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AGROFORESTRY RESEARCH IN FARMING SYSTEMS PERSPECTIVE: THE ICRAF APPROACH

by

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1 INTRODUCTION

The International Council for Research in Agroforestry (ICRAF) is an autonomous, non-profit international research council with a broad mandate to undertake work within the tropical and subtropical regions "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" (ICRAF Charter).

Although, the generation of appropriate agroforestry technology is the ultimate objective of ICRAF's work, as a research council rather than an institute, at present ICRAF has neither the mandate/nor the resources to undertake large-scale independent field research on the CGIAR model. Rather, ICRAF seeks to accomplish the necessary technology-generating research through collaborative undertakings with national and international partners. Thus, although ICRAF maintains a small field station of its own in Kenya, mainly for purposes of demonstration, training and some small-scale research of a pilot nature, the Council's involvement in technology-generating research is almost wholly through "outreach" activities. The ultimate purpose of these activities is to strengthen the capability of national institutions to undertake meaningful agroforestry research on the scale that is required to meet the burgeoning global demand for sound agroforestry technologies.

Initially, the main thrust of the Council's work was on the conceptual and methodological development of agroforestry as a new and, many people would argue, long overdue branch of applied science, emphasizing a holistic approach to land management. Although this on-going work of

1. Diagnosis and Design Project Leader & Collaborative Division Head, respectively.

concept development is far from complete, in the opinion of a recent external review committee (Cummings *et al.* 1985) sufficient progress has been made to justify confidence in the general soundness of the agroforestry approach and a more aggressive role for the Council in research and development of agroforestry technology in the field. Consequently, at the present time the Council is becoming increasingly involved in the direct staffing and joint management of collaborative R&D projects with a growing network of partners.

2 OBJECTIVES OF AGROFORESTRY SYSTEMS RESEARCH AT ICRAF

In established fields of agricultural commodity research there are normally many validated technologies for improving the production of individual crops. Under these conditions, the main objective of farming systems research is to identify constraints to the adoption of existing technologies by farmers. If possible, such technologies are then adapted to meet the prevailing circumstances. In agroforestry, however, there are only a few research-validated technologies. Many promising agroforestry technologies, whether found in existing farmers' practice or newly conceived by researchers, require considerably more research attention before they can confidently be recommended for wider adoption.

A systems approach appropriate to agroforestry, therefore, must be able to define the role of various agroforestry components in overcoming diagnosed land use problems, specify the desirable component characteristics, and indicate appropriate spatial arrangements and management practices. In other words, it must go beyond diagnosis to the *design* and evaluation of notional technologies, from which research needs can then be derived. Accordingly, the main objectives of agroforestry systems research at ICRAF are:

1) to inventory and catalogue existing agroforestry systems, compare their strengths and weaknesses, and evaluate their potential for improvement and extrapolation to other areas;

2) to develop a practical and effective methodology for the diagnosis of agroforestry-related land management problems and design of appropriate agroforestry systems (at varying scales of analysis with ancilliary tools and methodology modules);

3) to utilize the above methodologies and comparative perspectives on agroforestry systems to identify priorities for agroforestry research and actively support the development of technology generating research networks.

3 STATE OF THE ART

Agroforestry may be defined, following Lundgren (1982), as an approach to land use in which woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately combined on the same land management unit with herbaceous crops and/or animals, either in some form of spatial arrangement or temporal sequence. To describe such an association as an "agroforestry system" implies that there are ecological and/or economic interactions among the different components.

"Agroforestry" is a new word representing a new focus of organized scientific activity, but the practice of agroforestry is an ancient tradition among farmers in many parts of the world. As a new scientific field the novelty of agroforestry lies in the realization that many different land use systems and practices--some of which have traditionally fallen under the heading of horticulture, some under agriculture, some under forestry, and many others of which have not attracted any systematic attention whatsoever-- all share a common denominator worth exploring in a more systematic and scientific manner; namely, the role and potential of woody components to increase, sustain and diversify the production from the land (Lundgren 1982).

