methodology, the user should consult the present *Guidelines*. For more detailed suggestions on how to carry out specific procedures, and for access to a variety of diagnostic and design tools and resource materials, the user is referred to the *Resources*. The two-volume format has been chosen as a means of facilitating ease and flexibility in the use of the D&D Methodology.

It should also be emphasised that this is an *evolving methodology*. The present set of documents have been published in Working Paper form in order to obtain comments and suggestions for improvements of the methodology to be incorporated into future editions in the D&D Manual Series. Suggestions arising from actual applications of the methodology in the field will, obviously, carry greater weight in subsequent revisions than those resulting from a mere reading of these documents, but all manner of critical review and comment is welcome.

The present documents concentrate primarily on the use of diagnostic and design procedures at the formulation stage of agroforestry projects. To develop sound technologies to fulfill the diagnosed agroforestry potentials, however, will require a sensitive approach to project guidance which could benefit from an extension of the basic D&D process into the implementation stage of agroforestry research and development projects. This will be the subject of methodology development efforts for future manuals, and specific suggestions from project implementers on how to accomplish such an extension of the D&D process will also be most welcome.

Finally, the ultimate objective of using the diagnostic and design process to advance the science and practice of agroforestry in the field can only be accomplished through knowledge arising from a large number of applications in a wide range of different physical and socioeconomic environments around the world. To facilitate the documentation and dissemination of D&D results ICRAF has initiated a publication series on *Case Studies in Agroforestry Diagnosis and Design*. Case study reports will be available from ICRAF on request, and users of the methodology are encouraged to submit

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1. GENERAL INTRODUCTION

1.1 OBJECTIVES OF THE METHODOLOGY

The aim of ICRAF's Diagnostic and Design (D&D) methodology is to assist in the design of appropriate agroforestry systems, as a conceptual basis for the identification of research needs and the formulation of agroforestry research and development projects. The methodology is directed toward meeting the needs, solving the problems, or realizing the potentials of specific land use systems. The procedures described in these guidelines lead to the design of one or more agroforestry technologies which appear to have the potential to effect realistic improvements in the target land use system. The resulting 'design concepts' may then serve as the basis for planning a research programme to develop the identified agroforestry technologies through a combination of on-site and on-station research.

Although the logic of the D&D methodology is applicable to a wider range of technical options, and while non-agroforestry alternatives are given due consideration in the course of the D&D process, the methodology has been designed to focus on a systematic consideration of agroforestry-related aspects of existing land use systems, i.e. not to miss, through lack of appropriate analytical techniques, any significant agroforestry potentials which may be inherent in the land use system.

A problem-oriented or diagnostic approach is adopted as a logical route to the goal of good agroforestry design and the basic methodological guidelines have been adapted to the need for an efficient 'rapid appraisal' approach (Chambers, 1981) to project formulation. The methodology incorporates elements of the Farming Systems Research (FSR) approach (Collinson, 1981; Hildebrand, 1981; Zamora *et al.*, 1981; Shaner *et al.*, 1982) but goes beyond the content of existing FSR methodologies in order to address the broader range of production and conservation roles which can potentially be played by agroforestry. Although a major emphasis is placed on the household management unit as, in most cases, the basic decision-making unit vis-a-vis land use, the methodology employs a sliding scale of analysis ranging from intra-household processes to the local community, regional and national levels of socioeconomic and ecosystem organization.

While the focus of the present guidelines is on the use of the D&D methodology at the formulation stage of agroforestry projects, a continuing role for the basic D&D process is envisaged throughout the life of a project as part of its 'internal guidance system.'

1.2 AGROFORESTRY DEFINED

Agroforestry is a collective term for systems of land use in which woody plants (trees and shrubs) 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. For a land use system to fall within the concept of agroforestry, there should be both ecological and economic interactions between the woody plants and other components of the system (Lundgren, 1982).

Agroforestry may involve the integration of trees into farming systems or crops and livestock into forests. In practice, a high proportion of agroforestry systems involve the growing of trees on what is primarily agricultural land. Crop or livestock production on land devoted primarily

to forestry is less common but also within the scope of agroforestry. To avoid frequent qualifications, the terminology used here and in the companion document (ICRAF, 1983) is phrased primarily in terms of agroforestry applications in farming systems, but the methodology is also applicable to the design of appropriate agroforestry systems for forest reserves (see the companion document for specific guidelines on forestry applications). Similarly, the term "farmers" is employed, for brevity, to include all actual or potential categories of land manager, including pastoralists and foresters.

1.3 THE DIAGNOSTIC APPROACH

One of the major principles underlying the Diagnostic and Design methodology is derived from an analogy with medicine i.e. that *diagnosis should precede treatment*. In the first instance, this means simply that research oriented toward the development of new land management technologies should be relevant to the actual needs and potentials of land use systems. It is no use developing a technology which works beautifully on the research station if there are reasons why it cannot be taken up by a significant proportion of the intended users. Rather than leaving such aspects to chance, or to a later 'evaluation' stage in the project cycle, the diagnostic procedures are intended to insure that the research undertaken is oriented in the right direction from the start so that the technology to be developed will be relevant to the needs of the area.

The analogy with medicine entails the further implication that priority should be given to the development of *problem solving* agroforestry technologies. While it is true that agroforestry holds promise for achieving a wide range of land use potentials, it seems obvious that the priority claim on the use of scarce research and development resources lies in developing agroforestry's potential to provide urgently needed solutions to pressing problems of failing production systems and degradation of the resource base of future generations. As in medical practice, the principle of *triage* applies.

Furthermore, there is little use in conducting sophisticated research to realise some ideal conception of the biological potential of a land use system as long as the system in question is suffering from crippling problems which prevent it from achieving those potentials. By analogy, there is no use in trying to make an athelete out of someone suffering from a chronic debility. The debility must first be removed before the patient can go on to realize his atheletic potentials. The 'patient' in D&D perspective is the existing land use system and a diagnostic approach is a direct and logical route to the realization of system potentials through the identification and removal of system constraints.

While the medical analogy may help in defining standards for agroforestry practice, the situation in agroforestry departs from that of medicine in at least one very important aspect: in agroforestry the methods of 'treatment' have frequently not yet been developed or scientifically proven. In the present early stage of the scientific development of agroforestry there are few 'off the shelf' solutions. Hence, the need for research before widespread extension of agroforestry technology. Hence, also, the need for a reliable and efficient methodology for identifying priorities for cost-effective research based on sound agroforestry designs.

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1.4 CRITERIA OF AGROFORESTRY DESIGN

There is no substitute for good design. The criteria of good agroforestry design are threefold: *productivity*, *sustainability* and *adoptability*. The improvement of productivity, or output from the land, is almost everywhere required, by governments as well as by farmers themselves and needs no further discussion here. The 'sustainability' criterion is an attempt to operationalize the conservation objectives of agroforestry in terms of the farmer's production objectives. In most cases it means that production aims should be achieved without degradation of the land resources. Where degradation has already occured, agroforestry technologies may seek to reverse the process and place the production system on a sustained-yield basis.

The 'adoptability' criterion means that the techniques and systems proposed for development should be capable of adoption by a significant percentage of the intended users. This implies, for example, that the technologies must not call upon resources which the farmers are not likely to possess (e.g. excessive capital, machinery or labour requirements) nor be incompatible with unchangable features of the existing land use system, nor require forms of management the farmers are unable or unwilling to adopt (e.g. keeping livestock off pastures for prolonged periods). In recognizing adoptability as a design criterion on an equal footing with productivity and sustainability, the agroforestry designer accepts the challenge of addressing the social as well as the physical dimensions of land use systems. The D&D methodology is intended to provide assistance in carrying out this more demanding, and yet potentially far more successful, approach to design.

1.5 RAPID APPRAISAL AND MULTIDISCIPLINARITY

Although the D&D procedures are adaptable to a range of different needs and applications, the basic guidelines are designed to allow the use of rapid appraisal methods by a highly qualified multidisciplinary team. A rapid appraisal approach is adopted for practical reasons: the planning of research and development projects is usually subject to constraints on the cost and availability of skilled manpower which often severely limit the time available for survey and research planning activities. This is particularly true in the case of agroforestry, where the broad scope of the subject normally requires the participation of several disciplines in order to insure adequate diagnostic coverage and a broadly conceived approach to design.

1.6 MANPOWER REQUIREMENTS

Manpower requirements will vary with circumstances, but a minimal D&D team should normally include one or more representatives of each of the following disciplines: *agricultural science* (general agronomy, horticulture, and livestock sciences), *forestry* (in the broadest sense including, if relevant, individuals with a knowledge of horticultural and multipurpose trees), *social science* (sociology/anthropology, human geography and economics), and *natural sciences* concerned with land resource survey (ecology, soils science, climatology). Within these broadly defined disciplinary categories, generalists will normally be more useful as members of a D&D team than narrowly specialised individuals. It may often be possible to economize on the manpower requirements of a D&D team

by recruiting individuals who combine within themselves a working knowledge of more than one discipline (e.g. climate and soils knowledge in a land evaluation expert, natural and social sciences in a geographer or a human ecologist). Arrangements can usually be made for consultation with specialists to supplement the knowledge of the generalists when the need arises.

Whenever a technology generating research project is to be formulated on the basis of the D&D survey results, every effort should be made to involve the eventual technology developers directly in the process as members of the D&D field team in order to maximize the understanding and use of the results by the most directly relevant recipients.

1.7 THE INSTITUTIONAL SETTING

The intended users of the D&D methodology include: research scientists at national and international research institutes, land use planners and resource managers, development project implementation staff, rural development fieldworkers and non-government organizations, university researchers, and representatives of donor agencies involved in formulating projects to support agroforestry research and development activities at any of these levels. The methodology can be flexibly adapted to meet the needs and resources of these varied institutional settings.

Given the need for research in the present state of agroforestry, primary emphasis is placed on the use of the methodology in formulating research projects to develop and test needed agroforestry technology, but there is nothing to preclude the use of D&D procedures to arrive at agroforestry designs for more direct development-oriented applications, particularly if the development project incorporates a research component to support the testing and refinement of the proposed agroforestry systems.

Many client institutions wishing to make use of the D&D methodology will not possess a standing D&D survey team of the desired multidisciplinary composition. This is particularly true in the case of agroforestry, since agricultural and forestry staffs are often housed in separate institutions. Again, this need not prevent the use of the methodology since good D&D results have been obtained with ad hoc inter-institutional teams assembled for the purpose on a temporary basis. More permanent arrangements for inter-institutional cooperation may be necessary, however, to carry out a multidisciplinary research and development project in agroforestry.

The desirability of a multidisciplinary team approach, likewise, does not preclude the use of D&D procedures by clients lacking the resources to field such a team. Experience has shown that there is considerable scope for success in even single-person D&D applications, providing that the individual is adequately conversant with the relevant disciplinary perspectives and that there is opportunity for consultation with appropriate disciplinary experts in the course of the exercise. Simply attempting to follow the logic of the D&D procedure can be expected to produce some improvement in the planning of agroforestry efforts in almost any institutional setting, regardless of personnel or resource endowment.

1.8 DURATION AND TIMING OF D&D ACTIVITIES

There are two basic possibilities with respect to the duration and timing of D&D activities at the project formulation stage:

1. Rapid appraisal plus followup, or
2. Straightforward extended application

In a typical 'type 1' application of D&D procedures by a multidisciplinary team, it normally takes about two weeks to carry out the diagnostic survey, analyze the results and develop appropriate design concepts for agroforestry interventions to improve the existing land use system. This period of concentrated diagnostic and design effort is normally preceeded by a month or two of preparatory data gathering by a small prediagnostic working group and is followed by up to several months of less intense pre-project followup work, again by a smaller working group, to round out and refine the initial D&D results arrived at by the full multidisciplinary team and develop a detailed project implementation plan. This type of D&D application is designed to economize on the use of time and manpower resources and make the best use of limited time available for high level multidisciplinary collaboration.

The timing of 'type 1' applications also accords well with the normal phasing of activities in the formulation of donor-sponsored projects. The rapid appraisal D&D process corresponds to a substantial 'project identification' or a preliminary 'project formulation' type of exercise which defines the overall thrust and the framework of the project. This, then, serves as the basis for a request for proposals to formulate, in the pre-project followup phase of the D&D process, a detailed project implementation plan. If adopted by donor agency project identification teams, the D&D process in its rapid appraisal form could provide an efficient and reliable means of putting well conceived agroforestry projects out to bid. At present we can only speculate on the effect this would have on the cost-effectiveness of donor sponsored agroforestry projects, but one has reason to believe that it would be beneficial.

Although the developers of these guidelines have taken pains to insure that the suggested D&D procedures are compatible with a rapid appraisal approach (see detailed guidelines and suggested procedures in *Resources for Agroforestry Diagnosis and Design*), there is nothing to prevent the application of the D&D logic in lengthier 'type 2' exercises in cases where time and personnel resources are not constraining. In that case, rather than a 'type 1' D&D application which reaches the required depth through a two-stage process which postpones some of the more detailed and time consuming work until the followup stage, the 'type 2' application would proceed straightforwardly through the logical sequence, taking everything as it comes up in whatever detail is deemed necessary.

Thus, in 'type 2' applications it might take 6 months to a year to work through the D&D procedures, rather than 2 weeks for an initial 'type 1' application. It goes without saying that there are a whole range of intermediate possibilities as well. One variation worth mentioning is that of allowing a substantial pause in 'type 1' applications between the diagnostic and design phases in order to allow the D&D team to fully digest the design implications of the diagnosis and to informally explore notional design alternatives.

It should be pointed out, however, that even when time is 'unlimited,' there may be distinct benefits to an initial rapid appraisal application. Anyone who has ever managed a multidisciplinary research team knows how difficult it can be to reach an interdisciplinary consensus. Experience with the rapid appraisal form of the D&D methodology would suggest that the pressure of having to arrive at a definite consensus within a circumscribed time period can result in a higher degree of interdisciplinary synthesis than would otherwise be possible under less pressured conditions. Such a consensus, achieved at an early stage of the project cycle and regarded as 'provisional' and subject to revision as the project progresses, can have a beneficial impact on the quality of

interdisciplinary collaboration throughout the life of the project. Even in the rare case where an excellent base of interdisciplinary collaboration has already been established in an existing multidisciplinary team, it may still be of value to first conduct a 'type 1' exercise to obtain an overview of the essential aspects of agroforestry diagnosis and design before getting down to the more detailed work of diagnostic elaboration and design refinement.

1.9 THE SCALE OF D&D APPLICATIONS

It is often said that agroforestry technologies are 'location specific,' but it is more correct to say that agroforestry technologies are 'system specific,' if by 'system' we mean a combination of biophysical and socioeconomic factors associated with a given land management unit which make it suitable for some specific and limited set of land management technologies and not some other. It follows, then, that any process of diagnosis and design undertaken for the purpose of developing appropriate technologies must, of necessity, be a system-specific exercise for the simple reason that technologies appropriate to one system of land use may not be appropriate to another.

There is considerable latitude possible, however, in the definition of 'the system' for D&D purposes. In the companion volume to these guidelines (*Resources for Agroforestry Diagnosis and Design*) specific suggestions are made as to the application of the basic D&D logic to a sliding scale of analysis involving a nested hierarchy of systems ranging from national and regional levels, to local watersheds and communities, to household and intra-household levels of organization.

For most purposes, however, the *focal system*, which is defined as the basic departure point or 'touchstone' for all other scales of D&D analysis, will be the household, family farm, or other similar land management unit, since this is where most land management decisions are made. If other, larger or smaller, decision-making units are present in the area and relevant to the D&D exercise (e.g. forest management units), then they too must be analysed to expose their own agroforestry-related objectives, constraints and potentials. All other relevant processes which are not under the jurisdiction of decision-making systems are treated as part of the *environment* of such systems.

In saying that applications of the D&D methodology must be system-specific it does *not* mean that the methodology is only applicable to very small areas or that the D&D team cannot deal with more than one land use system in a given exercise, and it certainly does not mean that a separate D&D analysis must be conducted for each and every farm. What it does mean is that the design of specific agroforestry technologies must be linked to the diagnosed needs and potentials of specific land use systems, at whatever scale they may exist. One of the first tasks in the D&D procedure is to *define* the relevant systems for D&D purposes.

It is assumed that agroforestry research and development efforts will not be undertaken for truly minor and insignificant land use systems within a country and it is expected that users of the D&D methodology will exercise judgement in the definition and selection of land use systems for D&D treatment. It is further assumed that the sites selected for D&D exercises, and within the sites the management units selected for D&D survey, will be broadly representative of major land use systems within the country which are important enough to justify the expenditure of scarce research and development resources. (See *Resources for Agroforestry Diagnosis and Design*: for detailed guidelines and suggested criteria for the definition and selection of land use systems for D&D purposes.)

On completion of the D&D-based agroforestry research and development project it is very likely that the technologies developed for the selected land use system(s) can be treated as 'prototype' technologies which can be adapted to the needs of similar systems outside the original project area. Thus, even within the system-specific context of the D&D methodology, a certain amount of generalization will be possible with respect to the resulting technological products.

1.10 ON THE OPTIMUM LEVEL OF DOCUMENTATION

Regardless of the type of application, the purpose of the D&D methodology is not to generate a massive volume of documentation for its own sake. Documentation of the results of each step in the D&D process should be regarded, not as an end in itself, but as a *means* of 1) aiding the D&D team toward greater clarity and specificity in the consensus developed, and 2) communication of the consensus to others. Minimally, the team should strive for a level of documentation which adequately communicates the *design result* (in sufficient detail to avoid misinterpretation of precisely what technology is envisaged) as well as the *diagnostic rationale* for it. In regard to the maximal limit, the users of the D&D methodology should avoid producing such a volume of documentation that no one would be tempted to read it. As an aid to documentation the companion volume to these guidelines (*Resources for Agroforestry Diagnosis and Design*) contains a set of Worksheets for use at each step in the D&D procedures. These might form the basis for something like an 'optimal' level of documentation, but they would have to be tied together by a prose account to produce a readable case study report.

In an effort to assist in the documentaion and dissemination of D&D results, ICRAF has inaugurated a series on *Case Studies in Agroforestry Diagnosis and Design*, where suitable case studies might be published. Also, to foster the use of case study material to aid in the development of agroforestry, similar to the use of case studies in the development of medical science, ICRAF is establishing a computer-based D&D data bank at its headquarters in Nairobi. A recording form for coding of case study information is being developed for users of the methodology who may wish to contribute to the global data bank, without necessarily having to produce a full case study report. All users of the D&D methodology are urged to contribute to this global documentation effort in one form of the other. Due acknowledgements will be given to the contributors of such information in any publication making specific use of it.

1.11 D&D AS PART OF THE 'INTERNAL GUIDANCE SYSTEM' OF AN R&D PROJECT

These guidelines concentrate on procedures for Diagnosis and Design at the formulation stage of agroforestry research and development (R&D) projects, but the need for the basic process of diagnosis and design does not vanish once the project is under way. Even with adequate pre-project D&D preparation it is unlikely that the project implementation staff will have the same view of technological prospects for the project area at the end of the project as at the beginning. There is usually a learning process which causes project staff to modify their view of technical options as the project progresses. Unfortunately many projects are 'writ in stone' from the beginning and there is little opportunity to benefit from this learning process.

The suggestion that the D&D process should be continued throughout the life of the project is intended as a corrective to this situation by formally acknowledging the importance of the mid-project learning process and giving it a central place in project design. Figure 1 presents a schematic representation of the key features of the D&D paradigm, showing the feedback linkages which enable it to fulfill its potential role as part of the project's internal guidance system.

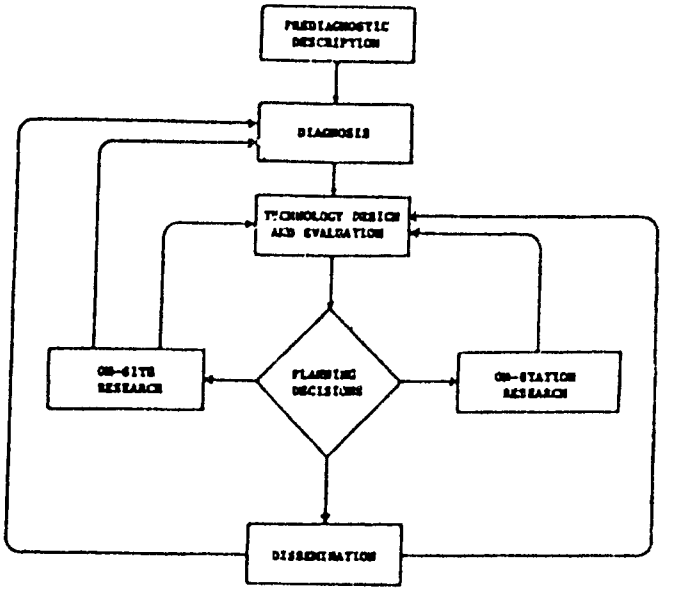

Figure 1. Components of project design incorporating the D&D process as part of the projects internal guidance system. Note feedback loops.

Both *on-station research*, involving controlled experimental investigation of fundamental aspects of the proposed technologies, as well as *on-site research*, involving in situ trials of candidate 'technology packages' on representative land management units in the project area, are necessary components of a coherent and effective R&D programme to develop appropriate agroforestry technologies. The initial guidance for the type of research which is needed for both of these research components is given by the initial D&D exercise. As the project progresses, however, new information will be generated, both from a deepening of the diagnosis resulting from longer exposure to the client land use system at the research site as well as from an improved understanding of the technical options from on-site and on-station research. This information provides feedback which may suggest refinements in the diagnosis and modifications in the design. The *diagnosed situation itself will change*, moreover, as a result of the introduced technology, thus requiring a fresh diagnosis of the new condition of the system. Feedback of these various types of information will allow the project implementation team to 'track' the changing situation and 'home in' on an increasingly optimal design for improved system performance.