3.1 COMPONENT RESEARCH

Multipurpose Tree Inventory

Early identified as a key area of agroforestry research, the focus on multipurpose tree species (MPTs) has resulted in an ICRAF project to systematically inventory and catalogue the broad range of trees and shrubs which fit this category. To sharpen the focus on the most important species, a "systems approach" is evident in the concept of multipurpose trees adopted for this project:

> A multipurpose tree is a tree which clearly constitutes an essential component of an agroforestry system or of other multipurpose land-use systems. Regardless of the number of its potential or actual uses, a multipurpose tree has to have the capacity to provide in its specific function(s) in the system a substantial and recognisable contribution to the sustainability of yields, to the increase of outputs and/or the reduction of inputs, and to the ecological stability of this system. Only a tree which is kept and maintained or introduced into an agroforestry system especially for one or more of these purposes qualifies as a multipurpose tree (von Carlowitz 1984).

Although numerous useful publications on multipurpose trees have come out in recent years, much of the information is anecdotal or not specifically comparable. Hence, to build up a data base of reliable and comparable information a "Multipurpose Tree Data Sheet" was devised and distributed widely for completion by persons with expert knowledge of particular MPTs. To date, more than 600 records on over 400 trees have been entered into the MPT Data Base at ICRAF. This information is maintained on an IBM PC microcomputer at ICRAF headquarters in Nairobi and is accessible through a user friendly software package based on the "Knowledgeman" DBMS. It is used constantly to conduct interpretive searches and to answer queries about MPTs received by ICRAF.

A related activity at ICRAF has focused on the compilation of data on the feed value of tree fodders, following a literature review of the role of woody perennials in agroforestry with animals (Torres 1983). The data base, compiled by P.J. Robinson, contains over 1500 records on the chemical composition of fodder samples taken from different tree parts under various conditions. Maintained on "Dbase-II" software for 64 K CP/M operating systems, interpretive analyses and searches can be carried out in response to queries.

ICRAF has recently joined forces with the Nitrogen Fixing Tree Association in Hawaii to promote coordination among various MPT data bases in different parts of the world and to streamline future work in data collection, evaluation and dissemination. In addition ICRAF has recently begun work on a Multipurpose Tree Seed Directory which will serve as a practical, up-to-date register of sources of MPT seed supplies.

Methodology for Experimental Research on Multipurpose Trees

Another major research concern in agroforestry is the investigation of the properties of and interactions between MPT's and other plant and animal components in managed agroforestry associations. Although the methodology for this kind of research draws on standard disciplinary methodologies for investigation of the individual component types, a fully adequate and integrated methodology for experimental investigation of interactions among components of complex agroforestry systems is lacking. Consequently, this has been an area of concerted methodological effort at ICRAF.

These and other concerns relating to the investigation of multipurpose trees have recently been addressed in the form of a massive and periodically updated compilation of "Source Materials and Guidelines on Methodology for the Exploration and Assessment of Multipurpose Trees." See Huxley (1984) for an introduction to this material. Many of the technical issues of concern in this work were addressed in an international expert consultation on Plant Research and Agroforestry (Huxley 1983). More recently, an informal network has been formed to further this work.

Other Component and Disciplinary Research

It is beyond the scope of this paper to attempt to cover all of the various other component and disciplinary research activities at ICRAF. For an overview of these activities the reader is referred to ICRAF (1983c) and, of course, to the Annual Report of the Council. A current listing of ICRAF publications is available from ICRAF's Information and Documentation Programme.

3.2 SYSTEMS RESEARCH

Agroforestry Systems Inventory

One of the most important prerequisites of an effective effort to generate improved agroforestry technology is a systematic inventory of existing agroforestry systems and practices. This has been the objective of the global Agroforestry Systems Inventory Project (AFSI) at ICRAF, which is now nearing completion of its initial phase. Begun in 1982, the project has finished the first round baseline inventory, data analysis and cataloguing of the most prominent agroforestry systems in the following regions: Southeast Asia, South Asia, East and Central Africa, West Africa, the American Tropics and the Pacifc.

Records of the catalogued systems are maintained in an agroforestry systems register on microcomputer at ICRAF headquarters in Nairobi for consultation in response to queries. Collation and analysis of the inventory data have led to the proposal of a general purpose classification scheme for agroforestry systems and practices (Nair 1985a), although it is recognized that no single classification can purport to be definitive, since which of many possible classification schemes is preferred will depend upon the purposes of the analyst. Maintenance of the standardized inventory data on versatile DBMS software allows sufficient flexibility in the retrieval and interpretation of the data to accommodate a wide variety of analytical purposes.

In addition to the use of the AFSI data banks as a tool for answering specific queries about existing agroforestry practices, a number of system descriptions from different ecological and geographical regions have been published in an on-going series in *Agroforestry Systems* journal and also reissued in the ICRAF Reprint Series (Fernandes *et al.* 1984, Boonkird *et al.* 1984, O'Kting'ati *et al.* 1984, Fonzen and Oberholzer 1984, Evans and Rombold 1984, Bourke 1984, Liyanage *et al.* 1984, Johnson and Nair 1984, Allen 1985, Escalante 1985, May *et al.* 1985). Special purpose analyses using early AFSI data have also been published (Nair *et al.* 1984, Nair 1985) and undoubtedly others will be forthcoming as the data base becomes fully operational. Since it is unlikely that an inventory of this type can ever be considered finally completed, the intention is to maintain and update the AFSI files continuously as new information comes in. Further analytical work is planned with the inventory data to identify promising agroforestry systems for in-depth study, to assess the extrapolability of such systems, and to identify directions for system-improving research.

Diagnosis and Design of Agroforestry Systems

A "systems approach" was mandated to ICRAF from the very beginning and written into its institutional charter. ICRAF's founders felt it was impossible to deal with a field of the complexity and scope of agroforestry without adopting a systems perspective. The task of developing one was felt to be especially important for a new field like agroforestry. Otherwise, lacking an established research tradition of its own and without the benefit of a holistic perspective on the land use potentials of agroforestry, the fledgling interdisciplinary science was in danger, during the critical "proof of concept" period, of squandering its limited resources on *ad hoc*, piecemeal research (Steppler 1981). Eschewing disciplinary or "pet technology" biases in the identification of research priorities in agroforestry, ICRAF began work in 1981 on the development of a farming systems type of approach, especially designed to meet the needs of agroforestry (Steppler and Raintree 1983).

The development, still continuing, of what came to be known as the "Diagnosis and Design", or "D&D", methodology has been recorded in numerous documents to date (ICRAF 1982, Raintree 1982, Lundgren and Raintree 1983, Hoekstra 1983, ICRAF 1983a,b, Raintree 1984a,b, Rocheleau 1984, Huxley and Wood 1984, Hoekstra 1985, Young *in press*). Some illustrative case studies have been published (Raintree 1983a, Torres and Raintree 1984, Hoekstra 1984, Rocheleau and van den Hoek 1984) and a more complete volume of case materials is planned.

The logic of the D&D methodology is is at least implicit in most variants of the farming systems approach. It is, fundamentally, the logic of any problem-solving approach. In the development of the D&D methodlogy we have consciously striven to eliminate ideosyncratic elements and reduce the methodological framework to its essential "common sense" logic. In some cases this has resulted in the apparent addition of methodological steps (in the more detailed guidelines). In fact, what we have done is to make *explicit* certain aspects of the underlying logic which often remain *implicit* in other farming systems methodologies.

Table 1. Basic logic of the D&D discovery procedure (Raintree 1984a). See ICRAF (1983a, 1983b), Huxley and Wood (1984), Young (*in press*) for more detailed listings of suggested step-by-step procedures.

D&D STAGES	BASIC QUESTIONS TO ANSWER	KEY FACTORS TO CONSIDER	MODE OF INQUIRY
PREDIAGNOSTIC	HOW DOES THE SYSTEM WORK? (what does it look like, how is it put together, how does it function?)	PRODUCTION OBJECTIVES AND COPING STRATEGIES	SEEING THE SYSTEM
DIAGNOSTIC	HOW WELL DOES THE SYSTEM WORK? (what are its problems, limiting constraints and problem-generating syndromes?)	PROBLEMS IN MEETING SYSTEM OBJECTIVES (production short-falls, sustainability problems)	TROUBLESHOOTING THE SYSTEM
		CAUSES OF THE IDENTIFIED PROBLEMS	IDENTIFICATION OF INTERVENTION POINTS
DESIGN	HOW TO IMPROVE THE SYSTEM? (what is needed to improve system performance?)	SPECIFICATIONS FOR PROBLEM SOLVING OR PERFORMANCE ENHANCING INTERVENTIONS	ITERATIVE DESIGN AND EVALUATION OF ALTERNATIVES
PLANNING	WHAT TO DO TO DEVELOP AND DISSEMINATE THE IMPROVED SYSTEM? (what specific R&D & extension actions are needed?)	RESEARCH AND DEVELOPMENT NEEDS, EXTENSION NEEDS	RESEARCH DESIGN, PROJECT PLANNING