If we may be allowed a martial analogy, an R&D project without a mechanism for continuing diagnosis and redesign is like a missile without an internal guidance system. Without it the ability of the project to reach its target will be dependent on the accuracy of the initial 'sitings.' With it the project can redirect its efforts in accordance with continuously improved information on what is needed and how to achieve it.

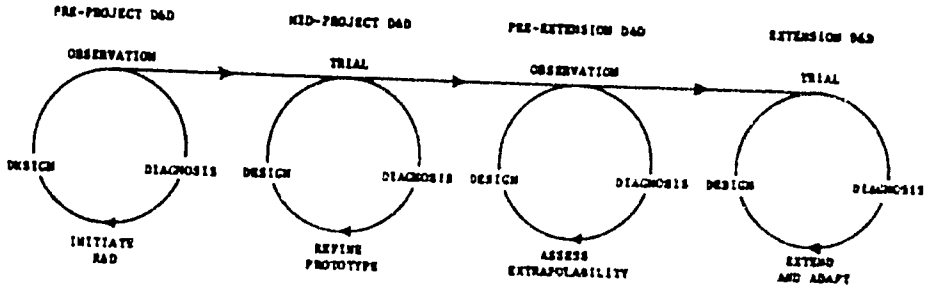

Figure 2. The iterative D&D process in the life cycle of a technology generation and dissemination project.

In its fully developed form D&D is an iterative process which is repeated throughout the project cycle for different purposes at different stages (see Figure 2). In the initial 'pre-project' or 'project formulation' stage the D&D process is used to arrive at prototype designs to initiate the R&D project and set it moving along *generally appropriate* lines. At the 'mid-project' or 'project implementation' stage, the D&D process is repeated more-or-less continuously to deepen the diagnosis and refine the prototype designs in order to develop *specifically appropriate* designs for the given land use system. In the course of time the project will arrive at the point where the technology developed is considered ready for dissemination throughout a wider recommendation domain. At this 'pre-extension' stage a modified D&D process incorporating an expanded land evaluation exercise comes into play to assess the extrapolability of the developed technology and define the recommendation domain. The dissemination to new sites at the 'extension stage' will, in turn, generate new feedback information which can be used, through a scaled-down D&D process, to adapt the technology to a wider range of site-specific conditions (see Raintree, 1983a for an elaboration of this scheme).

Thus, in its fully developed form, the D&D methodology is a *process approach* to project implementation which, it should be noted, cannot be simply equated with 'Monitoring and Evaluation' as this is normally understood. In Monitoring and Evaluation various components of the project are monitored and the degree to which the project is meeting its objectives is evaluated. There is no explicit mechanism within the 'passive-critical' role conception of Monitoring and Evaluation to actively follow through with project modifications, let alone redesign project technology. What makes D&D different is its explicit focus on the technology generation process and its incorporation of active feedback mechanisms for institutionalizing the project learning process at the level of the implementing personnel. D&D does not replace Monitoring and Evaluation in the overall adminstration of the project, but it does provide an additional means by which project personnel may improve on their ability to generate appropriate technologies.

2. SPECIFIC PROCEDURES

2.1 THE LOGICAL SEQUENCE OF STEPS

The procedures for project formulation consist of a series of information gathering and analytical steps, leading logically form one to the next. This sequence entails a hierarchical progression from the general to the particular, which is designed to economize on time and effort by excluding irrelevant information from further consideration while developing a progressively sharper focus on essential information. By this open-ended but structured approach the D&D methodology avoids the seemingly endless and needlessly complicated data collection and processing task characteristic of an unstructured approach to systems analysis. The progression of steps is divided into four stages as follows:

Prediagnostic Stage (Steps 1-3)

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

Diagnostic Stage (Steps 4-6)

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

Technology Design Stage (Steps 7-9)

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

Follow-up Planning Stage (Steps 10-12)

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

The remainder of this section contains an overview of the step-by-step procedures in outline form, showing the content of each step. This is followed in the next section by a prose summary which might usefully be read in parallel with the outline. Most of the methodological aids mentioned in the outline under 'Useful Tools' can be found in *Resources for Agroforestry Diagnosis and Design* (ICRAF, 1983).

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, 1983)

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, 1983)

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 diagnosis of household production systems, with supplementary guidelines for forestry and watershed applications, input-output analysis, matrix tools, modeling techniques and other useful tools (ICRAF, 1983)

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 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)
- Farmers' strategies for coping with identified problems

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

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, 1983)

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, 1983)

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, 1983)

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, 1983); 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, 1983; Hoekstra, 1983; Etherington and Mathews, 1983)

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, 1983); Huxley (in press)

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: 1) a general outline of major project activities (research and/or dissemination), suggested by the D&D team; 2) a more detailed project proposal suitable for submission to potential donors, prepared by a small pre-project working group; 3) detailed project implementation plan, prepared by the project implementation team; 4) 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 (1); pre-project followup activities (2 & 3); the iterative D&D process during the course of project implementation (4)

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: Documentation of the previous steps; step-by-step worksheets contained in ICRAF (1983)

2.2 SYNOPSIS OF THE FOUR STAGE PROCEDURE

THE PREDIAGNOSTIC STAGE

This stage commences with a description of relevant background conditions in the study area: the physical environment, economic and social conditions, and the functioning of the human ecosystem. The background description provides an overall framework within which the analysis is to take place and indicates broad limits on the nature of contemplatable developments (e.g. as conditioned by climatic zone or overall income levels).

The next step is to identify the *land use systems* within the area. A land use system consists of a combination of a *land unit*, as set by the physical environment, with a *management unit*, with distinctive production objectives and resources.

The land use systems which result from such combination of land resources with management units form the subject of agroforestry diagnosis. Frequently, one or more dominant land use systems will be singled out as the focus for diagnosis and design. Where more than one land use system is identified for diagnosis, the steps which follow are conducted with respect to each selected system.

The prediagnostic stage is concluded by *description of the selected land use systems*. This covers their objectives, production activities, output and internal organization. As a basis for subsequent activities, particular attention is given to identifying the *output subsystems* geared to meeting the basic needs of the land users. The following needs are considered: food, water, energy, shelter, raw material, cash, savings/investment, and social needs. Food and water are self-explanatory. The most common energy need is for domestic fuelwood. Raw materials refers to needs for cottage and local processing industries. Cash, for regular day-to-day expenditure, is distinguished from savings/investment, for infrequent expenditure on special purposes. Finally, there may be forms of output required to meet ceremonial or social obligations which cannot always be translated into money terms.

The prediagnostic stage establishes the basis for the steps which follow, by giving basic physical and socioeconomic information and identifying and describing the land use systems to be considered.

THE DIAGNOSTIC STAGE

Two steps, diagnostic survey and analysis, are closely linked. Diagnosis commences with *identification of land use problems*. At the level of management units they are initially idenfified as *shortfalls in the output subsystems:* for example, occasional food shortages, present or anticipated fuelwood shortages, lack of materials for shelter or cottage industry, inadequate or unreliable income, etc.

Parallel with these problems at the level of the management unit, there may also be problems at the community or ecosystem level, beyond the control of individual farmers, which also need to be identified, e.g. erosion gullies along the boundaries between farms or lack of adequate marketing facilities for cash crops.

Having identified problems in achieving the objectives of the output subsystems, the *causes* of these problems are then ascertained. For example, food shortages might be caused mainly by recurrent drought, by decline in soil fertility through over-intensive cultivation, through inability of the farmers to obtain fertilizers, or any combination of causes. Where cash income is dependent on sales of livestock, the causal chain might involve overstocking and pasture degradation, seasonal fodder shortages or protein deficiency. Fuelwood shortage is most frequently caused by over-exploitation, sometimes complete removal, of indigenous trees.

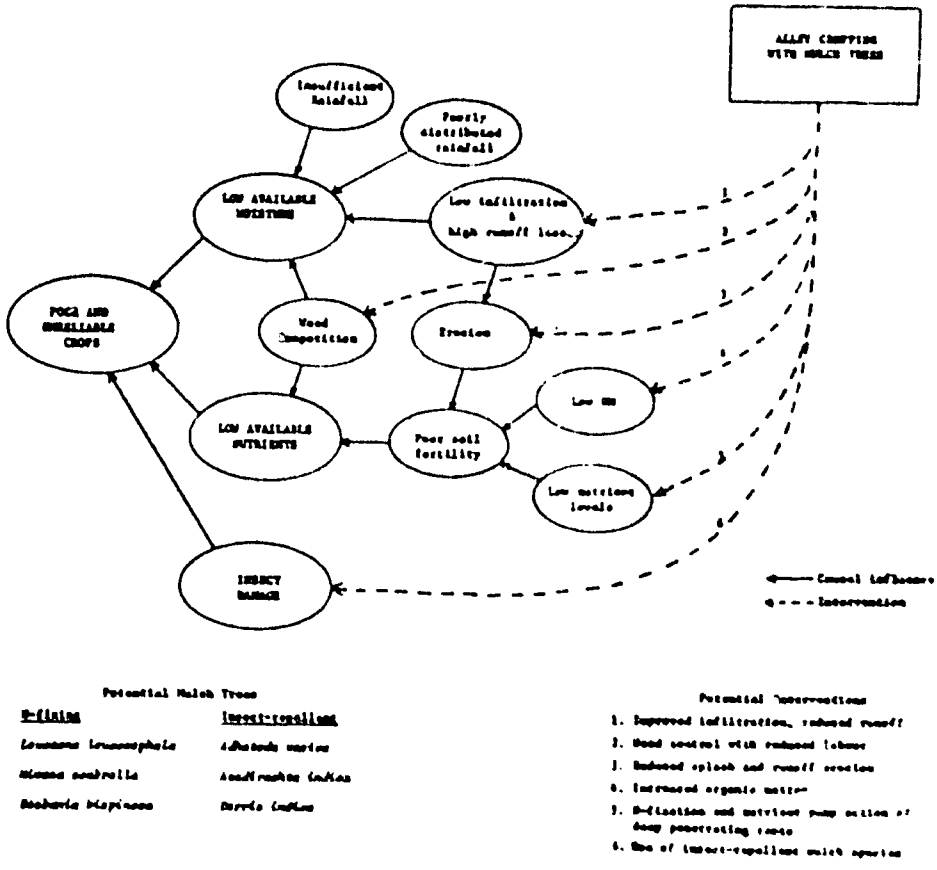

Figure 3. The use of causal diagramming to elucidate the etiology of a problem and identify potentials for appropriate technological interventions in the system.

The output shortfalls or other problems and the causes which underlie them may be summarised in a *causal diagram*. Attention is then given to *potentials for removal of constraints*, and thus for improving output. These potentials may include non-agroforestry solutions (e.g. improve the fertilizer supply system, or provide rural credit) as well as agroforestry techniques. An *agroforestry intervention* is an apparent potential for agroforestry techniques or systems to remove output constraints; for example, to ameliorate energy shortage by growing fuelwood-producing hedgerow trees, protein shortage for cattle by growing browse-producing trees, or low soil fertility through the soil-improving effects of tree leaf litter. Figure 3 shows the use of causal diagraming to elucidate the causal background to a problem and to assist in identifying appropriate interventions (in this case the suggested intervention is 'alley cropping').

Constraints to such production-improving technologies are set by considerations of sustainability and adoptability. Improved sustainability, or resource conservation, may be involved as an element in the removal of constraints. However, further consideration needs to be given to ensure that the proposed agroforestry solutions themselves meet sustainability requirements.

Adoptability is given particular attention during diagnosis. The technological level, attitudes, capital resources and labour availability of the farmers are examined, together with the institutional and social framework within which they operate (e.g. land tenure systems). Economic conditions, notably markets and levels of income expectancy, are also critical. This stage of the study leads to identification of the *constraints to adoption of improved technologies*.

The discovery of potentials for removal of constraints in the existing pattern of production, or of potentials for new production patterns which make better overall use of available resources to meet the farmer's objectives, together with considerations of sustainability and adoptability, leads to the formulation of *design specifications for appropriate technological interventions* in the system. These consist of a set of functional specifications for what the technology must accomplish (e.g. 'relieve fodder protein shortage in the dry season'), together with constraints on candidate technologies (e.g. 'inadequate capital to purchase feed concentrates'). Considered within the context of an appropriate development strategy for the system, the design specifications provide the link between the process of diagnosis and that of design.

THE DESIGN STAGE

Starting from the design specifications, the procedures of design commence with the process of *technology appraisal*. This is based on the body of available technical knowledge, from research stations or farming experience. In the future it should become possible to an increasing degree to draw upon experience from agroforestry projects in comparable settings.

This leads to the process of *technology design* per se, in which selected elements of agroforestry technology are combined in a design for an improved land use system. Combining agroforestry techniques with the existing farming practices may lead to constraints and require modifications in the design as a whole, e.g. as arising from labour peaks.

Merging with the design process comes *design evaluation*. In this process, the proposed design is reviewed with respect to the three criteria of productivity, sustainability and adoptability using various techniques of economic, ecological and social evaluation. The agroforestry proposals

are also compared with non-agroforestry solutions to the diagnosed problems. Since the evaluation may suggest modifications in the design, in practice there may be an alternation between the two processes leading to a progressively more refined design.

THE FOLLOWUP PLANNING STAGE

In the present state of knowledge it is unlikely that many of the proposed agroforestry technologies will be ready for widespread implementation. In most cases they will need to be developed and tested through a research programme tailored to the specifications of the *research needs* assessment. This is based on an assessment of gaps in present knowledge with respect to the technologies identified in the design stage. Research to fill in these gaps may include *on-station research*, conducted under controlled conditions (usually at field stations), and *on-site research*, conducted on farms or under other natural conditions at sites within the study area.

On-site research is designed to allow monitoring of social attributes of the candidate technologies, such as ease of adoption, labour problems, management difficulties, etc., along with technical elements. On-site research, particularly if conducted on farms, will usually involve testing of 'best bet' technical packages, and should not normally involve elements of high risk. One of the unique aspects of on-site research is the possibility of obtaining valuable feedback in the form of spontaneous modifications of the design made by farmers to adapt it better to local farming conditions. On-station research is designed more-or-less according to the normal principles of agricultural and forestry research, e.g. with replication, deliberate exceeding of limits of plant spacing, etc., in order to determine boundary values and design curves. The types of layouts involved in on-station research may bear little resemblance to the designs for 'technology packages' tested on farmers' fields. Although plant research in agroforestry may involve departures from standard designs developed for agronomic or forestry experiments, the main departure from 'conventional' on-station research is that the specifications arising from the diagnostic process are used to limit and direct the technological range and focus of the research undertaken.

This will complete the technical aspects of the D&D exercise, but before the exercise can be concluded two further aspects of followup planning need to be addressed: identification of *topics needing further D&D attention*, and development of a *plan for project implementation*. In rapid appraisal type applications of the methodology, the design result will normally be regarded as preliminary and provisional, pending more detailed elaboration and refinement in a 'pre-project followup' exercise, when a smaller working group will have ample time to develop the ideas initiated by the full multidisciplinary D&D field team. Likewise with any unresolved diagnostic issues which the D&D team may not have had time to cover in what it considers sufficient detail for final project planning. Requirements for further diagnostic and design work to be carried out during the followup phase (including more in-depth ex ante evaluation and redesign work) should be specified by the D&D team before it adjourns.

The D&D field team in rapid appraisal type applications will also not be likely to develop a final, fully detailed project implementation plan, not only because of time limitations, but also because crucial financial and other administrative decisions may not have been taken.

What the team should aim for, rather, is to produce an outline of its recommendations, specifying likely manpower, land and other resource requirements to carry out the envisaged research, and giving its suggestions on how to set up internal feedback mechanisms, project review procedures, etc. Even though these recommendations may be modified, as a result of the wider range of technical and administrative consultations that may occur in the post-D&D exercise period, an effort should be made to give project planners the benefit of the perspective developed by the full multidisciplinary team.

If, rather than a rapid appraisal type exercise, a straight-forward extended application of the D&D procedures has been undertaken, the above mentioned limitations will not apply.

Before concluding this account of the Diagnostic and Design methodology, it may be useful to show an example of the type of result that may be obtained. Table 1 on the next page gives a site summary of D&D indications from an application undertaken at an ICRAF research site in Kenya. While it by no means exhausts the full spectrum of D&D results and followup activities undertaken at the site, this tabular summary may serve to give an impression of the type of perspective which the methodology can be used to create.

Table 1. Summary of farm level diagnostic and design indications for a representative management unit at the Kathama research site in Kenya (adapted from Raintree, 1983b).

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 3.5% Avg. Farm Size 3.5 ha	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 baking 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, lack of viable cash crop enterprise SAVINGS/INVESTMENT - Lack of savings/ investment alternative to livestock, livestock potential limited by dry season feed gap SOCIAL PRODUCTION - Difficulty in making "harambee" contributions	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 SUSTAINABILITY PROBLEMS Erosion Declining Soil Fertility Degradation of grazing land vegetation DESIGN CONSTRAINTS Low capital Labour bottleneck Long dry season, frequent 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.

3. CONCLUSION

The process of diagnosis and design in its wider sense does not end when the rapid appraisal team packs up and goes home. A fully operational plan of action based on the use of D&D procedures is expected to lead, first to the production of research results which will validate or modify the candidate technologies and, secondly, to the dissemination of successful technologies throughout the recommendation domain by local extension services. In the course of time, further experience will be generated concerning the success or limitations of prototype agroforestry systems under field conditions. This information can be cycled back into the diagnostic and design process; thus leading, by an iterative discovery procedure, to successive gains in knowledge and to the development of genuinely productive, sustainable and adoptable agroforestry systems.

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3.2 Practical Exercises

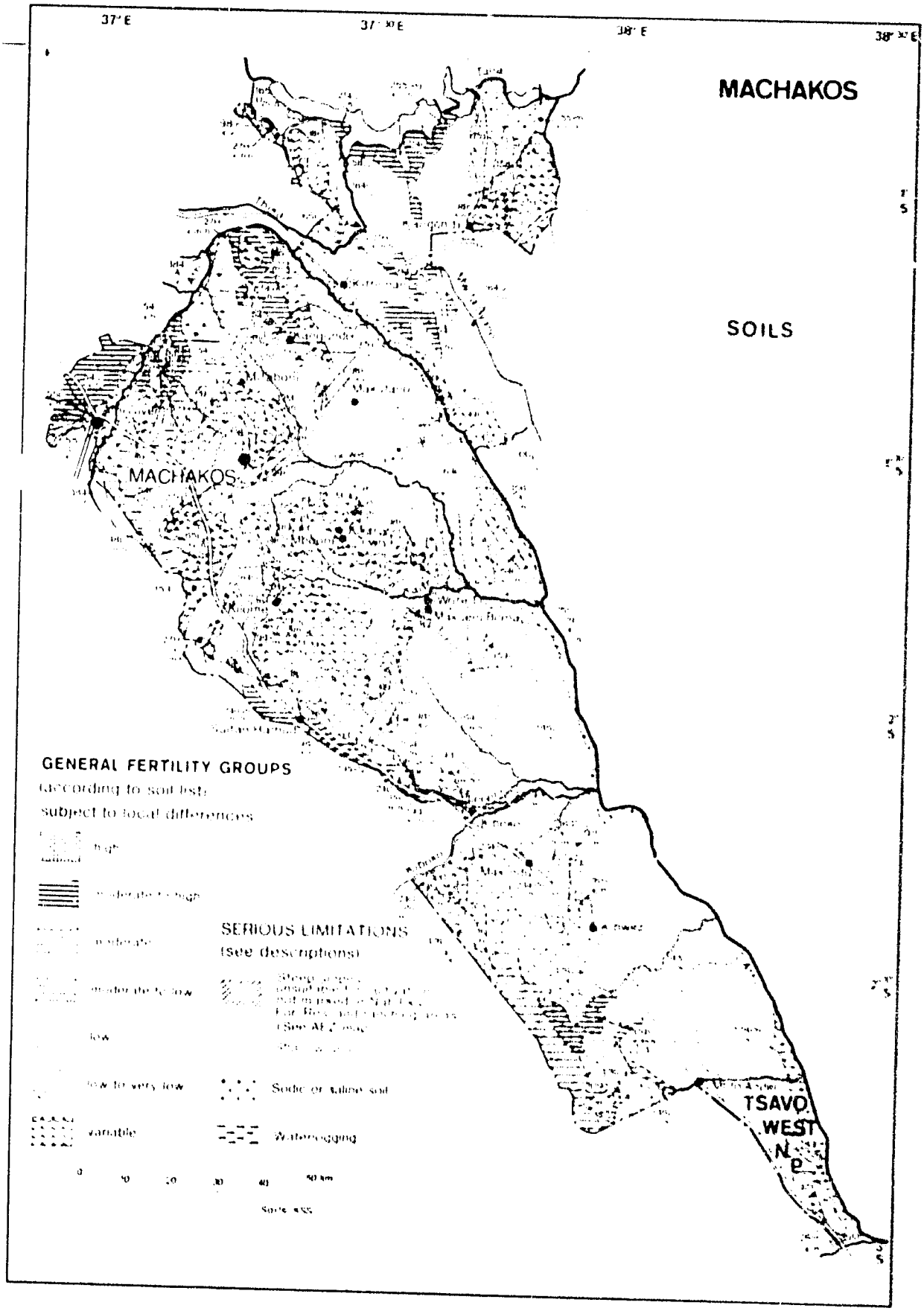
- Case Study Review in Costa Rica
- Case Study Review in Malaysia
- Economic Analysis of AF