Assuming familiarity with the general FSR approach, it will suffice simply to highlight the most distinctive features of the D&D methodology. As compared with other farming systems methodologies, the diagnostic and design procedures for agroforestry are generally charactertized by :

1) wider diagnostic scope
2) a more deliberate connection with the objectives of the land user
3) a variable scale of application
4) a more elaborate technology design step
5) greater emphasis on the iterative nature of the basic D&D process

Diagnostic scope

All extant diagnostic methodologies in FSR tend to be limited in scope by the technological biases imposed by the institutions in which they have developed. They tend to be restricted in their sensitivities to those areas of the farming system which their technologies have the capability of affecting. In this respect, agroforestry poses relatively few limitations on the scope of the required diagnosis. In order to do justice to the technological scope of agroforestry there is not much about a farming system that an agroforestry diagnostician can afford to ignore. Moreover, in contrast to most other fields, agroforestry is as much concerned with conservation of resources as with increased production in farming systems. This is generally reflected as a greater emphasis on the sustainabilty of production. Table 2 gives an indication of the broad scope of potential agroforestry interventions in farming systems. At ICRAF we usually prefer to speak of "land use systems" rather than "farming systems" to allow greater scope for forestry and livestock-oriented components of land use, although for most purposes the terms are interchangeable.

Objectives of the land user

What is the best entry point for agrofaorestry diagnosis? What diagnostically accurate and yet somehow simplifying logic can we apply to streamline the diagnostic task? Collinson (1981) has shed light on one of the most widely employed entry points in FSR. Making use of the "pairing principle" (minimal diagnostic team = agronomist plus social scientist) the essential goal of the diagnostic exercise is to discover "leverage points" for technological interventions in the farming system. The first clue to the existance of a leverage point is the recognition by the agronomist of a technical "compromise" in the existing farming practice. He recognizes such compromises by comparing what he sees on the ground with the technical standards for recommended practices which he carries around in his head. The social science partner in the team then proceeds to investigate the farmer's reasons for doing things in this "compromised" way. Together they evaluate whether things have to be done this way or whether, in fact, there is an improvement that would be adoptable by the farmer.

Unfortunately this technique is not as useful in agroforestry for the simple reason that, in the current early stage in the development of the interdisciplinary field, we have no established standards of what the recommended agroforestry practice should be and, therefore, no simple way of recognizing technical compromises when we see them.

Table 2. Potential contributions of trees and shrubs to basic needs production subsystems. After Raintree (1983b), Raintree and Lundgren (1985).

FOOD SUBSYSTEM

1. Human food from trees (fruits, nuts, leaves, cereal substitutes, etc)
2. Livestock feed from trees (one step down the trophic chain)
3. Fertiliser from trees for improving the nutritional status of food and feed crops through a) nitrogen fixation, b) access to greater volume of soil nutrients through deep rooting trees, c) improved availability of nutrients associated with higher CEC and organic matter levels
4. Soil and water conservation effected by runoff and erosion contolling arrangements of trees in farming systems (indirect benefits through enhanced substainability of cropping systems).
5. Microclimate amelioration associated with properly designed arrangements of trees (e.g. shelterbelts, dispersed shade trees) in crop and grazing lands (indirect production benefits)

WATER SUBSYSTEM

1. Improvement of soil moisture retention in rainfed cropping systems and pastures through improved soil structure and microclimatic effects of trees)
2. Regulation of streamflow for reduction of flood harzard and more even supply of water through reduction of runoff and improvement of interception and storage in infiltration galleries through various watershed protection practices involving trees.
3. Protection of irrigation works by hedgerows of trees
4. Improvement of drainage from waterlogged or saline soils by phreatophytic trees.
5. Increased biomass storage of water for animal consumption in forage and fodder trees (higher water content of tree fodder in dry season)

ENERGY SUBSYSTEM

1. Firewood for direct combustion
2. Pyrolytic conversion products (charcoal, oil, gas)
3. Producer gas from wood or charcoal feedstocks
4. Ethanol from fermentation of high carbohydrate fruits
5. Methanol from destructive distillation of catalytic synthesis processes using woody feedstocks
6. Oils, latex, other combustible saps & resins
7. Augmentation of windpower using appropriate arrangements of trees to create venturi effects (windpower is proportional to the cube of wind velocity)

SHELTER SUBSYSTEM

1. Building materials for shelter construction
2. Shade trees for humans, livestock and shade loving crops
3. Windbreaks and shelterbelts for protection of settlements, cropland and pastures
4. Living fences

RAW MATERIALS SUBSYSTEM

1. Wood for a variety of craft purposes
2. Fiber for weaving industries
3. Fruits, nuts, etc. for drying or other food processing industries
4. Tannins, essential oils, medicinal ingredients, etc.