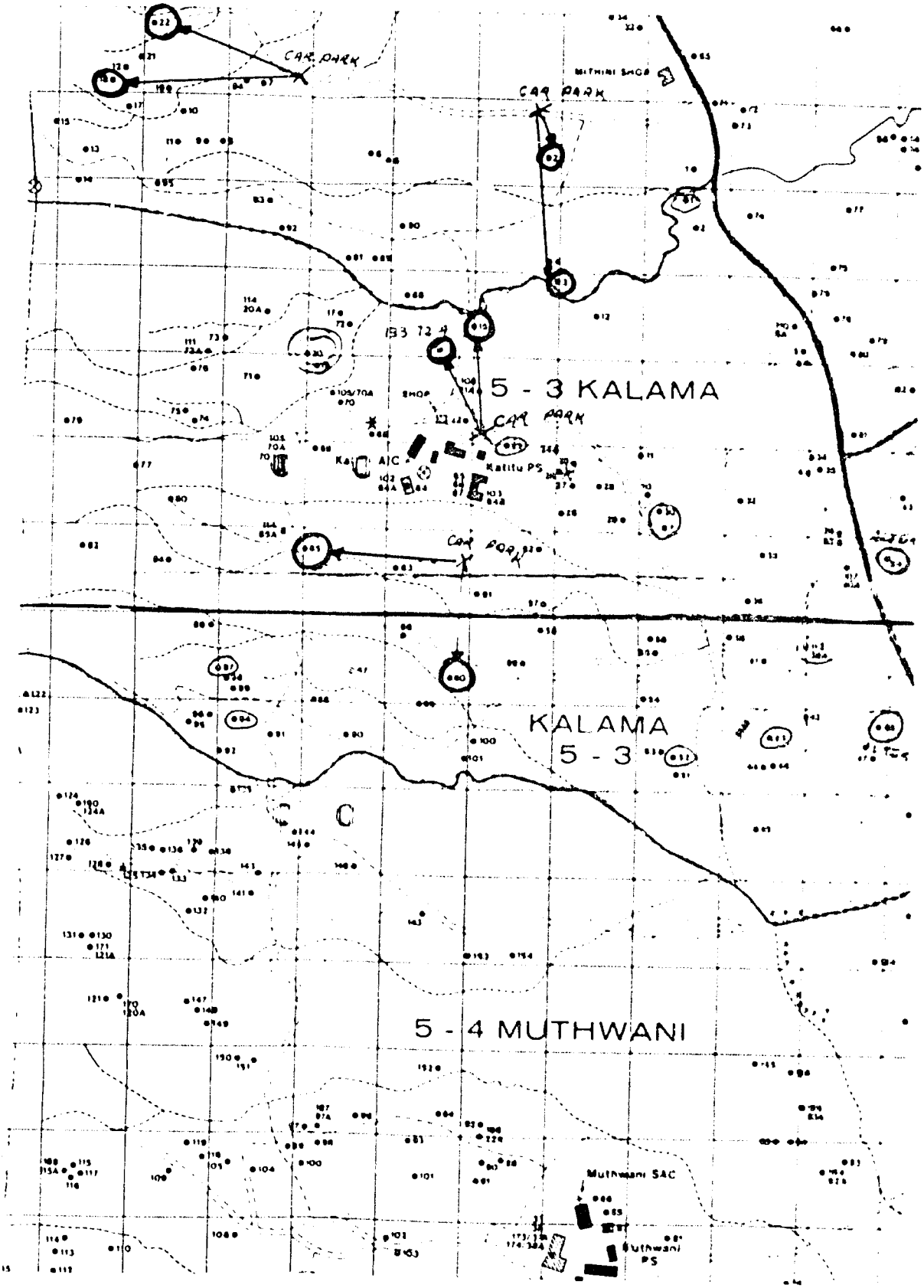
  Models - Selangor Forest Reserve (Dirk Hoekstra)
- Ex-ante Economic Evaluation of Alley Cropping Systems

  (Dirk Hoekstra)

FIELD EXERCISE IN KATHAMA (See map)

GROUP No.	GROUP LEADERS/ INTERPRETERS	PARTICIPANTS	FARMERS TO INTERVIEW					
			NOVEMBER 9		NOVEMBER 10		NOVEMBER 15	
			Name	No.	Name	No.	Name	No.
1 HIGHLANDS	John Raintree Veronica Ndunge	Massane, M Rakotomanana, JL Sniyenda, S Chisenda, A Gustola, G Ogera, J	Mr. Kaloki Mr. Musembi Mutoo Village: 5 - 2 Mango	22 2	Mrs. Mulela Mrs. Roda Kisusu Village: 5 - 3 Kalama	85 133-72A	 Village:	
2 HIGHLANDS	Diane Rocheleau Lawrence Kyongo	Abu, J Baragengana, R Bashir, J Nartomber, Y Matru, H	Mr. Mbevi Mbuvi Mr. Ndeto Mutoo Village: 5 - 2 Mango	16 3	Mr. John Mbithi Mrs. Mzula Village: 5 - 3 Kalama	60 15	 Village:	
3 LOWLANDS	Dirk Hoekstra Japheth Kyengo	Kamweti, B Mwinomwe, S Ramkissoon, J Sarlan, G Twila, A	Mr. Ndeto Mutisya Mrs. Mbiu Makau Village: 4 - 6 Mutula	32 69	Mr. Isaac Masandi Mr. Mulei Kyova Village: 4 - 6 Mutula 4 - 5 Utithini	12 25	 Village:	
4 LOWLANDS	Filemon Torres Richard Mwendandu	Brockman-Amissah, J Sawkabemba, C Jackle-n, Z Munyakabem-, B Pellek, P	Mrs. Nguma Muthoka Mrs. Rithei Musyoka Village: 4 - 6 Mutula 4 - 5 Utithini	43 120B	Mr. Musila Ngumbi Mr. Muasya Nzau Village: 4 - 6 Mutula 4 - 5 Utithini	10 17	 Village:	


37° E
37° 30 E
38° E
38° 30' E
MACHAKOS
SOILS
MACHAKOS
GENERAL FERTILITY GROUPS
(according to soil list)
subject to local differences
high
moderate to high
moderate
moderate to low
low
low to very low
variable
SERIOUS LIMITATIONS
(see descriptions)
Sodic or saline soil
Waterlogging
0 10 20 30 40 50 km
TSAVO
WEST
N.P.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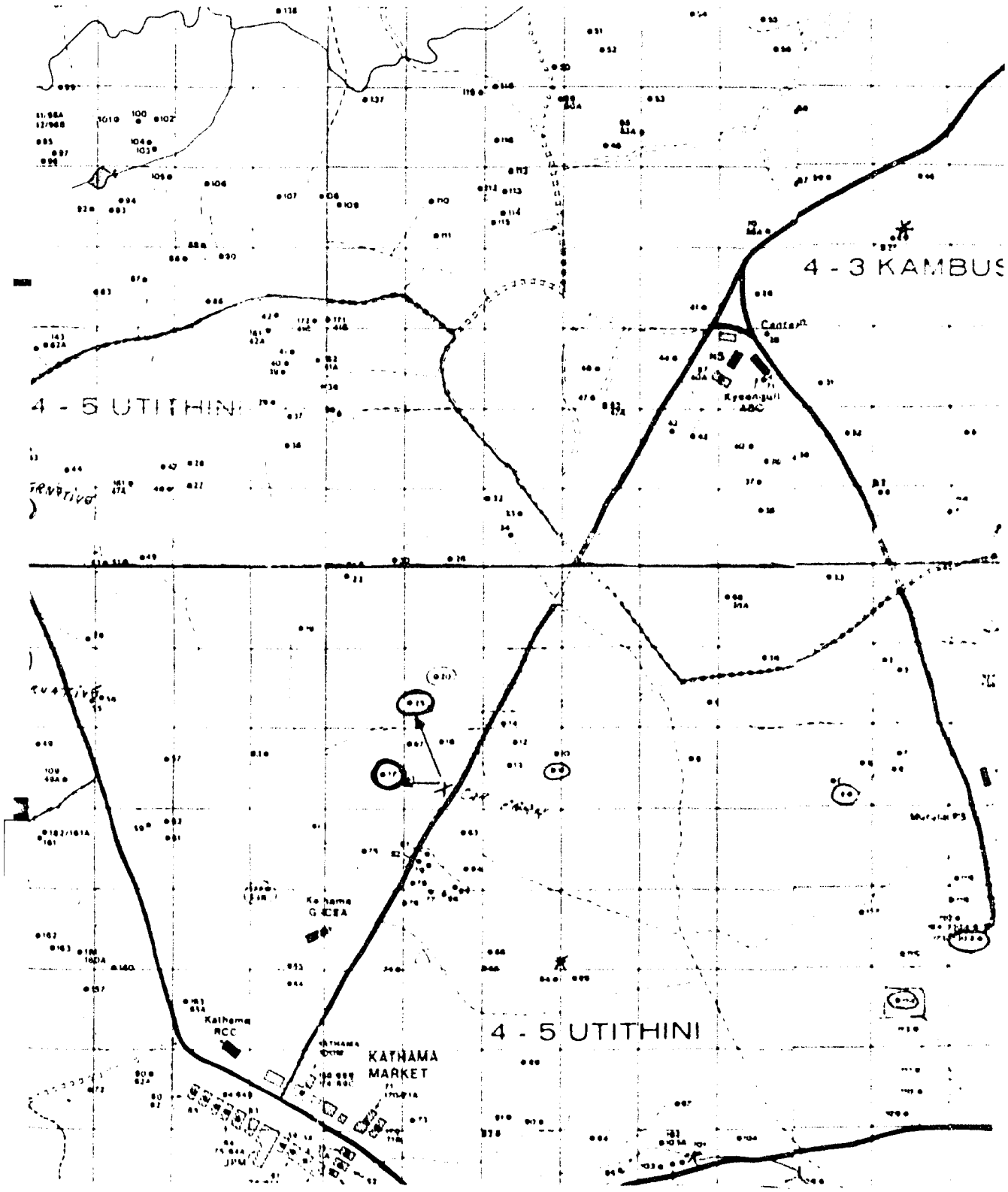
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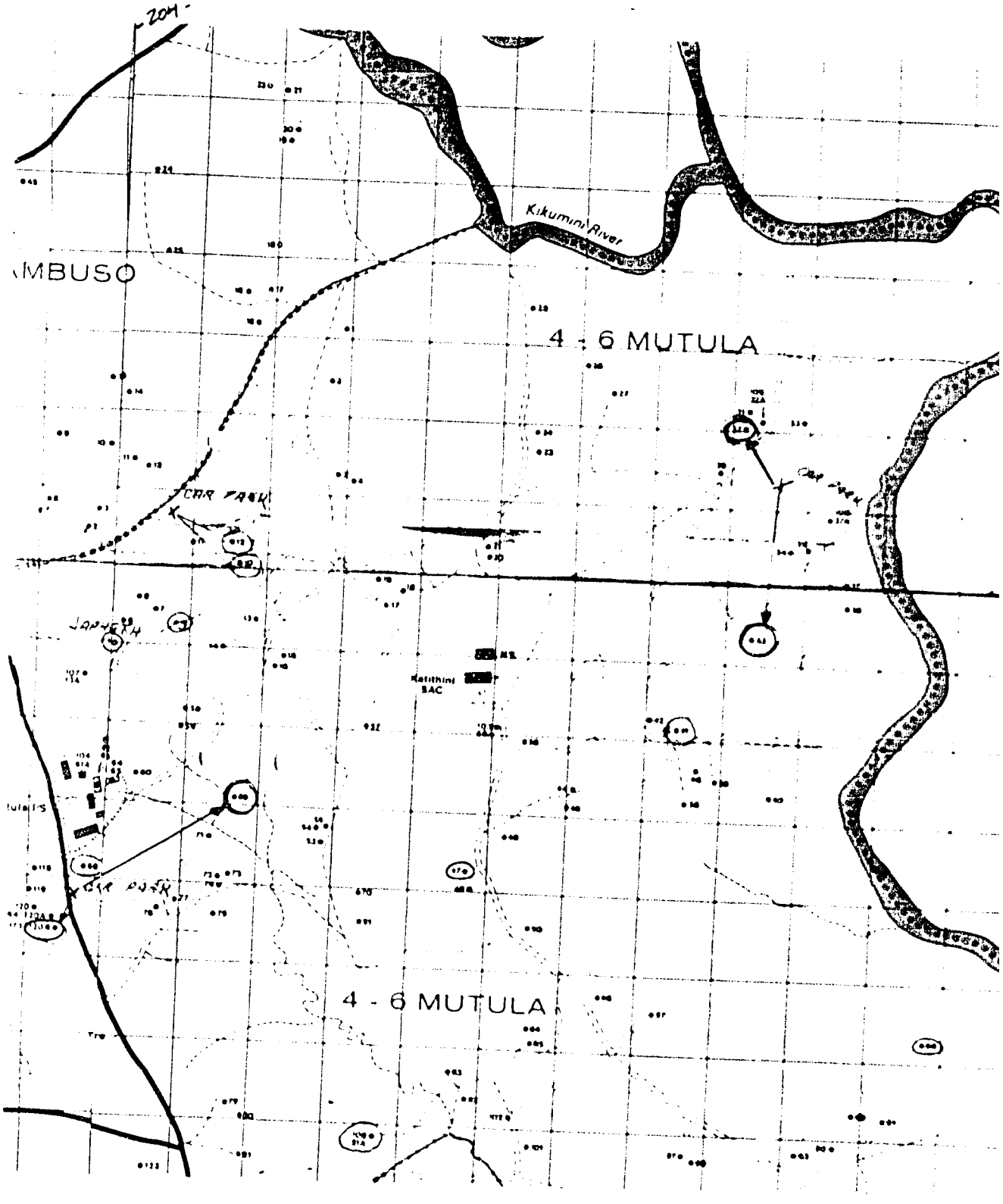

204
Kikumini River
MBUSO
4 - 6 MUTULA
CAR PARK
Katithini
SAC
4 - 6 MUTULA

3.3 Supplementary Material

- Note on the ICRAF Basic Needs Approach
- Watershed/Ecosystem Analysis
- Interview Guidelines for Agroforestry Diagnosis and Design
- Sample Diagnostic Survey Form
- Resources for Agroforestry Diagnosis and Design
- Woody Components of Existing Agroforestry Systems
- On-Farm Experimentation: New Methods for an Old Concept? (Roger Kirkby)
- Pre-Diagnostic Information on Kathama Site (Remko Jonk)
- Site Summary of Agroforestry Diagnosis and Design Indication on a Representative Farm (Table)
- Combining Disciplines in Rapid Appraisal: The Londeo Approach (Peter Hildebrand)
- Some notes on the Art of Informal Interviewing (Robert Rhoades)
- An Inventory of Trees and Shrubs in the Northern Division of Machakos District (Els Fliervoet)
- Ex-Ante Economic Analysis of Candidate AF Systems/Technologies (Dirk Hoekstra)
- Selected Bibliography of Agroforestry (Lucille Majisu and Richard Labelle)
- ICRAF'S Publications
- Economic and ecological description of the land use system, structure and function
- Constructing Input - Output Model
- Discount Rate Farmers (Dirk Hoekstra)

APPENDIX A-6

NOTE ON THE ICRAF BASIC NEEDS APPROACH*

As the concept of "basic needs" has been developed and applied in different ways in other contexts, it is important to specify clearly what is meant by this approach as developed for agroforestry purposes by ICRAF. The basic points are as follows:

1. In analyzing land management systems, we have identified the household management unit as a prime focus of D&D attention because this is where most of the land management decisions are made.

2. In our approach to the modeling of household land management systems, we define the subsystems in terms of *outputs*. In other words, the *output subsystem* is defined as the set of all activities, resources and other landuse factors which are involved in generating an output which satisfies one of the major production or land management objectives of the household.

3. In deciding specifically what output categories to consider in defining the major subsystems, it is important to satisfy two requirements:

   a) general applicability, and

   b) adequate representation of the characteristics of local land use systems

4. To satisfy both requirements and also to facilitate subsequent linkage with categories of agroforestry potentials, a basic needs approach is indicated. The production outputs which may be considered basic to the economic wellbeing of people everywhere are:

- food
- water
- energy
- shelter
- raw materials for local industries
- cash
- savings/investment
- social production

*Contributed by J.B. Raintree

5. The assumptions which underlie this approach are

a) that the needs in the above list are basic and universal, and

b) that local and regional land use systems are in large part organized so as to satisfy these basic needs.

6. It is important to emphasize that, in espousing this approach, the aim is to insure satisfaction of basic needs but *not* to restrict development efforts to only minimal satisfaction of these needs. Rural development needs *floors*, not ceilings. One implication of this approach is that, once subsistence needs are adequately satisfied, the emphasis shifts to improvements in the cash or savings/investment subsystems.

7. To further clarify this point, in referring to "basic" needs we mean basic *types* of needs, rather than basic *levels* of need satisfaction. For example, a particular household may be well above the subsistence level in its production of cash but, because of drought or deforestation may have serious problems in meeting its food and fuel requirements. Cash income, which is normally taken as the prime indicator of economic wellbeing, is not always readily convertable into a form which satisfies the other basic needs (e.g. one definition of "famine" is that there is no food to buy, even if you have the money). For this simple reason, it is necessary to consider the performance of each basic output subsystem separately.

8. Having identified the subsystems in which the problems exist, and having traced the symptoms and antecedent causal factors, analytical aids are then used to model problem etiology and identify agroforestry potentials (see Appendix B-7). For each subsystem the general question is: *Is there anything that trees can do to improve the performance of this subsystem?*

A partial list of the general types of answers which are possible is given below.

POTENTIAL CONTRIBUTION OF TREES TO BASIC NEEDS SUBSYSTEMS

Food Subsystem

a) *Human food* from trees (fruits, nuts, cereal substitutes) at low input levels on marginal land

b) *Livestock feed* from trees (one step down the trophic chain)

c) *Fertilizer* from trees from improving the nutritional status of food and feed crops (through the *addition* of atmospheric nitrogen

to the soil system by leguminous trees, through *improvement of access* to a greater volume of soil nutrients by the nutrient recycling action of appropriate trees and also by the *improved availability* of soil nutrients which often accompanies the higher CEC levels associated with the higher organic matter levels and improved physical structure of tropical soils under the influence of appropriate tree canopies)

d) *Soil Conservation* effected by trees in agroforestry intercropping systems has a ~~direct and~~ measurable long term benefit on the production of food crops from the protected fields

e) *Micro-climate amelioration* associated with properly spaced trees (e.g. the "shelterbelt effect") can also have a direct impact on food crop production (e.g. 30% increase in Russian wheat yields attributable to shelterbelts)

Water Sybsystem

a) *Regulation of water delivery* for human consumption, household use, watering of livestock, etc., through reduction of runoff and improvement of interception and storage in infiltration galleries (various watershed management practices involving trees)

b) *Improvement of soil moisture retention* by rainfed cropping systems and pastures (soil structure and microclimatic effects of trees)

c) *Protection of irrigation works* by hedgerows of trees

d) *Prevention/reduction of downstream flood damage* by various watershed management uses of trees

e) *Improved drainage* from waterlogged or saline soils by phreatophytic trees

f) *Increased biomass storage* of water for animal consumption in forage and fodder trees (higher water content of feeds in dry season)

Energy Subsystem

a) *Woodfuels*

i) firewood
ii) charcoal

b) *Methanol* (wood alcohol)

c) *Ethanol* (from fermentation of high carbohydrate fruits, e.g. *Prosopis* pods)

d) *Producer gas* from charcoal

e) *Latex* and other combustible saps and resins

f) Other fuels and energy technologies under the general heading of *biomass*

g) Augmentation of *windpower* by jet stream effects of appropriate tree arrangements

Shelter Subsystem

a) *Building materials* for housing

b) *Shade trees* for humans and livestock (and even some heliophobic crops)

c) *Windbreaks* around settlements, fields and pastures

d) *Living fences*

Raw Materials Subsystem

a) *Wood* for a variety of craft uses

b) *Fiber* for weaving industries

c) Ingredients for *medicinal preparations*

d) Etc.

Cash Subsystem

a) *Direct cash* benefits from sale of the above listed products

b) *Indirect cash* benefits of non-tree crop productivity improvements effected by trees (e.g. higher profits from savings in fertilizer costs)

Savings/Investment Subsystem

a) *Addition of a savings/investment enterprise* on farms now lacking one (e.g. growing of high value timber trees for future educational expenses, etc.)

b) *Improvement of existing savings/investment enterprises* by a variety of tree roles (e.g. fodder trees in systems where livestock play the role of "savings on the hoof")

Social Production Subsystem

a) *Production of goods in kind* for social exchange purposes (e.g. fruits, more livestock for ceremonial occassions or marriage needs, etc.)

b) *Increased cash* for social purposes (e.g. political contributions, taxes, gifts, etc.) by means of various productive or service roles of trees.

(excerpted from)

APPENDIX A-7

WATERSHED/ECOSYSTEMS ANALYSIS

DESCRIPTION AND ANALYSIS OF THE HUMAN ECOSYSTEM FOR D&D APPLICATIONS

Whether the project is aimed at a particular farming system, or at a whole ecosystem, the general procedure is the same. The difference will be one of detail and emphasis. The basic tasks are:

1. Definition of boundaries
2. Stratification (sub-division of the ecosystem and some of its components)
3. Description of system structure and function
4. Identification of problems and potentials and their distribution.
5. Elaboration of design specifications for solving problems and realizing potentials (for the ecosystem in general, or by sub-units in projects with an ecosystem focus).

Any one or all of these procedures may be used to complete Steps 5.3 and 13. Parts 1, 2 and 3 (above) are particularly applicable to Step 5.3, and parts 3 and 4 are most important for Step 13. Part 5 is intended as a supplement for Step 14, to add ecosystem-scale criteria to land use system criteria for technology design. Guidelines are provided below for each task and may be supplemented by information and guidelines from appendices A-7.1, B-1, B-2, B-6 and B-9.

1. Define the Human Ecosystem

The boundaries of the human ecosystem may be defined by various criteria. For the sake of convenience in mapping and analysis the suggested boundary is the watershed (drainage divide) that most closely approximates the socioeconomic environment identified in Step 5.2. See Appendix A-7.1 for further details on watershed definition and/or description.

This first option may not be appropriate for some cases, particularly in areas where topography and drainage conditions make watershed boundaries less significant. The most obvious alternatives are the land unit(s) or land system(s) identified in Step 5.1 or the corresponding socioeconomic environment unit (Step 5.2). The latter may be political or administrative boundaries, or the area served by a given market. The choice will depend on which boundary is more inclusive and/or distinct, as well as on the emphasis of the project.

Yet another alternative for ecosystem boundaries could be a finite expanse of a vegetation type (such as forest or savanna) or a land use type (such as a contiguous area of pastoralist lands within a larger savanna, or a large logged area within a much larger forest).

Once defined, provide a sketch or map of the ecosystem boundaries.

2. Sub-divide the Human Ecosystem into Functional/Structural Sub-units

This recommended option may be used for pre-diagnostic Step 5.3 or diagnostic Steps 13. Review the information on land units, land use types and population groups identified in Steps 3.1, 3.2, 5.1 and 5.2, then answer the following questions:

Is there an identifiable spatial organisation of the groups identified in Step. 5.2.

Are they associated as groups, or as functional combinations of groups, with any particular land unit(s)?

Is there a characteristic settlement pattern for the area as a whole by sub-area or by group?

Is the population clustered, dispersed, concentrated in one place or along a river or road?

Are activities associated with meeting each basic need (for the households in the ecosystem) relegated to a particular group and/or area?

Based on the responses to these questions and general knowledge about the ecosystem under study, consider the following suggested criteria for ecosystem stratification:

Land use
- type of product
- degree of commercialization
- intensity of use
- level of technology
- land cover

Land tenure
- type of ownership/terms of occupancy
- size of holdings

Group Function/occupation
example: farmers
artesans
merchants
wage laborers/farm workers

Ethnic group
example: indigenous farmers
recently-settled pastoralists

Land Units
example: hillslope
valley
ridge

Choose from those examples or from other pertinent criteria to

stratify ecosystem. Whenever possible try to combine socioeconomic and bio-physical criteria to arrive at the final grouping. The major criteria, for example, may be land use while secondary criteria include both land units and population type or population density.

Three examples are provided to illustrate stratification of ecosystems. In the first case the ecosystem is defined by watershed boundaries, and it is sub-divided geographically (see Fig. 1) into four areas defined by a combination of land units, land use, and population, as follows:

1. town in river valley, densely populated by landless laborers and merchants.

2. large cash crop farms on broad terraces and lowhills, sparsely populated by land owners and permanent employees.

3. small farms with subsistence and cash crops on foothills, populated by small landowning households.

4. forest and shifting cultivation plots on steep slopes, sparsely populated by landless farmers.

In the second example the ecosystem is defined by an administrative unit undulating to flat topography in a broad plain). It is subdivided by land use types which are functionally associated and occur in a repetetive pattern on the landscape (see Figure 2). The sub-divisions are:

1. densely populated town;

2. cash crop estates;

3. small farms and grazing land populated mostly by households that depend on employment in the estates; and

4. forest areas held by the estate owners and used for firewood, timber and food collection

In both cases there is a pronounced spatial organisation of land use and production activities. In the first case the pattern is unique within the ecosystem and is formed by 4 contiguous areas. In the second case the pattern occurs on a smaller scale and is repeated throughout the ecosystem. The sub-divisions in the latter case are defined more by land use than by location.

In an ecosystem where there are marked contrasts between ethnic groups, particularly when these transcend differences in land use *per se*, this may be the major criterion for stratification. An example would be an area where recently settled former pastoralists and traditional farmers reside in adjacent lands of simlar characteristics and both engage in semi-commercialized food crop production and cattle raising.

The stratification by ethnic group would be warranted for several reasons: the difference in *how* they perform the activities, their differential impact on the biophysical resource base, the distinctive socioeconomic organisation, the variation in requirements to fulfill basic needs, and the potential for complementary vs. competitive utilization of resources and production of goods and services.

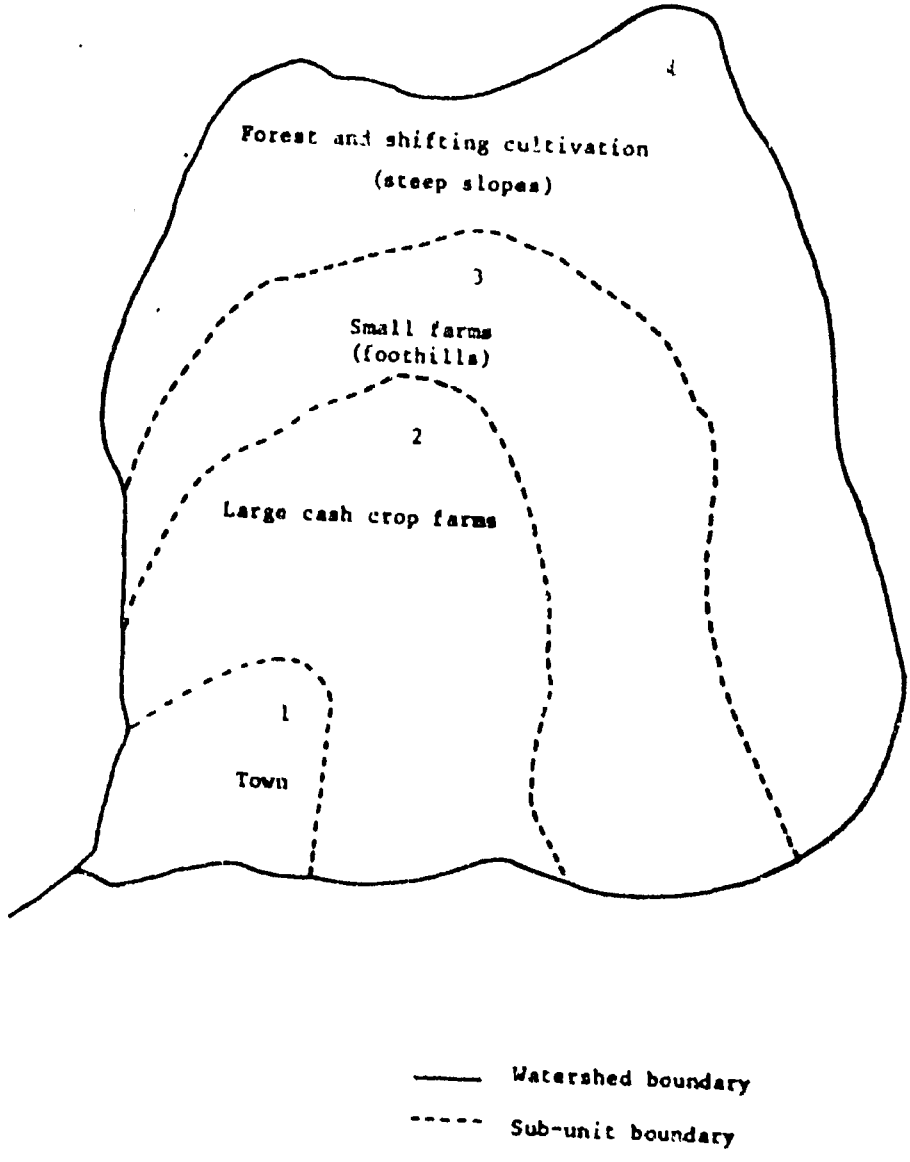
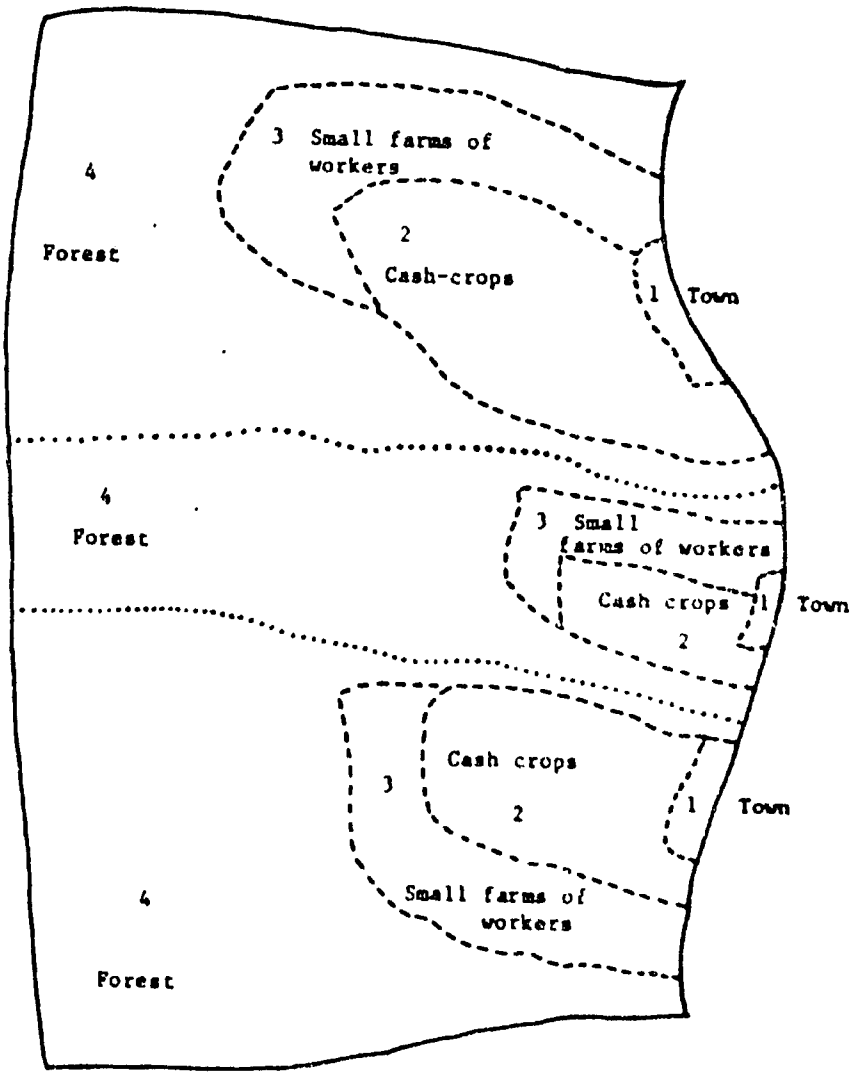


Figure 1

Geographical stratification



Administrative Boundary (bounded by river, roads)

Sub-unit Boundaries (Land Use)

Property line - estates

Figure 2

Stratification by Functional Criteria

Guidelines for Completing Input-Output Checklist for Evaluation of Human Ecosystem Structure and Function

The checklist (see next page) can be completed by answering two questions and coding the answers.

1. Do the households in this group or area import(-) export(+) or sustain themselves (√) with respect to the goods required to fulfill the basic needs or to supply the resources in the list across the top? In addition to noting import, export and self maintenance, is there a deficit (x) or a surplus (*) with respect to the categories listed? It is possible, for example, to import fuel and to still have a deficit. The code for fuel for such an area would be -x, for import and deficit. (See the checklist and the completed sample which follows).

2. What are the sources of imports and the destinations of exports? Each area or group within the ecosystem has a number assigned, including the groups and area outside the ecosystem which are assigned the last number. The cases where export(+) or import (-) are listed should also include the number of the destination or source areas. For example the food in area 1 is imported from within the ecosystem (3) so the food code for area 1 is -3, indicating that it is imported from area 3 in the ecosytem with no notable deficits or surplus in area 1. See legend on sample completed checklist.

The completed form can be used to draw a system diagram (Appendix B-8) or it can serve, as is, to identify the pathways of energy, material, cash and services between the subdivisions of the human ecosystem. An extension of this step, tentative identification of problems and potentials, easily follows from this input-output checklist. Deficits can be viewed as symptoms of problems and surplus as indicators of potential. The incidence of either one can be noted, by subdivision and by need/resources type. For example, in the sample checklist: valley farms/water deficit; hillslope farms/labor surplus; town/cash deficit; valley farms/cash surplus. These subdivisions and topics can be singled out for closer attention during the diagnostic phase.

Input-Output Checklist for Evaluation of Human Ecosystem Structure and Function.

Group or Area		Selected Basic Needs/Resources					
Name*	Numbers**	Food	Water	Fuel	Raw Materials for Shelter	Raw Materials for Industry	Labor
A	1						
B	2						
C	3						
D	4						
Exxx	5						

* Group area names should be placed here; letters placed for example only.

** Assign a number to each group for coding purposes on checklist.

*** The last category is always reserved for all the groups or areas *outside* of the ecosystem under consideration.

For an example of completed form see next page.

4. Identification of Problems, Potentials and Their Distribution

Problems and potentials at the ecosystem level can be identified, described and located by following the sequence listed below:

1. List the symptoms of problems (or potentials) for the ecosystem as a whole and (optional) for the sub-units defined previously by stratification of system. The aggregation of problems by ecosystem units and sub-units is an analytical step that does not necessarily imply new information needs. The general guidelines for problem identification at the pre-diagnostic and diagnostic phase should suffice for information gathering. Determination of problems and potentials at the pre-diagnostic phase can take the structural/functional analyses, part I. of this appendix and Appendix A-2 as points of departure for problem definition. Identification of ecosystem problems and potentials through diagnostic interviews and field observations should follow the guidelines in Appendices B-1, B-2, B-6, B-7 and A-7 (part 1).

2. Identify the apparent causes of the problems or unrealized potentials listed above. Causal or functional diagrams may be used, along with the functional ecosystem description and the input - output checklist, to trace each problem to its source(s). The latter exercise is especially useful if the causes are not very obvious or if they are multiple.

3. Locate causes by source area and/or by ecosystem sub-units. Indicate whether each major problem/potential (in the whole ecosystem and in each subdivision) has its source outside the ecosystem, within the ecosystem as a whole, or within a specific sub-unit(s). To determine the source(s) consider the questions which follow.

   Does the problem (or potential) have a definable cause attributable to a particular source inside or outside of the ecosystem? If so, list the sub-unit and specify the activities or land uses involved.

   If not, is the problem (or potential) based on an overall condition of the ecosystem (natural or otherwise)? If it is based on such a condition, is that condition changeable? (like current land use) or is it an inherent characteristic of the ecosystem (like rainfall)? If changeable, how readily could it be changed?

4. (Option)
   Transfer and code the information from the 3 previous steps onto the problem/potential checklist for ecosystems. It is helpful to complete the checklists for structural/functional description and input-output analysis, prior to this step. A blank checklist with instructions, and a sample completed form are provided for identifying problems/potentials by sub-units affected and by sources.

... Checklist for Distribution of Problems/Potentials in Human Ecosystems

Group or Area Affected by Problem/Potential

Basic Needs Affected

Name	Number	Food	Water	Fuel	Shelter	Raw Material for Industry/Handicrafts	Cash
Source(s)							
Source(s)							
Source(s)							
Source(s)							
Source(s)							

On the top line of the first box list the name of the area/group affected, in the next column list the number assigned to it, then list the main problem(s) or potential(s) under each basic need and list the number of source area(s) or group(s) on the line under the problem. Of the problem source is a condition of the whole ecosystem the area/group number is 0. In this case also list L if it is an inherent limit of the ecosystem and list C if it is a temporary or changeable constraint of the whole ecosystem. See the sample completed checklist, with legend for clarification.

APPENDIX B-2

INTERVIEW GUIDELINES FOR AGROFORESTRY DIAGNOSIS AND DESIGN*

Farming systems Research and Extension programs and farming systems rapid appraisal methodologies have been developed and tested under diverse conditions within recent years. The widespread application of an integrated farming systems approach has fostered the testing and refinement of several rapid appraisal techniques (Chambers, 1981) including the "sondeo" of Hildebrand for FSR/E programs (Hildebrand, 1981), the cropping systems approach developed at IRRI (Zandstra et al., 1981) and the step-wise series of interviews and surveys used by Collinson (1981) in East Africa. Summaries of these methodologies and the related interview techniques are also reviewed in a compendium on Farming Systems Research by Shaner et al. (1982). A useful discussion of the art of the informal diagnostic survey is contained in Rhoades (1982). As such, general farming systems applications of diagnostic methods have been discussed and described in the literature and need not be treated here.

To the extent that agroforestry systems D&D differs from the usual farming systems approach it requires some additional guidelines, both on content and methods of interview. The major objectives of agrofor. technology development are:

1. to meet basic needs of client populations
2. to improve the sustainability of production systems
3. to further improve quality or quantity of production where possible, once the first two conditions are satisfied.

The first objective usually refers to the basic needs of the farm household: food, water, fuel, shelter, cash and raw materials for cottage industry (See Appendix A-5). This emphasis introduces a sliding spatial scale to the analysis (and the interviews) ranging from the intra-household level (distribution of labour, responsibilities, and benefits relative to each need) to the ecosystem level (distribution, use, and management of off-farm water, fuel, related land resources, labour and socio-economic and physical infrastructure).

The second objective, by definition, extends the time scale of the diagnosis. To judge system sustainability under existing technologies and proposed alternatives we require some knowledge of past conditions, as well as trends in production rates and the state of the resource base. On this basis we can determine likely trends for the future. The fact agroforestry deals with combinations of long-lived trees and shrubs, together with annual crops and animal production, also reinforces the need for a longer time frame than that normally applied to farming systems analyses.

*Contributed by D. Rocheleau

Historical accounts of land use, production, household conditions and ecosystem condition become important tools both for diagnosis of sustainability and production constraints and for feasibility evaluation of proposed solutions. Imagining the futures - possible, with the farmers' help, becomes important for judging technologies that require present investments for relatively long term returns. Sustainability considerations may also require topical emphases on soil, water, and/or labour depending on which resource is, or is likely to become, limiting. In many cases agroforestry technologies are intended as methods for maintenance or rehabilitation of soil and water resources in fragile and/or degraded ecosystems.

The third objective, improved production, does not differ substantially from the usual focus of farming systems analyses and surveys. As such it requires no special guidelines beyond those already referred to in the literature.

Interview guidelines are presented for determining intra-household perceptions of problems and potentials with respect to basic needs, for determining historical trends and exploring futures possible at the farm and ecosystem scales, for describing the interaction between the farming system and the larger ecosystem (including the community), and for diagnostic interviews in soil and water conservation or watershed management projects.

I. GENERAL INTERVIEW GUIDELINES

Intra-household distribution of labour and interests re: basic needs.

Problem diagnosis can easily be biased by speaking exclusively to adult males and/or heads of household. For example, in many areas, although men are recognized as farm managers and heads of household, they specialize mainly in cash and food production. It is also necessary to consider the role of women as managers of water, fuel, milk, food supplies, cottage industries and small animal production. Children are often employed in such tasks as well, usually under maternal supervision.

Early on in the interview (perhaps just after a brief overview of the farm's layout and the land use history) the team should determine who is responsible for collecting, producing, purchasing and/or managing each of the end-products identified as basic household needs. Based on the answer, part or all of the team may wish to question the farmer's wife or husband, some of the children, a parent, or other members of the farm household. It is often helpful to let one or two team members split off and converse with other persons while the group stays with the main farm (or unit) manager.

These parallel interviews contribute two types of information: First, the concerns and opinions of each sub-manager or participant about the activities and needs of greatest import to them; and secondly, verification of data obtained from other informants. Differences between responses to certain common questions asked of all informants

(land use history, trends in yields, trends in environmental conditions and utilization of labour on and off-farm, etc.) can be verified in this fashion, as well as by comparing responses between similar farm households. The first type of information is more uniquely the province of intra-household stratified interviews and should take priority in terms of time and emphasis given in the interviews.

For these supplementary interviews the actual questions to be asked may vary little from the checklist and questions suggested for each basic needs in Appendix B-1. The major differences will be in the range of basic needs discussed and in the format for discussion itself. For example one might walk to the well, river or waterhole (if nearby) with the farmer's wife to discuss a problem or water supply (quality, quantity, transport) or the interview might take place inside the cooking area while food is being prepared, or in a milking area near the house. Conversation about other related concerns of the women such as child-rearing may lead to identification of nutritional or health problems, fuel shortage or household labour shortages. These informants may be invited or requested to tour other parts of the farm premises with the team member(s) if it will help to clarify activities managed by that person in another part of the farm holding or environs. In the case of cottage industry one or more team members may enter the work area or shop if, for example, there is a separate building for weaving, sewing or similar activities. Artisans may be interviewed at their working, gathering or collecting sites for raw materials may also be visited, if pertinent.