CASH SUBSYSTEM

1. Direct cash benefits from sale of above listed products
2. Indirect cash benefits from productivity increases of associated crops or livestock

SAVINGS/INVESTMENT SUBSYSTEM

1. Addition of a viable emergency savings or investment enterprize to farms now lacking one
2. Improvement of existing savings/investment enterprises (e.g. fodder for cattle as savings on the hoof)

SOCIAL PRODUCTION SUBSYSTEM

1. Production of goods for socially motivated exchange (e.g. cattle for bride price, ceremonial foods, etc)
2. Increased cash for social purposes (ritual expenses, development levies, political contributions, etc)

What then is the entry point for an agroforestry diagnosis? Faced with a diagnostic task of potentially great complexity, the D&D methodology focuses straightaway on assessing the performance of the system in meeting the objectives of its human managers. Thus, somewhat more explicitly than in most other farming system methodologies, it is the judgement of the farmer which provides the pivotal clue to problems in the system, supplemented, of course, by the observations and judgement of the diagnostic team in the field, particularly in matters relating to sustainability problems.

The basic principle behind this approach is applicable across the whole FSR field. Since we are dealing with land use systems which are, in the final analysis, organized by human purpose to accomplish certain objectives, it is only reasonable to begin the diagnosis of the system with the managers' own assessment of the system's performance in meeting its objectives. This method has the advantage of ensuring that the technical improvements suggested by the exercise are more directly relevant to the farmer's own perception of problems and priorities and, thus, more likely to lead to a favourable adoption response. All other things being equal, diagnostic methods which only indirectly address the objectives of the farmer and, instead, take their conscious starting point straight from the analysis of technical relationships in the farming system cannot offer the same assurances.

From the assessment of problems in meeting production objectives within each of the relevant "basic needs subsystems" (listed in Table 2), the logic of the D&D discovery procedure progresses through a trouble-shooting exercise, tracing out the causality of the identified problems, toward an identification of the leverage points, within the network of causal factors and constraints, at which agroforestry (or other) technological interventions could make significant improvements in the system. The general "system specifications" for an appropriate functional intervention at each of these points are then derived, followed by the detailed "technology specifications" and, finally, by a concrete design for technology capable of meeting these specifications.

Variable-scale diagnosis and design

In most cases the initial focus of D&D activities is on the household land management unit (the family farm, the household herd, etc.) for the reason that this is where most of the land management decisions are made. It must also be acknowledged, however, that the origin of many land use problems relevant to agroforestry cannot always be ascribed to individual farms and may, in any case, require a *larger-than-farm* approach to the design and implementation of solutions. Watershed problems are a typical case in point, where erosion processes on one farm may orginate or have impacts on other parts of the watershed. Adequate diagnosis and design of treatments for such problems cannot be approached as simply the aggregate of numerous household level D&D applications, but require an appropriately scaled approach of their own to complement the household level activity.

Likewise with smaller-than-farm scale or *intra-household* level problems and potentials associated with the internal division of production responsibilities and opportunities (usually along gender role lines). These aspects may be particularly significant for agroforestry in regions where women, in addition to a heavy burden of domestic chores, may also have primary responsibility within the household for subsistence food production, fuelwood supply and care of livestock, and where production decisions and responsibilitiles may operate in sexually segregated spheres (Hoskins 1980, Fortmann and Rocheleau 1984).

For these reasons a flexible, variable-scale approach to agroforestry diagnosis and design is required. Preliminary guidelines have been developed to assist users of the D&D methodology in the choice and implementation of appropriately scaled diagnostic methods (ICRAF 1983b). Case studies illustrating the elaboration and application of these methods at watershed and intra-household scales of analysis have also been published (Rocheleau and van den Hoek 1983, Rocheleau 1984).