It should be kept in mind that to the extent the team splits up for part of the interview time, some post-interview discussion will be required for the team to synthesize the results and complete the diagnosis. If only one person can be interviewed, due to logistic, cultural or other constraints, then some attention should be directed toward questions about the concerns and work of other people within the farm household. To the extent possible, interviewers should pose questions that might indicate indirectly whether other household members face problems with respect to each of the basic needs categories. For example time-and-distance questions with respect to fuel and water collection can indicate potential problems in labour utilization within the household. Where such indicators prove positive one can probe further to elicit the second-hand impressions of the farmer interviewee with respect to such activities and related problems. It is, however, always preferable to speak to two or three members of the household whose responsibilities and labour are divided.

2. INTERVIEW [illegible] AND EXAMINE THE TIME SCOPE OF THE DIAGNOSIS

The rapid appraisal time constraints for the diagnostic process itself do not necessarily limit the time span considered in diagnostic and design interviews. The agroforestry RAP methodology includes a dynamic analysis conducted within [illegible] cultural context.

The back drop for such an analysis fits well into the needs of the interview team. After the introduction at the outset of the farm tour the team can ask the land manager about his/her length of residence in the vicinity and on the present holding. This can be followed by an open question about the history of land use and management on the farm and its immediate surroundings. Further prompting should be directed

toward: land use/farm management changes and the reasons for them; trends in yields and prices of farm products, trends in amount and prices of purchased production inputs and purchased household goods; past problems experienced by the farm household, the responses to them and the eventual outcome; differential impact of past economic or natural stresses on various land use types and on fulfilment of the various basic needs at the household level. Other specific questions may arise based on the responses of the interviewee. Discussion of the current situation may be guided somewhat by this knowledge of the land use history, but the general approach would follow the guidelines normally used for farming systems interviews about present conditions.

Projecting the present conditions and alternative technologies or systems into the future should be presented casually as an exercise in imagination. The potential for this technique will vary with personal and cultural attitudes about the future and planning in general. However, in many cases the farmer may anticipate future problems not yet apparent (and seek solutions to them). Informants may also veto some suggested alternatives based on latent constraints previously unknown to the team. The alternatives should be raised in very general terms leaving the field open for elaboration or other suggestions by the informant. The changing conditions on the farm must be imagined into these technology previews, including the demographic characteristics of the farm household, the condition of the natural resource base on the farm, price changes in farm products and purchases, and changes of all 3 three types in the wider environment of the farm. The informant may anticipate these, but if not some prompting should be provided to explore the impact of such changes on adoptability and performance of suggested technologies.

This same type of exercise could apply if the informant names a constraint that the team judges to be ephemeral or realistically subject to removal. Then the question "what if that were changed?" could be used to postulate an alternative future condition for technology adoptability/performance.

3. INTERVIEW GUIDELINES FOR CHARACTERIZING FARM-ECOSYSTEM INTERACTIONS

The relationship of the farm to the larger ecosystem is important to agroforestry D&D for three reasons:

1. The need to better understand and cope with farming systems opportunities and limits that reside (or originate) in the next larger system of which the farm is a part.

2. The need in many projects (which currently apply a farming systems approach) to serve a broader client group than a particular type of farm household.

3. The need to analyse the combined use of private and public (or otherwise shared) resources in rural agricultural and forest production.

Two major topics of interest can provide focal points for discussion with land managers (unit managers) about the relationship of the land use unit to its surroundings. First, discuss dependence on local off-farm resources for satisfaction of basic needs, especially fuel and water, which

are often collected off-farm but nearby. Cash may also be earned from nearby off farm work [illegible] to local [illegible]. The degree of direct dependence on local off-farm resources can be established by asking about the relative amounts and the importance of the goods secured off-farm. Ask about who owns and uses these resources and about the terms of use, trade, purchase or collection. If possible try to get the farmer's impression as to the future reliability of the quality, quantity and accessibility of these resources.

The second related point is the reliance on local market services for transactions with external sources. Questions about where the household sells its goods, where it makes its purchases and what kind of items are traded, should be directed toward establishing the degree of interdependence between local farms and other land use systems and the degree of interaction with (or dependence on) outside sources of basic household needs.

As a complement to the farm interviews it is advisable to go to public plazas or similar gathering places with one who knows the settlement or town. Visit homes, if necessary, to conduct interviews and visit some businesses or market place locations if possible. Rely on local team members or guides to identify potential informants and request their participation in a discussion. The feasibility of doing this in a park, marketplace or business will vary with the cultural predisposition to talk to strangers under these circumstances and will also vary with the timing of the interview (e.g. crowding, noise level, presence of potential interviewees, etc.).

Once an introduction has been made, begin by discussing current conditions that relate to local production and livelihood of the inhabitants: the weather, this season's harvest, current prices in the market. Determine the length of time the informant has lived in the area, his/her place of residence, size and type of holdings, if any, and occupation. This should be accomplished if possible with general open-ended questions to avoid placing the informant in a defensive position. Ask more specific (but still open-ended) questions about the availability of food, water, fuel, shelter, employment, raw materials, labour, desired "imported" goods, and markets for local products. With respect to these topics, informants may be asked for their opinions on the general case for the community at large, their own case, and how the situation varies by group or location.

If interviews are being conducted in a public place try to stay out of earshot of other groups. Be particularly careful of mixing people of different socio-economic groups if small-group interviews are conducted, especially when treating issues such as employment, markets, and labour. Even among peers it is possible that responses to some questions may be biased by the informant's efforts to maintain his/her image.

A significant part of the information on farm-ecosystem interactions may also come from discussions with other qualified informants such as civil servants, extension agents, health and/or social workers. Reliance on any single agency (such as agricultural extension) should be avoided since this would bias both the content and the conclusions of information on

community needs and problems within the ecosystem. For example, the obstacles to adoption of new technology should also be discussed with public servants concerned with other evaluation criteria.

Some landless people and some who have very small farms and depend primarily on off-farm income should be interviewed, especially if their numbers are large and more so if the ecosystem analysis is being conducted within the context of a rural development project. To determine the condition as well as the current role of these people within the ecosystem, questions should address a wide range of topics: sources of cash and/or materials for fulfillment of basic needs; the degree to which these needs are met; problems or potentials for improvement perceived by the informants; and the degree and type of interaction with local land use systems and the larger system. Note types of activity, location, timing (if seasonal) and exchanges of goods/services/cash.

Ask about time of residence in the area and in their current home. Probe for predisposition to remain in the area and to engage in employment (on or off-farm) related to potential agroforestry technologies or land use changes. Present these alternatives as part of an array of future possibilities so as not to bias reponses. Encourage informants to suggest future alternatives or solutions to current problems, since this gives the team an idea of what people must need, want and are willing to do.

4. INTERVIEW GUIDELINES FOR AF APPLICATIONS TO SOIL AND WATER CONSERVATION OR WATERSHED MANAGEMENT

The rapid appraisal or diagnostic survey offers a vehicle for gathering pertinent qualitative information about the soil, water, vegetation animals and water resources of the region and the local ecosystem(s). Farm families and other residents often have considerable knowledge of the characteristics and behaviour of their environment.

It is advisable that these interviews be conducted by the whole team or at least by two members in order to utilize both social science skills and ecological knowledge.

It is particularly important, for design purposes later on, to diagnose the local perception of the soil and water management problems, as well as the characteristics, magnitude and trends of the problems. Moreover, the will and ability to apply specific conservation practices or technological solutions must be gaged, if possible, particularly with regard to agroforestry substitutes or supplements to standard practices.

Trends in the degradation of water and vegetation can also be identified and described, particularly by elderly residents. This type of information can indicate whether such trends are perceived as 'problems," and whether there is a market relationship to land use and management. This in turn indicates whether agroforestry technologies might be used for rehabilitation or stabilization purposes at the ecosystem scale.

For example, flood frequency and intensity, and its variation with land use over time, may be estimated for ungaged streams for information gained in interviews with reliable informants. This is best accomplished by independent questioning of several people, including 2 or 3 elderly residents who live near regularly observed streams or rivers of interest. Their description of flood crests should be related to recognizable features on or near the stream banks so as to allow location on topographic maps or aerial photographs later on. Other questions about flood frequency and characteristics can also be answered in qualitative terms. It is important to avoid leading questions about the trends involved or the potential relationship to land use.

It is best to broach the subject of the river, it's behaviour and it's history and then to let the informants relate their experiences, observations, impressions in a more or less uninterrupted fashion (if time permits and it information is relevant). If the information is not volunteered, some specific questions should be posed regarding the situation during the informant's childhood and young adult years. The answers can be compared later with statements about the current condition and behaviour of the stream. It is usually possible to determine: the highest flood on record or in memory, the relative frequency of lesser flood magnitudes, including before and after specific land use changes of interest, the approximate extent of the mean annual, 5 year and 10 year floodplains, the rate of channel erosion and changes over time, the relative amounts of sediment transported and deposited in stream or river channels during floods, the existence of seasonal water shortage problems, whether there are apparent effects from upstream land use, and whether residents relate watershed management or land use to stream behaviour, stream water quality, dependability of water sypply or damage to floodplain fields.

The historical development, probable causes and effects of prominent erosion features, such as gullies and landslips, or outcrops exposed by erosion, can also be ascertained in this manner. This is often an easier topic than river reviews, in watersheds, since farmers are usually more aware of such features and the time frame required for their analysis is relatively short by comparison. After establishing how long the person has lived on the farm in question determined whether the current features on or near the farm (or any, fully for example) pre-date his/her arrival.

The time of appearance and the conditions (land use, management, weather) under which a particular feature occurred may offer clues as to the cause. If he/she does not recognize such a feature as a "problem" per se it may be useful to probe for the reason.

If soil or water conservation programs have been promoted or introduced in the past it is usually important not to refer directly to erosion control or conservation practices until the farmer has had a chance to indicate his/her attitude towards land condition or specific features. Otherwise results are likely to be biased by "official line" responses known to be the "correct" answers. If the answers seem to be of this type interviewers can probe by asking about the labour and capital requirements for such practices, or by asking about where they have been applied and what have been the results. Also, one may ask if other farmers are implementing the recommended practices, and why (or why not).

The informant or the team may observe that significant effects exist but are felt primarily off-farm. In such a case the persons or groups most directly affected may be identified and interviewed, depending on the importance of soil erosion/land degradation within the context of the project. Such special interviews (on land degradation effects) can determine whether the effects are perceived, how serious they are (and are perceived to be), if those affected relate the problem to land use or to natural causes, if there are discernible historical trends in the occurance and/or magnitude of the effects, and what measures have been taken to combat/correct the problems (by whom, how, at what cost?).

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APPENDIX B-3

SAMPLE DIAGNOSTIC SURVEY FORM

LOCATION _____ DATE _____

FARMER'S NAME _____ INTERVIEWER _____

This survey guide assumes that the representativeness of the farm being surveyed has been more-or-less established by the Prediagnostic Working Group, but section 2 on resource endowment and utilization will assist the D&D Survey Team to accurately classify the farm and decide whether, in fact, the farm is representative of the selected land use system. (This will determine whether or not the interview is to be continued.)

ON ARRIVAL AT THE FARM: Greet the farmer, explain the purpose of the visit and ask him/her to take the team on a quick inspection tour of the farm. During this tour take note of prominent landscape features, general land use pattern and variations in soil type, crop stand, vegetation cover, farm infrastructure, etc.

During this tour initiate enquiries contained in sections 1 and 2 below. On completion of the farm tour and sections 1 and 2, the team should decide whether the farm is representative and whether or not to continue the interview. If the decision is not to continue, thank the farmer for his/her cooperation and depart gracefully.

Try to address specific enquiries to the most knowledgeable/appropriate household member.

1. LAND USE HISTORY

How long has the farmer been living in the area?

How long has he/she been farming this particular land?

What form of land use was practiced at the beginning of the period? What changes in land use have occurred? Why ?

What was the condition of the land at the beginning of this period? What changes in land condition (including vegetation changes, etc.) have occurred in the meantime?

2. RESOURCE ENDOWMENT AND UTILIZATION

2.1 *LAND*

Subdivide the holding in terms of the following land use types, ascertain the approximate area of each, and note any pertinent observations about the quality or quantity of particular land resources. Add other land categories as needed. Find out whether the farmer owns or makes use of other plots outside the immediate farm boundaries and be sure to include them in the survey. Note also the amount, type and quality of water resources on the farm (or, if none, the nature of and distance to off-farm sources). Check land tenure

Land Use Type	Approx. Area	Observations/Notes
rainfed cropland		
irrigated cropland		
pastures		
rough grazing land		
orchards		
woodlot/forest land		
home compound		
_____		
_____		
_____		

Water sources on farmland:

Land tenure:

Additional Notes:

2.2 *LABOUR*

Ascertain the labour resources of the farm in terms of *source* (family, hired, community, etc.), *type* (adult male or female, children, others) engagement in *off-farm activities*, and *availability for farm activities*. Specify numbers in terms of persons and availability in terms of percentage of time available for farm work (or man-days if it is difficult to elicit).

Source and Type		Number	Non-Farm Activities	Availability for Farm Work
Family:	adult male			
	adult female			
	children			
Hired:	adult male			
	adult female			
	children			
Other (Specify)				

Additional Notes:

2.3 *OTHER RESOURCES*

Livestock (Specify)	Number	Use or Purpose	Observations/Notes

Farm machinery/implements

_____
_____
_____
_____

Other resources

_____
_____
_____
_____

2.4. *LIMITING RESOURCES*

Having ascertained the resource endowment of the management unit, the team should now try to determine which resources are most limiting for farm production. This step is broken down into two parts dealing with the main *production factors* and *land qualities*.

Production Factors

Which of the following factors constitutes the main limitation to farm production? If there is more than one limiting factor, try to rank them in order of constraint. Probe the farmer's response with such questions as: "If you wanted to increase the production of the farm, which of the following would you need most? Next most?" etc. "For what purposes?"

Rank	Factor	Observations/Notes
____	Land	
____	Labour	
____	Draught animals	
____	Machinery/implements	
____		
____		
____		

Land Quality Limitations

Ascertain, through questions and direct observation, whether there are any qualitative limitations to production for the crops raised on the farm. This is to be done at a very preliminary and general level; more detailed examination of limiting constraints will be carried out as part of the trouble-shooting exercise in section 3. (See Appendix 3-9 for further guidelines.).

Climatic Limitations	Observations/Notes
_____	
_____	
_____	

Soil Limitations

_____

_____

_____

Topographic and Other Site Limitations

_____

_____

_____

Additional Notes:

3. PROBLEM IDENTIFICATION IN HOUSEHOLD PRODUCTION SUBSYSTEMS

This is a progressive, trouble-shooting type of exercise. First determine farmers production objectives with respect to each basic needs category, then ascertain what problems there are in meeting these objectives (the symptoms will usually be in the nature of supply shortages), then probe for possible causes of each problem (through a combination of question, direct observations and general discussion). See Appendices B-1 through B-9 for more detailed guidelines on specific diagnostic procedures.

3.1 *FOOD PRODUCTION SUBSYSTEM*

The focus here is on crops and livestock products grown for home consumption, and whatever is involved in growing them.

Production Objectives

Ascertain primary and secondary objectives with respect to the household's strategy for supplying itself with staple foods.

Production	Primary Objective	Secondary Objective
Staple food self-sufficiency	____	____
Supplementary production of staples	____	____
Purchase		
Purchase of most staples	____	____
Supplementary purchase of staples	____	____
Sale		
Sale of food cash crops	____	____
Sale of "surplus" food	____	____

Supply Problems

Seasonal shortages of staples occur:	only in bad years	____
	in most years	____
What season?	even in good years	____

To better understand the supply situation it may be useful fill out the following supply calendar for the main crops and livestock products related to food supply problems. Check discrepancies between times of main consumption, harvest and purchase. (Indicate times in months or seasons)

	Main Times of			
Main Foods	Consumption	Harvest	Purchase	Observations/Notes

Diagnosis of Causal Factors Responsible for Food Supply Problems

Detailed guidelines for the trouble-shooting analysis of possible causal factors involved in the the generation of food supply problems are given in Appendices B-1 through B-9 (see especially B-6). Most of the contributing causes will fall into the following categories. Add other categories and notes as required. Check as applicable and give explanatory notes (why, when, how, etc.).

CROP PRODUCTION

	Causal Factors	Explanatory Notes
____	Land shortage	
____	Labour shortage	
____	Draught power	
____	Moisture deficiencies	
____	short growing season	
____	unreliable timing of rains	
____	midseason moisture stress	
____	Poor infiltration of rain	
____	Low water holding capacity	
____	Poor rooting conditions	
____	shallow soils	
____	poor structure/consistency	
____	poor drainage/aeration	
____	Tillage problems	
____	workability	
____	rocks, stones, roots	
____	Soil nutrient deficiencies	
	specify:	
	evidence:	
____	Soil erosion	
____	gully	
____	sheet	
____	wind	
____	Other hazards	
____	flooding/waterlogging	
____	salinization	
____	soil toxicities	
____	weeds	
____	crop diseases	
____	insect pests	
____	other pests	
____	theft	
____	Inadequate supply of inputs	
____	Inadequate knowledge or skill	
	Other factors:	
____		
____		
____		

LIVESTOCK PRODUCTION

Problem/Causal Factors	Season	Observations/Notes
____ Weight loss or low rate of gain		
____ Low milk production		
High mortality		
____ unweaned animals		
____ adult animals		
____ Low reproduction rate		
____ Land shortage		
____ Labour shortage		
____ Water shortage		
____ Pasture shortage		
____ Browse shortage		
____ Fodder shortage (cut-and-carry materials, etc.)		
____ Poor quality of feeds specify which:		
____ Pasture degradation		
____ Bush encroachment		
Soil erosion		
____ gully		
____ sheet		
____ wind		
____ Fire Hazzard		
____ Inadequate fencing		
____ Inadequate shade		
____ Inadequate veterinary services		

Other factors:

____

____

____

____

Measures Taken to Alleviate Problems in the Food Production Subsystem

How does the household cope with supply shortages? What strategies have they got for dealing with crop failure? What measures are taken to reduce or mitigate causal factors and constraints? Are these measures adequate? Probe and discuss until the team feels it has an adequate picture of household strategy with respect to the alleviation or avoidance of food problems.

3.2 *WATER SUPPLY SUBSYSTEM*

Water is not "produced" on the farm in the same way that the other basic needs are produced, but water management practices can affect the overall supply of water on the farm. Problems associated with indirect consumption of water on the farm (e.g. for crop and livestock production) are dealt with in other sections. This section deals with problems involved in the supply of water for direct household consumption.

	Problems/Causal Factors	Observations/Notes
____	Inadequate drinking water	
____	Inadequate water for other uses (bathing, etc.)	
____	Lack of water source on farm	
____	Time & distance to water source	
____	Poor allocation of water resources	
____	Poor watershed management	
____	overgrazing	
____	deforestation	
____	inadequate runoff control	
____	poor infiltration	
____	Lack of drainage and storage infrastructure	
____	High evaporation losses from surface storage facilities	

3.3 *ENERGY SUPPLY SUBSYSTEM*

First ascertain the household's present pattern of energy use by filling out the table below. Then probe for answers to the questions which follow.

	Type of Energy	- Uses - Cooking	Heating	Industry	- Means of Supply - Produce	Collect	Purchase	Adequacy of Supply
____	Firewood							
____	Charcoal							
____	Crop residues							
____	Dung							
____	Kerosene							
____	Gas							
____	Electricity							
	Other							
____								
____								
____								

Location of woodfuel (firewood, charcoal) sources?

How much time is spent in meeting the household's energy requirements?

Is the household using what it considers to be inferior energy sources? Why?

Are supply, time or cash expenses required for meeting energy needs considered to be a problem by the person(s) responsible (usually the women)?

Are energy shortages anticipated in the future?

3.4. *SHELTER SUBSYSTEM*

Shelter in various forms is another basic need (inclusive of the following shelter types and resources). Probe present status and unfulfilled needs.

Shelter Type or Resource	Present Status	Needs
Housing for people		
Housing for livestock		
Stores		
Windbreaks		
Shade		
for people		
for livestock		
for crops		
Fencing		
around cropland		
around grazing land		
for pens, bomas, kraals		
for security purposes		
Delineation/protection		
of boundaries		
of paths		
of catchment areas		
of drainage/irrigation features		
Building materials		
poles		
posts		
saw wood		
other		

3.5 *RAW MATERIALS SUBSYSTEM*

Identify the main cottage industries engaged in by household members whether for home consumption or sale (e.g. handicraft, food processing, carpentry, brick making, etc.). Next, identify the type of source (farm produced or purchased) of the main raw materials and ascertain whether there are supply problems now or any anticipated in the future. Record analysis of the causes of these problems.

Cottage Industry	Raw Material	- Source - Produced	Purchased	Problems/Causes

3.6. *CASH SUPPLY SUBSYSTEM*

Identify the main cash expenditures (household expenses, farm inputs, others) and the main sources of cash income. Note times of cash outflow and inflow (by month or season). Ascertain whether there are any difficulties in raising the cash to meet these expenses. (Identify time discrepancies between cash inflow and outflow and probe for problems.) Trouble-shoot the cash enterprises to identify the causes of these problems. (Some of the causes may have already been identified in the diagnosis of previous subsystems.)

	Expenditures	Time	Problems/Causes
____	Food		
____	Clothing		
____	Fuel		
____	Shelter		
____	Raw Materials		
____	Social expenses		
____	School expenses		
____	Crop inputs		
____	Hired labour		
____	Equipment purchase or rental		
____	Livestock purchase		
____	Veterinary expenses		
	Others		
____			
____			
____			

	Income Sources
____	Sale of cash crops
____	Sale of surplus foods
____	Sale of Livestock
____	Sale of cottage industry products
____	Off farm employment
____	Gifts and remittances
	Others
____	
____	
____	
____	

What are the main times during the year when cash becomes a bottleneck?

3.7 *SAVINGS/INVESTMENT SUBSYSTEM*

In addition to maintaining an adequate cash flow throughout the year, most households have savings or investment aspirations (e.g. to send the children to college, buy land, improve the farm, pay bride price or dowry, build a new house, move to town, or simply have something to sell to meet emergency medical expenses). Unfortunately, not all households with genuine savings aspirations have viable savings/investment enterprises. (Livestock serve this function in many systems; high value timber plantings could be another example of a savings/investment enterprise). First determine what savings/investment enterprises there are, if any, and then trouble-shoot them to identify problems and causes. (The lack of any savings/investment enterprise could itself be considered a problem).

There is no savings/investment enterprise (check if applicable).
Is this perceived as a problem? Why is there no such enterprise?

Existing Savings/Investment Enterprises	Problems/Causes

3.8 *SOCIAL PRODUCTION SUBSYSTEM*

The maintenance of good social relations within the community of immediate relevance to the household is an economic imperative and a basic human need. Many types of "social production", not easily classified under any of the above categories, come under the heading of this general umbrella term for all production activities and expenditures which are undertaken for explicitly social (or political) purposes. In some societies, this amounts to a large proportion of the total labour effort. In all societies, there will be "social expenses" of one sort or another. Rites of passage (birth, marriage, death, ascendency to political office, etc.) are common occasions of often unbelievably high expenditures for social purposes. Identify the major forms of social production and expenditure, the associated problems and (if the problems are significant) the causes of these problems.

Social Production/Expenditure	Problems/Causes

4. *FARMER'S ASSESSMENT OF AGROFORESTRY POTENTIAL*

Probe for farmer's free response to the suggestion that trees might play a role in the solution to some of his problems with questions like:

"What role can a tree/shrub play to solve some of the problems you have?"

"What kind of trees would you plant and where?"

"Why have you not planted them yet?"

Team members may also wish to probe the farmer's response to specific technical suggestions, explained to him/her in the field.

Notes:

Excerpt from

RESOURCES FOR AGROFORESTRY DIAGNOSIS AND DESIGN

STEP 6. DERIVATION OF SPECIFICATIONS FOR APPROPRIATE TECHNOLOGY

This is the final and most integrative step of the Diagnostic Stage. It is here that the design implications of all proceeding steps (including those of the Prediagnostic Stage) are analysed and spelled out in terms of a complete set *design specifications* for appropriate technology. To insure full treatment of all important design considerations, this Step has been broken down into four substeps. The notes entered in the corresponding Worksheets (6.1 - 6.4) will, collectively, constitute the terms of reference for subsequent design activities. That is to say, they will define the *design problem* to be tackled by the team at the Design Stage.

6.1. DEVELOPMENT STRATEGY

Before commencing on the design of technologies for improvement of the diagnosed land use systems, it is imperative that the team come to a general consensus on two overriding questions:

1) What general approach to take in developing the system?

2) How to deal with the time dimension in design?

These questions involve certain interrelated issues which, once resolved, would tend to define the general design strategy for the development of the system, thereby giving shape to subsequent design thinking.

What General Approach to Take in Developing the System?

The options can be succintly stated as follows:

a) improving vs. transforming approach

b) problem-solving vs. potential realizing approach

Neither of these issues necessarily involve mutually exclusive options, but thinking of them as partial options helps clarify important differences in emphasis which could lead to radically different designs. The first issue is whether it is best to take a design approach which aims at making discrete technical interventions in the system to bring about incremental improvements or whether the approach should aim at total transformation or substitution of the existing system by a new system of land use.

Generally speaking, experience has tended to indicate that total system transformation is rarely acceptable to farmers. On the whole, small-scale, traditional land users are far more likely to respond favourably to incremental improvements in their existing system. Since the "adoptability" criterion in technology design will, in the final analysis, be the determining one with regard to the practical impact if an otherwise good design, as a first principle of design, preference should be given to an "improving" approach (Torres, 1980; Raintree, 1983). (See Appendix C-1).

This injunction does not stand without qualification, however. There are situations in which a "transforming" approach to design may be indicated; notably, when dealing with modern, commercialised farmers who have demonstrated a willingness in the past to adopt innovations which have resulted in major changes in their pattern of land use, *or* when dealing with traditional systems that have been stressed to the breaking point and in which there is simply not much scope for improvements based on the traditional way of doing things.

As previously stated, the two approaches are not mutually exclusive. For example, in the case of a worn out traditional system where a transforming approach may be indicated, the designers can still try to incorporate familiar elements of the old system into the design for the new one. It is psychologically important, for a good rate of adoption, to give the farmers something they can relate to.

in general, traditional farmers will be more susceptible to a transforming approach to cash crop rather than subsistence food production. Only in extreme cases, should the team contemplate a design which changes the basic production objectives of the management unit with respect to food crops grown for home consumption. Food habits are notoriously hard to change, although, in historical perspective, most of the major food crops now grown in the world represent local introductions from past ages of exploration and contact. But this situation took a long time to bring about.

On the related issue of whether to aim at providing solutions to existing problems or whether to try to realize inherent potentials within the system for more optimum use of existing resources, the conservative, adoption-oriented strategy would tend to favour the problem-solving approach. In general, farmers are more likely to respond favourably to technologies which offer solutions to perceived problems than to those which do not. Again, the two strategies are not mutually exclusive. A good overall design might incorporate elements of both. Nevertheless, to maximize the chances of awakening the farmer's interest in adopting the new technology, perceived problem-solving elements should be incorporated into the design. Once the main "selling points" have been included, there is no reason, given the extreme design flexibility of multipurpose agroforestry trees and production systems, why additional design elements cannot be incorporated. These might address unperceived problems, or problems with a low priority for solution in the farmer's thinking, or perhaps latent resources potentials of the system. (See Appendix C-2 for further notes on multipurpose design strategies)

How to Deal with the Time Dimension in Design?

The main issue here is: static vs. dynamic design. Agroforestry systems are likely to be a long time on the ground. Once land is committed to a specific form of land use involving long-lived trees, the system cannot be lightly changed. Moreover, a certain amount of research and development work is likely to be necessary before most agroforestry technologies are ready for dissemination to potential users. It would be a disappointing use of resources to spend five or ten years perfecting a new agroforestry technology, only to discover that in the meantime the target had changed so much as to render the design obsolete. For these reasons it is necessary to give adequate thought to the time dimension in agroforestry and to favour, whenever possible, a dynamic approach to design.

Minimally, a dynamic design approach would involve taking account of the trends and sustainability problems inherent in the system (viewed in the context of its wider environment) and at least ensuring that the technologies envisaged leave scope for developments which may become necessary or desirable in the future. A more complete approach to dynamic land use design would involve actually designing a step-wise series of technology developments for the system. Obviously, this would be a much more ambitious design undertaking, but perhaps the effort would be worthwhile in certain situations. Although it is difficult, at present, to give examples of proven agroforestry designs which demonstrate the latter approach, some general design principles can be suggested (See Appendix C-3).

One of the possibilities which a dynamic approach to design would tend to open up is that of a phased introduction of both problem-solving and potential-realizing technologies, i.e. first the problem-solving technologies and then, once the system has been stabilized, technologies which realize potentials for improved resource use could be added. A useful principle to keep in mind in all of these considerations is the fact, as Collinson [illegible] has emphasized it, that the existing system is the base upon which changes can be most successfully grafted.

To complete the step, the team should record the conclusions of its deliberations on the [illegible] in the space provided in Worksheet 14.1. Brief notes, indicating the team's recommendations and rationale with respect to a general strategy for development of the target system will suffice as a basis for further design thinking. It should be recognized, of course, that once the team has actually embarked on the formal design exercise, many ideas may emerge on technical options for implementing the general design strategy and that these concrete ideas may prompt the team to reinterpret or reformulate the development strategy.

6.2. FUNCTIONAL POTENTIALS FOR PROBLEM-SOLVING INTERVENTIONS

Based on the preceding analysis of present supply problems, production constraints, causal syndromes and farmer strategies together with the team's assessment of sustainability problems and bearing in mind the problems in the wider ecosystem (Step 5 and the general development strategy for the system (Step 6.1), the next step is to identify points within the system where interventions might be made to remove, reduce or by-pass constraints, alleviate detrimental syndromes, and solve or mitigate supply problems. The perception of these *intervention points* will naturally come simultaneously with the perception of the *functional nature of the interventions* at each point.

As previously noted, a complete causal diagram of the system problematique can be an excellent aid to this process. If a causal diagram has been produced, the team simply studies the diagram and, for each node in the causal network, asks such questions as: Can we think of anything that could be done to remove, reduce or by-pass this constraint? What would be the functional nature of a constraint-reducing intervention? What does this tell us about the functional needs of the system at this point and, hence, the functional potentials for technology interventions? Particular attention should be given to interventions which could reduce the effects of the major problem-causing syndromes within the system. Attention should also be given to functional potentials for the solution of problems (listed in Step 5) which exist within the wider [illegible] environment of the focal system(s).

The above questions will bring the team very close to thinking about the specifics of design, but the full benefit of the team's diagnostic preparations will only be realized if it stretches the design imagination just a little while longer. This means keeping the suggestions abstract rather than going directly to concrete technological alternatives at this point. Only if the thinking about functional potentials is couched in broad, abstract terms will the team be able to appreciate the full range of functional alternatives. Once the jump is made to concrete technological suggestions, the discussion will take on a [illegible] lively dynamic of its own which might tend to obscure some of the less obvious, but no less

interesting, alternatives. In other words, the interventions should be expressed abstractly in terms of *functions*, rather than concretely in terms of *technologies*, at this point.

Once the team has exhausted all the thinkable possibilities for functional interventions in the system, these should be loosely prioritized, and listed as *functional specifications* for problem-solving technologies in Worksheet 6.2. Some selectivity and judgement should be exercised at this point (i.e. the team should not list trivial interventions), but the general tone of the thinking should not be overly critical just yet. The purpose of this step, after all, is to begin to open up thinking about alternatives (including non-agroforestry alternatives). The time for critical assessment will come later.

6.3. POTENTIALS FOR IMPROVED USED OF RESOURCES

Drawing on environmental and economic information gathered at various Prediagnostic and Diagnostic Steps (1 - 4), the focus at this Step is on deriving design specifications for improved used of existing or introduced resources (e.g. new crops more suited to the land qualities of the area, alternative uses of land or labour resources, etc.). The discussion of land evaluation methods in Appendix 8-9 may be helpful in thinking through the biophysical potentials of the area. Insights into potentials of a more socioeconomic nature (e.g. more efficient use of labour) will mainly come from the Diagnostic Survey. Economic potentials for new crops or increased production of existing crops may be discovered by reviewing information collected at Step 1 and 4.

Notes on the team's conclusions should be entered in Worksheet 6.3. There may be some overlap with the results of the previous Step.

6.4. POSSIBLE CONSTRAINTS ON POTENTIAL TECHNOLOGIES

One of the main advantages of a systematic diagnostic approach to agroforestry (or non-agroforestry) design, is the increased probability of developing good designs based on a *complete* set of design specifications. The design specifications could not be considered complete however, if the team fails to specify possible constraints inherent in the system on potential technologies; hence, the need for this final pre design step.

Needless to say, the assessment of potential constraints on new technology at this Step will be of a preliminary nature, since the team will not yet have considered specific candidate technologies. Once this is done (in Step 7) a more focused assessment of specific constraints pertinent to the candidate technologies will be undertaken.
The purpose of this initial assessment is to identify the *general* constraints which would apply to *any* candidate technology, so as to give greater focus to the initial design considerations (i.e. not to waste time on technological suggestions which have little or no potential for fitting into the existing system). It will always be possible to revise the assessment of constraints if, at a later point in the design process, it becomes apparent that the design itself may change the pattern of constraints on candidate technologies.

Attention should be focused on assessing two different kinds of potential constraints: *resource constraints* and *intervention constraints*.

Resource constraints are those which may limit the suitability or the performance of a candidate technology by virtue of the system's inability to satisfy one or more of the resource requirements of the technology, e.g. climatic or soil requirements, labour or capital requirements, management skill, etc.

Interactional constraints are those which may limit the suitability or performance of a candidate technology by virtue of adverse interactions with existing system components, e.g. faunal pests, a strong local prejudice against the planting of trees on cropland, an unfavorable interaction with labour requirements of existing enterprises at a critical period in the establishment or operation of the new technology, etc.

As the last example indicates, there is no absolute dividing line between the two types of constraints, since the unfavorable labour interaction could also be categorized as a resource constraint. Nevertheless, there are many possible constraints on candidate technologies which would be hard to classify as resource constraints; for these the category of interactional constraints has been suggested. The point here is not to come up with an airtight classification scheme but, rather, to avoid overlooking any potentially significant constraints on new technology, at least as far as possible in this preliminary assessment. The proposed categories should be used flexibly for this purpose.

Space is provided in Worksheet 6.4 to list the identified potential constraints as additional (negative) specifications for appropriate technologies. Completion of this Worksheet brings to a close the Diagnostic Stage of the D&D exercise.

APPENDIX C-8

WOODY COMPONENTS OF EXISTING AGROFORESTRY SYSTEMS*

The following tables describe the roles (productive and/or service) performed by prominent woody components of existing agroforestry systems in different regions and ecoclimatic zones of the developing world. This information is the result of documentary searches carried out as part of ICRAF's on-going global Inventory of Agroforestry Systems Project. The information contained in these tables will be continuously updated as the project progresses.

Table 1

Table 1 gives an alphabetical listing of prominent woody species by geographical region. The role of the tree or shrub species in the region is noted in terms of its food, fodder, wood, service or other function. Additional references are given for further information on each species (see references at the end of this appendix). The regions covered are:

Southeast Asia
South Asia (Indian Subcontinent)
North Africa, Mediterranean and Middle East
East and Central Africa (Humid Zone)
West Africa and the Sahel (Semiarid and Arid Zones)
American Tropics

Table 2

Table 2 focuses on prominent leguminous trees and shrubs, the system or practice in which they are used, the major eco-zone and the countries in which these uses have been recorded.

Table 3

Table 3 contains many of the same leguminous species but sorts them according to the predominant type of agroforestry system in which they are found (agrosilvicultural, silvopastoral, agrosilvopastoral), the specific practice involved, the country and the ecological zone in which these uses of the various woody legumes have been reported.

Note: The country information in Tables 2 and 3 is intended to be exemplary rather than definitive. You may well find the same practices in other countries of the same or other geographical regions.

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*Table 1 contributed by E.C.M. Fernandes. Tables 2 and 3 excerpted from P.K.R. Nair, E.C.M. Fernandes and P.N. Wambugu. 1983. Multipurpose leguminous trees and shrubs for agroforestry. Paper presented to the International Symposium on Nitrogen Fixing Trees in the Tropics. Sept. 19-24. Rio de Janeiro.

Table 1. Functional Roles of Woody Perennials in Existing Agroforestry Systems, by Region.

S.E. ASIA

* FAIR
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SPECIES	FUNCTIONS/USES: FOOD						FODDER				WOOD						SERVICES								OTHER									REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Sea Forage	Fuel Wood	Charcoal	Building Material	Wood for Utensils & Tools	Sawn Timber	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Other	Vanes	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Social	Ornamental	Other		
Acacia auriculaeformis											**	**	*			Pulp											*					*			48,49,66
Ailanthus altissima											*	*	*		*		*		*																48.
Albizzia falcataria											*		*			Pulp			*		*						*	*				*			2,4,49,
Anacardium occidentale	*	*						*											*															Cash crop	53,67
Artocarpus heterophyllus	*	*	*				*	*			*												*												4.
Casuarina equisetifolia											***	**	*	*	*	Pulp	***		*	*	***						*								48
Durio zibethinus	*	*																																	2,4,45,46
Eugenia aromatica						* (S)																				*								Clovas	45,67
Gliricidia sepium							*			**	*		*	*	*		*	*				*												Tonic to horses	2,48
Helicteryes isophylla							*				*						*		*	*															48.
Leucaena leucocephala		*	*				*			*	**	**	*		*		*		*		*	*													2,4,46,48,49,66,75
Litsea odorifera																									*							*			75.
Lychee chinensis	*																																	Cash crop	66.
Magnifera indica	*		*		*			*			*												*							*		*			45
Mangroves	*										**	**	**	*		Pulp			*								*			*				Aquaculture	48
Mutingia calabura	*							*			**			*															*			*			48
Sesbania grandiflora	*			*																															2,4,45,46,75 -
Tabebuia spectabilis		*																	*		*														2,45,67
Pithecolobium dulce	*			*			*	*		**	*		*				*	*	*		*						*	*				*			46,48,49
P. joringa		*			*																*														45
Psidium guajava	*		*											*											*										4,46.

Table 1. Cont'd

S.E. ASIA

* FAIR
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SPECIES	FUNCTIONS/USES: FOOD						FODDER				WOOD					SERVICES								OTHER									REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Bee Forage	Fuel Wood	Charcoal	Building Material	Wood for Utensils & Tools	Farm Timber	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Other	Manes	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Social	Ornamental	Other		
Samanea saman	*						*	*					*	*	*						*														
Sesbania bispinosa							*				*					Fuel	*	*	*		*	*										*			46,49
Syzigium aqueum	*						*	*			*																	*	*					48.
S. cumini	*						*	*		**	*		*	*			*																	4,46
Thea oleosa				**						**	*		*	*													*					*		46,48
																			*											*				16

Table 1. Cont'd

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SPECIES	FUNCTIONS/USES: FOOD						FODDER				WOOD						SERVICES								OTHER									REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Sap Forage	Fuel Wood	Charcoal	Building Material	Wood for Handles & Tools	Sawn Timber	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Other	Vanes	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Social	Ornamental	Other		
Acacia albida							**	*	*	*	*			*					*		*	*						*	*				*			20,27,49,51,73
A. cornicolaniformis							*				*	**	*	*		pulp			*		*	*	*					*	*				*			27,48,49
A. mearnsii											*	*							*		*	**					**									27,48,64
A. nilotica							*	*		*	*	*		*						*							*	**		*		*				13,15,18,27,48,64
A. senegal		*					*	*	*	*	*	**	*	*			*		*		*	*						*								27,48,49,62
A. tortilis							*	*	*	**	**	**	*	*					**	*	*											*			Gum arabic	3,13,18,27,47,48,49
Adhatoda vasica											*	*																		*						48,70
Aegle marmelos	*						*			*							*																			5,27
Ailanthus excelsa							*		*		*						*		*											*						3,18,27,48
Albizia falcataria							*				*				*	pulp					*															49
A. lebbek							*				*		*	*			*		*		*	*					*	*				*				3,27,48,49
A. odoratissima							**				*		*								*													Fodder tree Nepal	35
Anacardium occidentale	*	*						*		*	*								*				*			*								Cash crop - nut, wine	13,18,33,64,71
Anogeissus latifolia							*				*	**	*	**		pulp											*	*							Sericulture	48
Acacia catechu		*											*	*																		**				
Artocarpus heterophyllus	*	*					*						*	*																			*			27,43
Azadirachta indica							*				*		*	*			*					*	*			*	*								Insect repellent	48,64
Balanites aegyptiaca	*		(*)	(*)			*				*		*	*																*						13,80
B. rubroglati	*						*				*		*	*																**				Contraceptive antidote	3.
Bauhinia reginae							*				*		*	*					*										*							37.
Bassia latifolia			*	*	*						*		*	*			*		*				*						*		*			Wine	27,64

Table 1. Cont'd

S. ASIA

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SPECIES	FUNCTIONS/USES: FOOD						FODDER				WOOD						SERVICES							OTHER									REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Dry Forage	Fuel Wood	Charcoal	Building Material	Wood for Utensils & Tools	Esp. Timber	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Other	Manna	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Social	Ornamental	Other		
Cassia siamea							•	•			•						•					•	•									•			
Casuarina equisetifolia											•••	••	•	•			••• ••		•	•			A				•					•		Sandalwood host	5,27,48,73
Celtis australis	•			•			•				•		•						•																27,48,64
Ceratonia siliqua	•		•		•			•			•								•		•						•	•		•				Vit. C. fruits	13,27
Cordia dichotoma	•						•				•	•																						Wine	5,7,13,48,79
Dalbergia indica							•				•																								5,27
Emblica officinalis	•						•	•			•			•								•							•	•				Insect repellent	48,
Erythrina arborescens							•				•			•							•	•				•			•	•				Rich vit. C	5,27,48
Gliricidia sepium			•				•	•		•	•		•	•			•	•	•		•	•													33
Gmelina arborea							•			••	•	•	•																			•		Toxic to horses	5,18,27,39,48,49
Grewia oppositifolia							•				•		•	•																					27,48
Kydia calycina							•				•	•	•		•				•																27,65
Leucaena leucocephala							•		•	•	•	•	•				•		•		•	•													5,27
Mangifera indica	•							•			•			•																					5,8,9,27,48,49,50
Mangroves	•										••	••	•			pulp			•								•			•				Cash crop	18,
Moringa oleifera	•		•	•			•						•	•																				Aquaculture	48,
Morus alba	•						•				•																			•				Drum stick tree	5,18,27
Parkia roxburghii			•				•				•			•	•				•															Horticulture	5,18,27,35
Populus ciliata							•				•		•	•	•				•								•			•		•			27,
Prosopis chilensis	•						•	•	•		•		•	•			•	•	•	•	•														27,
P. cineraria							••	•			•	••	•	•						•	•											•			5,7,10,13,19,48,49, 54,63,
																																			5,10,18,19,48,54