The latest developments have focused on methods for very large scale "macro D&D" applications which involve the integration of D&D with land evaluation methods (Young *in press*). Macro-scale D&D applications are now underway at a country level to identify regionally signficant prototype technologies as inputs to the development of "master plans" for agroforestry in the various agroecological zones of the Agroforestry Research Network for Africa (AFRENA), which is described below. The AFRENA effort will be further strengthened by a buildup of ICRAF's capacity for macroeconomic and regional policy analysis. Through this regionally integrated approach to diagnosis and design we hope to avoid the trap of site-specificity into which many FSR programmes have fallen.

Technology design

In most farming systems work when one speaks of "design" what one is usually referring to is *experimental design*, whereas at ICRAF what we generally have in mind is *technology design*. This seemingly minor terminological difference belies a major difference in the emphasis of systems research in agroforestry as compared to other farming systems approaches.

This difference in emphasis is due to two factors. In the first place, in contrast to other forms of FSR, the role of the farming systems perspective exercise is not to decide which of many proven technologies it would be appropriate to "pull down" into the farming system for trial and adaptive research. In agroforestry there is no large stock of scientifically proven technologies to draw upon. In most cases the purpose of the D&D exercise is to envisage *what technologies ought to be developed*. This requires a much more elaborate technology design step than most other farming systems methodologies.

Secondly, in research on agricultural cropping systems (e.g. varietal introductions, fertilizer trials, etc.), the technology design problem is often relatively trivial, and so the attention of the researcher quickly moves on the more important question of experimental design. When an agronomist puts up a fertilizer trial or introduces a new variety of maize in an on-farm experiment, it is not necessary to spend much time trying to visualize what this new technology will look like. It will look like a maize field! In agroforestry, however, the design problem is far from trivial, since the integration of trees into farming systems for productivity and sustainability may take many different forms.

To arrive at an appropriate agroforestry design for a given farming system an answer is required for each of the following interrelated design questions:

1. **What function(s)** should the tree or agroforestry combination perform within the farming system?
2. At **what location(s)** within the farm or wider landscape should these functions be performed?
3. **What components** or component combinations are best used to perform these functions?
4. **How many** of each component are required to meet production targets?
5. **What precise arrangement** of components is envisaged? (details of spatial and temporal associations at a given location)
6. **What management practices** are envisaged in order to achieve the desired performance characteristics?

The iterative nature of D&D

The utility of the basic process of diagnosis and design does not necessarily end with its initial application in a farming system. Once the experimental prototype is in place and functioning in the system a new round of diagnosis is called for to evaluate the changed situation and to assess opportunities for further improvement. Indeed, given the innovative nature of most agroforestry research, it is unlikely that the first design will be the best and final design. What can be expected from the initial, usually "rapid appraisal", application of the D&D process is a design for a prototype technology that is *generally appropriate* to the land use system in question, but further R&D will normally be needed to make it *specifically appropriate*.

By insisting on the iterative nature of the process and making provision for successive phases of *rediagnosis* and *redesign* the D&D methodology seeks to institutionalize the feedback mechanisms necessary to zero-in on an optimized technology. As such, it becomes part of the "internal guidance system" of a consciensciously designed R&D project (see Figure 1).

4. ON-FARM AND ON-STATION RESEARCH

The complementarity of on-farm and on-station research is implicit in all farming system methodologies, but rarely is it made an explicit part of the logic of the methodology. In D&D we have tried to do this by stressing the necessary and complementary nature of the feedback provided by each type of research in the context of the iterative D&D process. It is too early for ICRAF to have had much experience with this aspect of the later phase of D&D applications but we envisage it working somewhat as follows in the R&D project context:

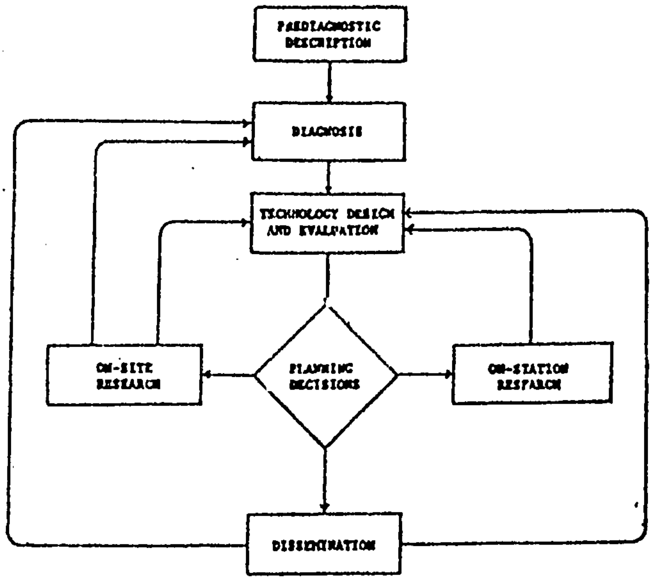

Figure 1. Components of project design incorporating the D&D process as part of the project's internal guidance system. Note feedback linkages.

Periodically, during the active R&D phase, the research team pauses to reconsider current plans in the light of accumulated experience, asking: "What have we learned from our on-farm work on the one hand, and our on-station work on the other, that will help us to improve the technology design?" From the on-station research come the results of investigations of component interactions under controlled conditions, component screening and breeding results, etc. From the on-farm research comes a general deepening of the diagnosis, which inevitably results from longer and more intimate exposure to the farming system, as well as information about new or revised design requirements, based on results of field testing of the experimental technology and on the updated diagnosis of the new situation. One of the most valuable kinds of feedback from on-farm research is the farmer's own evaluation of the technology and his/her suggestions for ways to make it more adoptable.

The feedback from these two complementary sources is then synthesised to come up with an improved design and a revised plan of research. Something like the process depicted by the feedback linkages shown in Figure 1 is implicit in most FSR work but the process is rarely carried out in a systematic way, although to do so could often result in a more coherent and cost-effective research programme.

Table 3 on the next page summarizes some of the main experimental characteristics of the various components of agroforestry systems. In view of the complexity of agroforestry systems and what would appear to be rather severe limitations on the use of conventional statistical and economic techniques in the evaluation of agroforestry systems, the role of *direct farmer evaluation* of technical innovations, and hence of on-farm trials, would appear to be that much more important for agroforestry than for simpler production systems (Fernandes 1985).

5 LINKAGES WITH NATIONAL PROGRAMMES

Collaboration between ICRAF scientists and multidisciplinary teams of national scientists in D&D applications for research planning purposes has been actively undertaken since 1982. Table 4 shows some of the results of these activities. A total of some 19 institutions from the agricultural, forestry and academic sectors have been actively involved in the project planning activities depicted in Table 4 (less formal collaborative activities with several other institutions are not shown). At the present time, six of the eight sets of research activities shown in Table 4 have been taken up for joint implementation by collaborating national institutions. Two of these projects are already on the ground and four are in the fund-searching phase.

Table 3. Characteristics of crops, livestock and trees and implications for experimental research on agroforestry systems. Adopted from Fernandes (1985) and Bernsten et al. (1983).

FACTOR	CHARACTERISTICS			IMPLICATIONS FOR AGROFORESTRY EXPERIMENTS
	CROPS	LIVESTOCK	TREES/SHRUBS	
Component arrangement	Generally standardized	Mobile/stall fed	Zonal, mixed, multistoried	Difficult to measure and control non-experimental factors
Life cycle	Generally less than 4 months	Generally over one year	Nearly always over one year	Increased cost, likelihood of losing experimental units
Production phases	Units generally synchronized	Units seldom synchronized	Units seldom synchronized	Difficult to find comparable units
Outputs	Grain, tuber, residue	Multiple outputs (meat, hides, milk, manure, power)	Multiple outputs (fuel, fodder, fruit, timber, poles, etc.)	Difficult to measure & evaluate treatment effect
Nonmarket inputs/outputs	Few	Many	Many	Difficult to value inputs & outputs, especially for protective roles
Experimental unit size	Small, divisible	Large, non-divisible	Large, divisible	Increased cost, risk to participating farmers
Local customs	Some social/ritual uses	Various taboos	Often complex tree tenure rules	Limitation on treatments
Management variability	Relatively low	High	High	Difficult to isolate treatment effects
Observation units	Many	Few	Few	Large statistical variability
Genetic compostion	Relatively homogeneous	Rel. homogeneous (domesticated)	Very heterogeneous (often wild)	Large statistical variability
Beneficial interactions	Crop residue for feed	Manure for crops	Fodder, mulch & green manure for crops, shelter for livestock & crops	Increased cost of more complex experimental design
Harmful interactions	Competition, allelopathy	Browsing damage, & trampling	Shade, competition, allelopathy	Increased cost of more complex experimental design

Table 4. Partial description of results from joint D&D exercises with national partners in ICRAF's Collaborative Programme, showing representative sample of agroforestry interventions suggested as focal points for national research programmes.