Table 1. Cont'd

S. ASIA

* FAIR
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SPECIES	FUNCTIONS/USES: FOOD						FODDER				WOOD						SERVICES								OTHER								REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Sheets	Bee Forage	Fuel Wood	Charcoal	Building Material	Wood for Implements & Tools	Saw Timber	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Other	Vanes	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Begis	Ornamental	Other		
P. juliflora	*			*			*			*	*	**		*																				5,18,27,48
Quercus incana							*	*			*		*	*													*	*	*	*				Wine/spirit	5,10,13,18,19,48,56
Quercus lanuginosa							*	*			*		*	*																*					27
Salvadora oleoides	*			*			*				*	*		*																*					35
Schima wallichii							*				*		*	**																					5,27
Sesbania grandiflora	*		*				*	*			*					pulp	*	*	*			**													35
Syzygium cumini	*									**	*		*	*			**										*	*							5,18,27,48
Tamarindus indica	*	*	*	*			*	*		*	*	***	*	*							*						*					*			18,27,48
Zizyphus mauritiana	*						*	*			*	*		**				*	*									*		*		*		Beverage	5,13,27,49
Z. nummularia	*						*	*			*							*	*								*			*				Sericulture shellac	5,27,48
																		*	*											*					27,48,70

Table 1. Cont'd

N. AFRICA MED M.E.

* FAIR
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SPECIES	FUNCTIONS/USES: FOOD						FODDER				WOOD						SERVICES								OTHER									REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Bee Forage	Fuel Wood	Charcoal	Building Material	Wood for Blacksmith & Tools	Farm Tools	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Other	Manna	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Relig.	Ornamental	Other		
Acacia senegal							*		*		*		*	*																					
A. ligulata							*		*		*																								49,52
A. nolliferea							*	*		**	**										*														52
																												*							49
A. seligna							*				*						*			***															
A. seyal							**	**			**		*	*														*							48,49
A. tortilis							**	**			**	**	*	*					*	*	*							*							13,38,48,49
Arbutus unedo							**												**	*	*											*			13,48,49
Atriplex halimus			*				*												*																38
Balanites aegyptiaca	*						*				*		*	*					*	*															13,17,26,38,52
Cassia sturtii							**		*		*																							Beverage	13,38
Ceratonia siliqua	*							**		*	*								*		*														49,52
Chenopodium Ambrosioides				*			**										*		*		*							**		*		*			7,13,49,70
Elaeagnus angustifolia							*				*		*						*																13,38
Fraxinus oxyphylla							*				*								*																13,38
Gleditsia triacanthos							*	*			*		*						*																38
Melaeylon aphyllum							*				*	*					*		*	**															38
M. pereiscum							*		*		**	*							*	**														Sarcophyo + Halophyte	48
Pistacia crassifolia							**				*			*																					48
Pinus alba	*						*	*																											38
Olea europaea	*			*			*				*																								38
																													*	*					13,38

Table 1. Cont'd

N. AFRICA MED H.E.

* FAIR
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SPECIES	FUNCTIONS/USES: FOOD						FODDER				WOOD						SERVICES								OTHER									REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Bee Forage	Fuel Wood	Charcoal	Building Material	Wood for Utensils & Tools	Farm Timber	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Other	Water	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Beliefs	Ornamental	Other		
Pistachia palaestina		*					*																												
Prosopis juliflora	*							*		**	***	**	*	*							*														13,38,52
Quercus calliprinos							*	*					*	*											*		*	*	*						13,38,48
Q. coccifera							*	*					*	*																					38,52
Q. ilex							*	*					*	*																					38,52
Rhus trilobata	*			*																															38,52
Vitex agnocastris							*				*						*										*		*						13
Ziziphus lotus							*				*																					*			38
Z. spina-christi			*				*	*			**							*	*	*															38
																		*	*	*															38
																																			13,17,48

Table 1. Cont'd

EAC AFRICA

* FAIR
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SPECIES	FUNCTIONS/USES: FOOD						FODDER				WOOD						SERVICES								OTHER								REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (L)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Bee Forage	Fuel Wood	Charcoal	Building Material	Wood for Utensils & Tools	Farm Timber	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Other	Manna	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Social	Ornamental	Other		
Acacia albida							*	*	*	*	*		*	*			*		*	*	*	*					*					*			12,15,20,49,58,73,77
A. mellifera							*	*	*	**	*	**									*														
A. senegal							*	*	*	*	***	*	*	*					*	*	*						*	**							23,
A. seyal							*	*	*	*	*	*							*		*													Gum arabic	12,15,23,62
A. tortilis							*	*	*	**	**	**	*	*					*	*	*						*			*		*			12,23
Adansonia digitata	*		*					*						*																					12,21,23,25,47,60
Anacardium occidentale	*	*						*		*	*								*				*			*	*	*			**			23,62,58,76,80
Balanites aegyptiaca	*						*		*		*		*	*																			Cash crop	12,33,71
Borassus aethiopum	*		*										*	*																*			Bilharzia control	12,23,80
Butyrospermum parkii	*			*																														17,58,62,80
Cassia siamea											*		*	*			**		*														Bark for bee-hives	43,80
Casuarina equisetifolia											***	**	*	*			***		*	*			*				*							58,58,73
Cathe edulis							*				*		*	*													*							12,46.
Cordeauxia edulis		*					*																							*	**		Cash crop	12,43
Euphorbia tirucalli											*								*								*						Drought feed	49
Moringa indica	*					* (L)		*			*						*	*																12,23,81
Mangrove	*										**	**	*	*																*		*	Cash crop	23,
Prosopis chilensis	*						*	*	*		*		*	*			*		*	*	*						*	*		*			Agroforestry	12,37
P. juliflora	*							*		*	*	**					*				*													39,48,63,73
Rhus tomentosa	*						*		*		**		*																					19,48
Simmondsia chinensis																														*				12,23
Terminalia brownii							*		*				**	*					*						***					*			Cash crop	29,41
																														*				12,25,35

Table 1. Cont'd

E&C AFRICA

* FAIR
** GOOD
*** EXCELLENT

FUNCTIONS/USES

SPECIES	FOOD						FODDER				WOOD						SERVICES								OTHER									REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiments (C)	Leaves	Fruit/Pods/Seeds	Shoots	Bee Forage	Fuel Wood	Charcoal	Building Material	Wood for Utensils & Tools	Sawn Timber	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Other	Waxes	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Social	Ornamental	Other		
Zizyphus mauritiana	*						*	*			*	*		*				*									*								12,48

Table 1. Cont'd

W. AFRICA

* FAIR
** GOOD
*** EXCELLENT

SPECIES	FUNCTIONS/USES: FOOD						FODDER				WOOD						SERVICES								OTHER								REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiments (C)	Leaves	Fruit/Pods/Seeds	Shoots	Bee Forage	Fuel Wood	Charcoal	Building Material	Wood for Utensils & Tools	Farm Timber	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Polish	Other	Veneer	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Social	Ornamental	Other		
Acacia albida							•	•	•	•	•	•	•	•					•	•	•	•					•					•			12,20,48,73,77
A. senegal							•	•	•	•	•	••	•	•					•	•	•						•	••						Gum Arabic	12,23,62
A. seyal							•	•	•	•	•	•							•		•														12,23
A. tortilis							•		•	••	••	••	•	•					••	•	•						•			•		•			12,21,23,25,47,68
Balanites aegyptiaca	•		•	•			•	•	•		•		•	•																•					12,23,80
Borassus aethiopum	•		•										•	•																					12,62,80
Cassia siamea											•		•	•			••		•															Toxic to sign	34,73,
Ceratonia siliqua	•	•						••											•		•								•			••		Coffee substitute	49,79
Chrysophyllum albidum	•										•		•	••																•					34,54
Cola acuminata		•					•		•																						•			Stimulant-caffeine	34,45,54
Sacrophrynum schultzii	•						•	•																							•				34,54
Elaeis guineensis	•			••									•	•																	••			Wine	34,45,54
Euphorbia balsamifera																	•	•	•																62
E. tirucalli											•						•	•	•																81
Ficus capensis			•				•	•			•																							Bat Roost	11,54
Garcinia kola		•		•									•	••																					45,54
Gliricidia sepium							•				•		•	•				•	•		•	••						•			•				1,59
Irvingia gabonensis	•	•				• (S)					•		•	••																			Toxic to horses	34,54
Leucaena leucocephala							•	•		•	•	•							•		•	••													8,9,48,49
Mangroves	•										••	••	•	•					•								•	•		•				Aquaculture	48

Table 1. Cont'd

W. AFRICA

* FAIR
** GOOD
*** EXCELLENT

SPECIES	FUNCTIONS/USES: FOOD						FUEL				WOOD						SERVICES							OTHER								REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Sap Forage	Fuel Wood	Charcoal	Building Material	Wood for Utensils & Tools	Farm Implt.	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Other	Manna	Essential Oils	Tannins (T) Dyes (D)	Gum	Fibres	Medicinal/Drugs	Cultural, Ritual Magic	Ornamental	Other		
Parkia biglobosa	*		*	*			*	*													*	*												7,20,43,80
P. speciosa	*		*				*	*											*		*												Beehive station	
Piaranocarpus milbredii			*				*						*	*	*																			7,45
Raphia species	*	*											**													*								34,54
Spondias mombin	*						**						*	*				*	*															45
Tamarindus indica	*	*	*				*	*	*	**	**		*	*																**		*		34,80
Treculia africana	*	*					*	*			*					Pulp																	Laxative drink	45,49
Elaeophorbia mauritanica	**						*	*			***	**	*	*				*	*	*							*			*				34,54
Z. spina-christi							*	*			**	**	*	*			*	*.	*	*														48
																																		48

Table 1. Cont'd

* FAIR
** GOOD
*** EXCELLENT

SPECIES	FUNCTIONS/USES: FOOD						FODDER				WOOD						SERVICES								OTHER									REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Dry Forage	Fuel Wood	Charcoal	Building Material	Wood for Utensils & Tools	Farm Timber	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Mulch	Other	Manna	Essential Oils	Tannins (T) Dyes (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Social	Ornamental	Other		
Acacia cyanophylla							•	•			•								•	••								•						A.Saligna	48.
Albizia lebbek							•				•		•	•	•						•	•						•							49
Alnus acuminata											•		•		•	•••nulg			••		•														
A. jorullensis											•		•		•								•											Coffee shade	11,48
Anacardium occidentale	•	•		•				•			•												•											Coffee shade	24
Bactris gasipaes	•	•											•	•					•				•		•										45,53
Brosimum alicastrum	•	•	•				•	•																										highly nutritious	11,45
Calliandra calothyrsus							•				•																								11,45
Copaifera langsdorffii																			••		•	•										•			48,49
Croton sonderianus																					•					••••				•				Dimol tree	73.
Elaeis guineensis		•		••••									•	•												••••								Kerosene tree	47
Erythrina berteroana																																		Wine	11,45
E. poeppigiana																	•				•														11.
Gliricidia sepium						•			••	•		•	•	•			••				•											•			11,49
Guazuma ulmifolia	•					•	•		••	•	•	•	•									••										•		Tonic for horses	48
Inga edulis									••																									Beverage	48
Inga vera																					•														11,49
Lonchocarpus species																		•			•													Coffee shade	11.
Leucaena leucocephala	•	•				•	•	•	•	•	•	•				•	•	•						•	•				••					Crosnoto fuegh	48.
Mangroves	•									••	••	•		•			•	•		•	••								•						8,9,11,48,49,50
Mimosa scabrella										•					nulg			•		•	•					•	•		•					Aquaculture	11,48
																															•				48

Table 1. Cont'd

AMERICAN TROPICS

* FAIR
** GOOD
*** EXCELLENT

SPECIES	FUNCTIONS/USES: FOOD						FODDER				WOOD						SERVICES							OTHER									REMARKS	REFERENCES
	Fruits/Pods	Nuts/Seeds	Vegetable	Oils/Fats	Starch	Spices (S)/ Condiment (C)	Leaves	Fruit/Pods/Seeds	Shoots	Bee Forage	Fuel Wood	Charcoal	Building Material	Used for Utensils & Tools	Farm Timber	Others	Windbreak	Live Fences	Soil Conservation	Dune Fixing	N Fixing	Organic Manure	Polish	Other	Vanes	Essential Oils	Tannins (T) Drug (D)	Gums	Fibres	Medicinal/Drugs	Cultural, Ritual Social	Ornamental	Other		
Mutingia calabura	*							*			**			*																				
Parkinsonia aculeata		*					*	*	*		*	*							*										*			*		42.
Pithecolobium dulce	*			*			*	*		**							*				*						*	*				*		48.
Prosopis alba							*	*			*		*	*			*		*		*													11,49
P. chilensis							*	*			*		*	*					*		*													49,56
P. juliflora	*						*	*		**	**	**	*	*					*		*											*		11,48,49,56
P. pallida							*	*		**	**	**	*	*					*		*													10,48,49,56
Samanea saman	*							*					*	*	*				*		*												Beverage	14,48,49,56
Simmondsia chinensis																																*		49.
Tecoma stans													*					*							***				*				Whole oil Substitute	29.
																																		11

Table 2. Some leguminous Woody Perennials Currently used in Tropical/Subtropical Agroforestry

SPECIES	SYSTEM/PRACTICE	MAJOR ECO-ZONE	COUNTRIES
Dalbergia sissoo	(SP)* CUT AND CARRY FODDER PROD.	TROPICAL HIGHLANDS	INDIA, NEPAL
Derris indica	(AS)* MULTIPURPOSE TREES ON FARMS	ARID/SEMI-ARID	INDIA
	(SP)* CUT AND CARRY FODDER PROD	" " "	INDIA
Diphysa robinoides	(AS) LIVEFENCES/SHELTERBELTS	HUMID/SUB-HUMID	COSTA RICA
Enterolobium cyclocarpum	(SP) SHADE/BROWSE TREES IN PASTURE	HUMID/SUB-HUMID	COSTA RICA
Erythrina abyssinica	(SP) LIVEFENCES/SHELTERBELTS	TROPICAL HIGHLANDS	ETHIOPIA
	(SP) CUT AND CARRY FODDER PROD.	TROPICAL HIGHLANDS	ETHIOPIA
	(ASP)* CROP/TREE/LIVESTOCK MIX AROUND HOMESTEADS	TROPICAL HIGHLANDS	ETHIOPIA
Erythrina poeppigiana	(AS) SHADE FOR COMMERCIAL CROPS	HUMID/SUB-HUMID	COSTA RICA
		TROPICAL HIGHLANDS	COSTA RICA
Gliricidia sepium	(AS) SHADE FOR COMMERCIAL CROPS	HUMID/SUB-HUMID	BRAZIL, COSTA RICA, PHILIPPINES
	(AS) LIVEFENCES/SHELTERBELTS	HUMID/SUB-HUMID	COSTA RICA, JAVA
	(AS) TREE GARDENS	HUMID/SUB-HUMID	JAVA
	(SP) CUT AND CARRY FODDER PROD.	HUMID/SUB-HUMID	PANAMA
	(ASP) CROP/TREE/LIVESTOCK MIX AROUND HOMESTEADS	HUMID/SUB-HUMID	JAVA
Inga edulis	(ASP) CROP/TREE/LIVESTOCK MIX AROUND HOMESTEADS	HUMID/SUB-HUMID	AMERICAN TROPICS
Inga jinicuil	(AS) SHADE FOR COMMERCIAL CROPS	HUMID/SUB-HUMID	MEXICO
Inga vera	(AS) SHADE FOR COMMERCIAL CROPS	HUMID/SUB-HUMID	PUERTO RICO, WEST INDIES
	(AS) AGROFORESTRY FUELWOOD PROD.	HUMID/SUB-HUMID	WEST INDIES
Lespedeza bicolor	(AS) MULTIPURPOSE SHRUB ON FARMLANDS	HUMID/SUB-HUMID	KOREA
	(AS) AGROFORESTRY FUELWOOD PROD.	HUMID/SUB-HUMID	KOREA
	(SP) CUT AND CARRY FODDER PROD.	" "	"
Leucaena leucocephala	(AS) SHADE FOR COMMERCIAL CROPS	HUMID/SUB-HUMID	NIGERIA, PAPUA N. GUINEA
	(AS) AGROFORESTRY FUELWOOD PROD.	HUMID/SUB-HUMID	PHILIPPINES
	(AS) HEDGEROW (ALLEY) CROPPING	HUMID/SUB-HUMID	NIGERIA
	(SP) CUT AND CARRY FODDER PROD.	" "	PHILIPPINES
	(ASP) WOODY HEDGEROWS FOR BROWSE, MULCH, GREEN MANURE AND SOIL CONSERVATION	" "	PHILIPPINES
Leucaena esculenta	(AS) SHADE FOR COMMERCIAL CROPS	" "	MEXICO
Mimosa scabrella	(AS) MULTIPURPOSE TREES ON FARMLANDS	" "	BRAZIL
		TROPICAL HIGHLANDS	BRAZIL
	(AS) AGROFORESTRY FUELWOOD PROD.	HUMID/SUB-HUMID	
		TROPICAL HIGHLANDS	BRAZIL
Parkia biglobosa	(AS) TREE GARDENS - Multispecies Multipurpose associations	HUMID/SUB-HUMID	CENTRAL AFRICAN REPUB.
Acacia albida	(ASP) CROP/TREE/LIVESTOCK MIX AROUND HOMESTEADS	ARID/SEMI-ARID	ETHIOPIA, NIGER
	(AS) AGROFORESTRY FUELWOOD PROD.	ARID/SEMI-ARID	NIGER, SENEGAL
	(SP) MULTIPURPOSE FODDER TREES	ARID/SEMI-ARID	ETHIOPIA, SENEGAL
Acacia auriculiformis	(AS) AGROFORESTRY FUELWOOD PROD.	HUMID/SUB-HUMID	PAPUA NEW GUINEA
Acacia mearnsii	(AS) AGROFORESTRY FUELWOOD PROD.	TROPICAL HIGHLANDS	JAVA, KENYA
	(AS) MULTIPURPOSE TREES ON FARMLANDS	TROPICAL HIGHLANDS	JAVA
Acacia senegal	(AS) AGROFORESTRY FUELWOOD PROD.	ARID/SEMI-ARID	SUDAN
	(SP) MULTIPURPOSE FODDER TREES	ARID/SEMI-ARID	KENYA, SUDAN
	(SP) SHADE/BROWSE TREES IN PASTURE	ARID/SEMI-ARID	KENYA, SUDAN
Acacia seyal	(AS) AGROFORESTRY FUELWOOD PROD.	ARID/SEMI-ARID	SUDAN, UPPER VOLTA
	(SP) MULTIPURPOSE FODDER TREES	ARID/SEMI-ARID	KENYA, SUDAN
	(SP) SHADE/BROWSE TREES IN PASTURE	ARID/SEMI-ARID	SENEGAL, SUDAN
Acacia tortilis	(AS) AGROFORESTRY FUELWOOD PROD.	ARID/SEMI-ARID	INDIA, KENYA, SUDAN
	(SP) SHADE/BROWSE TREES IN PASTURE	ARID/SEMI ARID	KENYA, SENEGAL, SUDAN
	(SP) MULTIPURPOSE FODDER TREES	ARID/SEMI-ARID	INDIA, KENYA, SUDAN

* AS = AGROSILVICULTURE, SP = SILVO-PASTORAL, ASP = AGRO-SILVO-PASTORAL

Table 2. Cont'd

SPECIES	SYSTEM/PRACTICE	MAJOR ECO-ZONE	COUNTRIES
Albizia falcataria	(AS) TREE FARMS	HUMID/SUB-HUMID	PHILIPPINES
Albizia gummifera	(AS) SHADE FOR COMMERCIAL CROPS	HUMID/SUB-HUMID	CAMEROUN
Albizia lebbeck	(AS) SHADE FOR COMMERCIAL CROPS	HUMID/SUB-HUMID	INDIA
		TROPICAL HIGHLANDS	INDIA
	(SP) CUT AND CARRY FODDER PROD.	HUMID/SUB-HUMID	INDIA
Albizia stipulata	(SP) CUT AND CARRY FODDER PROD.	TROPICAL HIGHLANDS	NEPAL
Alnus acuminata	(AS) SHADE FOR COMMERCIAL CROPS	TROPICAL HIGHLANDS	BRAZIL, COSTA RICA
	(SP) SHADE TREES IN PASTURE	TROPICAL HIGHLANDS	AMERICAN TROPICS
Andira inermis	(AS) SHADE FOR COMMERCIAL CROPS	HUMID/SUB-HUMID	BRAZIL, COSTA RICA
Cajanus cajan	(AS) MULTIPURPOSE SEEDS ON FARMLANDS	ARID/SEMI-ARID+HUMID/SUB-HUMID	INDIA
	(AS) LIVEFENCES/SHELTERBELTS	ARID/SEMI-ARID	INDIA
	(AS) AGROFORESTRY FUELWOOD PROD.	ARID/SEMI-ARID	INDIA
Calliandra calothyrsus	(AS) AGROFORESTRY FUELWOOD PROD.	HUMID / SUB-HUMID	JAVA
	(AS) MULTIPURPOSE TREES ON FARMLANDS	HUMID/SUB-HUMID	JAVA
	(ASP) WOODY HEDGEROWS FOR BROWSE, MULCH, GREEN MANURE AND SOIL CONSERVATION	HUMID/SUB-HUMID	INDONESIA
	(SP) CUT AND CARRY FODDER PROD.	HUMID/SUB-HUMID	JAVA
Cassia siamea	(AS) TREE GARDENS-MULTISPECIES. MULTIPURPOSE SPECIES ASS.	HUMID/SUB-HUMID	CAMEROUN
	(AS) AGROFORESTRY FUELWOOD PROD.	HUMID/SUB-HUMID, ARID/SEMI ARID	SUDAN
	(ASP) CROP/TREE/LIVESTOCK MIX AROUND HOMESTEADS	HUMID/SUB-HUMID	NIGERIA
Ceratonia siliqua	(SP) SHADE/BROWSE TREES IN PASTURE	ARID/SEMI-ARID	MIDDLE EAST
Colophospermum mopane	(SP) MULTIPURPOSE FODDER TREES	ARID/SEMI-ARID	ZAMBIA, ZIMBABWE
Parkia clappertoniana	(AS) TREE GARDENS Multispecies, multipurpose	HUMID/SUB-HUMID	NIGERIA
Parkia speciosa	(AS) TREE GARDENS	HUMID/SUB-HUMID	JAVA
Pithecellobium dulce	(AS) LIVEFENCES/SHELTERBELTS	ARID/SEMI-ARID	PHILIPPINES
	(SP) SHADE/BROWSE TREES IN PASTURE	ARID/SEMI-ARID	HAWAII
	(SP) CUT AND CARRY FODDER PROD.	" " "	PHILIPPINES
Prosopis africana	(AS) TREE GARDENS - Multipurpose. Multispecies associations	HUMID/SUB-HUMID	NIGERIA
Prosopis chilensis	(SP) SHADE/BROWSE TREES IN PASTURES	ARID/SEMI-ARID	BOLIVIA, CHILE, PERU
Prosopis cineraria	(AS) MULTIPURPOSE TREES ON FARMLANDS	" " "	INDIA
	(AS) AGROFORESTRY FUELWOOD PROD.	" " "	INDIA
	(SP) CUT AND CARRY FODDER PROD.	" " "	INDIA
	(SP) SHADE/BROWSE TREES IN PASTURES	" " "	INDIA
Prosopis juliflora	(AS) AGROFORESTRY FUELWOOD PROD.	" " "	HAITI
	(SP) SHADE/BROWSE TREES IN PASTURE	" " "	MIDDLE EAST
Prosopis tamarugo	(AS) AGROFORESTRY FUELWOOD PROD.	" " "	CHILE
	(SP) SHADE/BROWSE TREES IN PASTURE	" " "	CHILE
Pterocarpus erinaceus	(AS) TREE GARDENS - Multipurpose Multispecies associations	HUMID/SUB-HUMID	NIGERIA
	(ASP) CROP TREE LIVESTOCK MIX AROUND HOMESTEADS	HUMID/SUB-HUMID	NIGERIA
Samanea saman	(SP) SHADE/BROWSE TREES IN PASTURE	HUMID/SUB-HUMID	AMERICAN TROPICS
	(ASP) TREE/CROP/LIVESTOCK MIX AROUND Homesteads	HUMID/SUB-HUMID	NIGERIA
Sesbania bispinosa	(AS) MULTIPURPOSE TREES ON FARMLANDS	HUMID/SUB-HUMID	INDIA, VIETNAM
	(AS) AGROFORESTRY FUELWOOD PROD.	HUMID/SUB-HUMID	NORTH PAKISTAN
	(SP) CUT AND CARRY FODDER PROD.	HUMID/SUB-HUMID + ARID/SEMI-ARID	INDIA, PAKISTAN
	(ASP) WOODY HEDGEROWS FOR BROWSE, MULCH, GREEN MANURE, + SOIL CONSERVATION	HUMID/SUB-HUMID	INDIA, PAKISTAN, VIETNAM
Sesbania grandiflora	(AS) LIVEFENCES/SHELTERBELTS	HUMID/SUB-HUMID	JAVA

Table 2. Cont'd

SPECIES	SYSTEM/PRACTICE	MAJOR ECO-ZONE	COUNTRIES
Sesbania grandiflora (continued)	(AS) TREE GARDENS	HUMID/SUB-HUMID	JAVA
	(AS) SHADE FOR COMMERCIAL CROPS	" "	MALAYSIA
	(SP) SHADE/BROWSE TREES IN PASTURE	" "	JAVA
	(SP) CUT AND CARRY FODDER PROD.	" "	JAVA
	(ASP) WOODY HEDGEROWS FOR BROWSE MULCH, GREEN MANURE +SOIL CONSERVATION	" "	JAVA
	(ASP) CROP/TREE/LIVESTOCK MIX AROUND HOMESTEADS	" "	JAVA
Tamarindus indica	(AS) MULTIPURPOSE TREES ON FARMLANDS	HUMID/SUB-HUMID	INDIA
Trema orientalis	(AS) SHADE FOR COMMERCIAL CROPS	HUMID/SUB-HUMID	PHILIPPINES
	(AS) AGROFORESTRY FUELWOOD PROD.	HUMID/SUB-HUMID + TROPICAL HIGHLANDS	JAVA

Table 3. Woody Legumes by Agroforestry System and Practice

AGROFORESTRY			LEGUMINOUS SPECIES USED IN		
SYSTEM	PRACTICE	COUNTRIES	ARID/SEMI-ARID AREAS	HUMID/SUBHUMID AREAS	TROPICAL HIGHLANDS AREA
AGROSILVICULTURE	LIVEFENCES/SHELTER BELTS/WINDBREAKS	COSTA RICA		Gliricidia sepium Diphysa robinioides	Gliricidia sepium Erythrina abyssinica
		ETHIOPIA		-	-
		INDIA	Cajanus cajan		-
		INDONESIA (Java)	-	Sesbania grandiflora Gliricidia sepium	- -
		PHILIPPINES	Pithecellobium dulce	-	-
	MULTIPURPOSE TREES/SHRUBS ON FARMLANDS	BRAZIL	-	Mimosa scabrella	Mimosa scabrella
		INDIA	Cajanus cajan Dorrie indica Prosopis cineraria	Cajanus cajan Sesbania bispinosa	-
		JAVA	-	Calliandra calothyrsus	Acacia mearnsii
		KOREA	-	Leucaena leucocephala	-
		NIGER	Acacia albida	-	-
		SENEGAL	Acacia senegal		
		VIETNAM	-	Sesbania bispinosa	-
	HEDGEROW (ALLEY CROPPING) WITH FAST GROWING WOODY PERENNIALS	NIGERIA	-	Leucaena leucocephala	-
		INDONESIA (JAVA)	-	Calliandra calothyrsus	-
	TREE GARDENS Multipurpose Multispecies, associations	CAMEROUN	-	Senanec siamea Cassia siamea	-
		CENTRAL AFRICAN REPUBLIC	-	Parkia biglobosa Tamarindus indica	-
		NIGERIA		Parkia clappertoniana Prosopis africana Pterocarpus osyeusti	-
	SHADE FOR COMMERCIAL CROPS	NIGERIA	-	Leucaena leucocephala	-
		PAPUA NEW GUINEA			
		PHILIPPINES	-	Gliricidia sepium	Trema orientalis
		BRAZIL		Andira inermis	Alnus acuminata
		COSTA RICA		Inga edulis Inga vera Erythrina poeppigiana	Erythrina poeppigiana
		MEXICO	-	Inga jinicuil Leucaena esculenta	-
		MALAYSIA	-	Sesbania grandiflora	-
		PUERTO RICO	-	Inga vera	-
		W. INDIES	-		-
		CAMEROUN	-	Albizia gummifera	-
		INDIA	-	Albizia lebbek	-
	AGROFORESTRY FUELWOOD PRODUCTION	JAVA	-	Calliandra calothyrsus Trema orientalis	Acacia mearnsii Trema orientalis
		PAPUA NEW GUINEA	-	Acacia curiculiformis	-
		PHILIPPINES		Albizia falcataria Leucaena leucocephala	-
		BRAZIL	-	Mimosa scabrella	-
		PAKISTAN	-	Sesbania bispinosa	-
		W. INDIES	-	Inga vera	-
		SUDAN	Acacia senegal Acacia seyal	-	-
		NIGER	Acacia albida	-	-
		SENEGAL	Acacia albida	-	-
		INDIA	Cajanus cajan Prosopis cineraria		

AGROFORESTRY SYSTEMS	AGROFORESTRY PRACTICE	COUNTRIES	LEGUMINOUS SPECIES USED IN: ARID/SEMI-ARID AREAS	HUMID/SUBHUMID AREAS	TROPICAL HIGHLANDS AREA
SILVOPASTORAL	COMMERCIAL/ SHADE/BROWSE/ FRUIT TREES IN PASTURE	INDONESIA (JAVA)	-	Sesbania grandiflora	-
		ZAMBIA	Colophospermum mopane	-	-
		COSTA RICA		Enterolobium cyclocarpum, Samanea saman	Alnus acuminata
		SENEGAL	Acacia senegal		
		SUDAN	Acacia tortilis	-	-
		HAWAII	Pithecellobium dulce	-	-
		MIDDLE EAST	Ceratonia siliqua	-	-
		INDIA	Prosopis cineraria	-	-
		BOLIVIA	Prosopis chilensis	-	-
		CHILE, PERU			
		CHILE	Prosopis tamarugo	-	-
	MULTIPURPOSE FODDER TREES	KENYA	Acacia senegal		
		SUDAN	Acacia nilotica		
			Acacia tortilis	-	-
		INDIA	Dorris indica	Albizia lebbeck	
			Prosopis cineraria	Dalbergia sissoo	
			Sesbania bispinosa	Sesbania bispinosa	
		ETHIOPIA	Acacia albida	-	Erythrina abyssinica
		PHILIPPINES	Pithecellobium dulce	Leucaena leucocephala	-
		PANAMA	-	Gliricidia sepium	-
		INDONESIA (JAVA)	-	Sesbania grandiflora	-
		KOREA	-	Lespedeza bicolor	-
		NEPAL	-	Dalbergia sissoo	Albizia stipulata
AGRO-SILVO PASTORAL	WOODY HEDGE-ROWS FOR BROWSE, MULCH GREEN MANURE +SOIL CONSER-VATION	INDIA	-	Sesbania bispinosa	
		INDONESIA	-	Calliandra calothyrsus	-
		PHILIPPINES	-	Leucaena leucocephala	-
		INDONESIA (JAVA)	-	Sesbania grandiflora	-
	CROP/TREE/LIVE-STOCK MIX AROUND HOME-STEAD	ETHIOPIA	Acacia albida	-	Erythrina abyssinica
		INDONESIA (JAVA)	-	Gliricidia sepium	-
				Parkia speciosa	
				Sesbania grandiflora	
		NIGERIA		Cassia siamea	
				Pterocarpus osyeuxii	
				Samanea saman	

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SECTION 4. RELEVANT AGROFORESTRY EXPERIMENTAL APPROACHES

4.1 Main Notes

APPENDIX

SOME RESEARCH PROBLEMS CONSIDERED

BY

Peter A. Huxley

(Taken from Proc. IAEA Advis. Group. on Nuclear Techniques in the Development of Management Practices for Multiple Cropping Systems. IAEA Tech. Doc. 235, 1980. IAEA, Vienna).

SOME RESEARCH PROBLEMS CONSIDERED

Before going any further it may be as well to list some of the usual problems facing those designing agricultural or horticultural field experiments, and to note what added dimensions agroforestry may give to them.

1. Are we dealing with plant species which have an extensive range of germplasm available or is this still to be collected and evaluated?
   - In agroforestry the agricultural crops involved may well be in an advanced stage of selection or breeding but the woody species may not have been examined in any detail at all. Furthermore, they are likely to be out-breeding and therefore strongly heterozygous.

     Thus the research programme may need to be phased so that an initial supplementary investigation is made to select and screen suitable plant material.

2. Designs for field investigations may be simple or complex but they can always be made to yield more information if ancillary data are collected. There is now, certainly, a strong case to obtain some simple basic crop physiological information in order to help explain how "yield" has been obtained. The statistics to be collected have to be chosen with great discrimination, however, if the burden of work is not going to be excessive, especially as it usually has to be collected over a number of

consecutive seasons.

- In mixed cropping agroforestry systems these remarks apply with additional force as the key to productivity lies in the kinds and levels of plant interactions which are to be found. Depending on climatic variability, the number of experimental seasons required before any firm statements can be made about the response of agricultural crop or crops components has to be considered very carefully. The "yields" from woody components may take even longer to evaluate and then there is still the long-term effects on the environment to consider. All-in-all agroforestry experiments cannot be expected to yield information, other than of an interim nature, for many years.

3. When experimenting with agricultural crops the "time-of-sowing" is important as there is now considerable evidence for many tropical crops that late sowing can seriously reduce yields. When we come to consider mixed cropping there may be a complex and staggered series of sowing times. The reasons for this may be many: it may be because of the ways in which the growth and development of the individual species are related to seasonal changes in climate, it may be moderated by farmers' preferences for planting food before cash crops, or for obtaining the harvest of a particular species at an

appropriate time in his social life, or it may be decided by labour peaks, etc. etc.

- In agrotorestry systems a further consideration may be the phenology of the woody perennial component. There is very wide range of plant behaviour with regard to flushing, and leaf fall and, as the activity of the woody species is very relevant to the success or failure of any herbaceous crop (or grass) sown beneath it, this is an important factor to consider. Additionally, many tree and shrub species have seed dormancy and or some viability problems. Agricultural crops are not encumbered with such problems as they have been eliminated to a large extent in breeding and selection programmes.

4. In mixed cropping experiments with agricultural crop species the yield of any plant component in the system may depend very much on what happens to it in its early stages of growth.

- In agroforestry systems some species of trees and shrubs could have an extended juvenile phase. If such species are to be utilized for their fruits or seeds then the management of the system during the early stages may affect this. Furthermore, if more than one woody species is used in this way, and they have different juvenile periods, full comparisons will not be possible until they have all matured and some

into even bearing. Even at this stage 'bi-ennial bearing' may add greatly to the year-to-year variability of experiments.

There may well be a case, therefore, to split agroforestry experiments so that one set of investigations looks into what is happening in the early stages of growth and another set compares mature plants.

If the woody species are to be used for fruits and seeds then the nature of the breeding system and the possibility of incompatibility mechanisms has to be borne in mind.

5. Mixed cropping systems are often stated to confer benefits in terms of pest management.

- Pest management, especially of weeds, may be very difficult in mixed cropping systems with a "permanent" woody component. Generally speaking herbaceous weeds will be less of a problem the more dense the canopy of the woody plant component in the system. But this approach is self-defeating if there is an agricultural crop being grown beneath from which a regular high yield is expected.

  Woody perennial species tend to build up their insect pest and disease problems with time and these are more difficult to control chemically because of the plant habit and form. Interactions between woody and annual plant species in terms of pest management seems to be a field in which there is,

as yet, very little experience. Devising adequate measures of control at the start of an agroforestry experiment, when the problems have not even been defined, is something of a challenge.

6. Harvesting is nearly always more difficult in mixed cropping systems unless individual plants are very widely spaced

   - Where woody species are involved, and these are to be lopped or cut down at regular intervals, then the problems of harvesting may be greatly intensified.

7. In field experiments it is usually desirable to keep the variability within each treatment roughly equal. Indeed, the premises on which the analysis of variance is based demands that this is so. Even if transformation of the data can be made to achieve homogeneity of variances there can well be problems in mixed cropping experiments; especially where one plant component is environmentally less well-suited than the others, or it is subjected to a treatment which may adversely affect its growth.

   - Woody perennial species are commonly highly variable in almost all characteristics during their early stages of growth. This applies with even more force to the onset of fruiting and the development of yield when, with some species, extreme variability can be experienced. There may be, therefore, no sensible

comparisons to be made for some years in an agroforestry experiment, until the woody species has "settled down".

8. The different species in a mixed cropping system may represent a considerable measure of diversity in size and form. If this is so it has to be taken into account when considering plot size and guard areas, which may need to be greater than is usual in agricultural experiments.

   - The problems of using adequate guard rows in agroforestry experiments is mentioned in the next section but additionally, it is common practice in horticulture with woody species, as it is in forestry, to carry out sequential thinning. In Agroforestry experiments the question of maintaining a standard plant arrangement (as distinct from plant population and rectangularity) is a fact of considerable importance with regard to equalizing the interactions with an agricultural crop. If thinning is envisaged it must therefore be done so as not to affect plant arrangement, or there must be some means by which it can be taken into account if it does so.

4.2 Practical Exercises

4.3 Supplementary Materials

ICRAF

ICRAF/USAID AGROFORESTRY COURSE

Nairobi, 1-18 November 1983

PRE-COURSE FORM

Please, fill this form and return to the course Coordinator on Registration Day.

1. NAME .....

2. YOUR PRESENT JOB. Give a short description of your main tasks and responsabilities.

.....

.....

.....

.....

.....

3. THE PEOPLE WITH WHOM YOU WORK. Tick the boxes to show the frequency with which you meet them in your work.

PEOPLE	OFTEN	SELDOM	NEVER
Students			
Researchers			
Planners			
Instructors/Professors			
Members of local community			
Others (please, specify)			

4. YOUR FUTURE CAREER. Indicate the direction in which you expect your professional career to develop in the next few years.

I expect to remain as .....

.....

I expect to become a .....

5. THE AGROFORESTRY COURSE. Write a short statement (40-50 words) on how you would like to benefit from the course.

6. YOUR PARTICIPATION IN OTHER TRAINING EVENTS. List the training events (programmes not leading to a degree) you have attended in the last 5 years.

TITLE OR MAIN SUBJECT OF EVENT	DURATION	PLACE

7. AGROFORESTRY IN YOUR JOB. Thinking on your present work, select two specific topics/problems related to agroforestry for which you would like to seek information/alternatives/solutions/ guidelines.

Topic 1. (Write no more than 40 words)

Topic 2. (Write no more than 40 words)

ICRAF

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

(Post-Course)

EVALUATION SHEET

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

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

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

DAY	MONTH

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

TICK

YES	NO

1.3 Was pre-course information adequate?

TICK

YES	NO

1.4 Suggest any pre-course improvements.

_____

_____

_____

_____

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

TICK IN APPROPRIATE BOX

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

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

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

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

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

3.5 Suggested improvements.

_____

_____

_____

_____

_____

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

from 1-not adequate to 5-very adequate

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

4.12 Suggested improvements.

_____

_____

_____

_____

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

from 1-not adequate to 5-very adequate

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

5.6 Suggested improvements.

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

from 1-not satisfactory to 5-very satisfactory

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

6.6 Suggested improvements.

SECTION 7. Your General Comments about the course.

APPENDICES

LIST OF PARTICIPANTS

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CAPE VERDE

ICRAF SCIENTIFIC AND PROFESSIONAL STAFF

NAME	POSITION
Dr. Bjorn Lundgren	Director
Mr. Peter von Carlowitz	Forester
Dr. Till Darnhofer	Bioclimatologist
Mr. Karugor Gatamah	Secretary/Treasurer
Mr. Dirk Hoekstra	Farm Economist
Dr. Peter Huxley	Horticulturist/Agronomist
Mr. Richard Labelle	Information Officer
Dr. P.K.R. Nair	Agronomist/Soil Scientist
Mr. Richard C. Ntiru	Publications Officer
Dr. John B. Raintree	Ecological Anthropologist
Dr. Dianne Rocheleau	Geographer/Systems Ecologist
Dr. Filemon Torres	Range Management & Livestock
Prof. Anthony Young	Land Evaluation/Soil Science
Dr. Ester Zulberti	Training Officer
Ms. Esther Bulwanyi	Accountant
Mr. Erick Fernandes	Research Assistant
Ms. Lubaina Fidaali	Computer Programmer
Ms. Lucille R. Majisu	Documentalist
Mr. Dennis Wambuguh	Research Assistant
Mr. Peter N. Wambugu	Farm Manager
Mr. Patrick Robinson	Research Fellow
Dr. Michel Baumer *	Advisory Unit
Mr. Willem Beets	Advisory Unit
Mr. Peter Wood	Advisory Unit

INTERPRETERS

Japheth Kyengo

Veronica Ndunge

Lawrence Kyongo

Richard Mwendandu*

ICRAF SUPPORT STAFF WORKING FOR THE COURSE

Musa, Amina Secretary

Kuria, Michael

Gitao, Fred

* ICRAF Trainee

INVITED SPEAKERS

- Dr. Roger Kirkby
  Program Officer Crop and
  Production Systems
  International Development Research
  Centre (IDRC)
  Regional Office
  P.o. Box 30677
  Nairobi, KENYA

- Dr. Michael P. Collinson
  Regional Economist
  Centro International para el Mejoramiento
  del Maiz y Trigo (CIMMYT)
  (International Maize & Wheat Improvement Center)
  P.o. Box 25171
  Nairobi, KENYA

- Dr. P. Anandajayasekeram
  Regional Training Officer
  CIMMYT
  P.o. Box 25171
  Nairobi, KENYA

- Dr. Amare Getahun
  Senior Agroforester
  Energy Development International
  P.o. Box 62360
  Nairobi, KENYA

Training Course - ICRAF Orientation Course for Agroforestry Concepts, Practices and Methods (26-18 November 1983) Nairobi

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 1 (Tuesday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 2 (Wednesday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 3 (Thursday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 4 (Friday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 7 (Monday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 8 (Tuesday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 9 (Wednesday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 10 (Thursday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 11 (Friday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 14 (Monday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 15 (Tuesday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 16 (Wednesday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 17 (Thursday)

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

ICRAF/USAID TRAINING COURSE

AGROFORESTRY RESEARCH FOR DEVELOPMENT

Nairobi, 1-18 November 1983

DATE: November 18 (Friday)

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

COURSE ENDS