COUNTRY	ENVIRONMENT	PREDOMINANT LAND USE SYSTEM	MAIN AGROFORESTRY INTERVENTIONS
Philippines	Humid tropical low-lands w/ dry season	Subsistence oriented hillside plough agriculture with water buffalo for draught power	Hedgerow intercropping with N-fixing trees to control erosion & correct nitrogen deficiency associated with low maize yields
Malaysia	Permanently humid tropical lowlands	Government reforestation scheme with encroachment by small scale market oriented farmers	Joint production schemes designed to meet objectives of both farmers and foresters: 1) Timber trees alternating in contour strips w/ annual cash crops & pasture 2) mixed associations of timber trees and horticultural tree crops
India	Monsoonal subtropical to temperate montane environment in outer Himalayas	Subsistence farming on teraced hillsides with bullocks for draught power & water buffalo for milk	1) Hedgerows on risers for fodder & runoff control, 2) fruit trees on rear of terraces using labour released from fodder collection by #1, 3) improved management of fodder & fuel trees on eroded commons, 4) trials on minimum tillage w/ view toward reduction in numbers of unproductive bullocks to ease fodder pressure on forests & labour
Kenya	Subhumid to semiarid equatorial midlands with bimodal rainfall	Subsistence mixed farming with cattle for draught power & savings	1) Hedgerow intercropping with N-fixing, mulch & fodder producing shrubs for erosion control, moisture conservation, fertility maintenance & fodder for dry season feed gap, 2) rehabilitation of pod-producing trees in grazing land, 3) fruit trees for cash, 4) watershed protection with productive trees
Costa Rica	Subhumid seasonally dry vulcanic highlands of Central America	a) Small scale coffee-based subsistence farming b) Medium scale commercial mixed farming	a) Hedgerow intercropping for fertility maintenance & erosion control on steep slopes b) Timber trees in contour strips protected by living fencerows of fast gr[illegible]ing fodder trees, alternating with pasture, to arrest erosion and diversify production
Peru	Humid tropical lowlands in Amazon Basin	Semi-commercial bush fallow cultivation	1) Fallow enrichment by N-fixing trees to accelerate restoration of soil fertility & control of weeds, 2) hedgerow intercropping experiments with acid tolerant tree species, 3) high value timber & fruit trees on farm boundaries, in home gardens & intercropped w/ plantains for cash & longterm investment
Peru	Seasonally dry humid tropical lowlands in Amazon Basin	Commercial mixed farming & dairying	Fodder producing living fences to reduce capital requirement of rotational grazing on improved pastures and to supplement dry season feed resources for dairy herds

indirect influences on the research activities of international and associated national institutions which have participated in these project planning exercises are evident. Even before the formal project got underway, the North Carolina State University Tropical Soils Program at Yurimaguas adopted D&D recommendations to include research on hedgerow intercropping in its programme to develop low-input technologies.

Subsequent to other D&D missions, CIAT Tropical Pastures Program started screening for shade-tolerant leguminous pastures for the Amazon and CATIE commenced investigations of mulching with tree leaves. In the Philippines, a large World Bank sponsored upland development project has been using an adapted version of the D&D methodology to plan its agroforestry activities, with training support from the agricultural college team that participated in ICRAF's first D&D mission to the Philippines. On the NGO front, CARE has adapted the D&D methodology and put it to work in an agroforestry extension project in western Kenya, which will serve as a pilot for other agroforestry projects in CARE's worldwide network.

A number of factors combine to enhance ICRAF's role as a catalyst for collaboration among national institutions in joint agroforestry research. In the first place, ICRAF's staff represents the most comprehensive multidisciplinary team in the field of agroforestry and, operating in an interdisciplinary way under the umbrella of a "second generation" farming systems approach, this gives ICRAF an *institutional capability* which is unique in the field. What may be even more important, however, is ICRAF's inherent *neutrality* with regard to the traditional disciplinary biases and age-old conflicts between agriculture and forestry institutions, which enhances ICRAF's ability to function as a convenor of collaborative activies among organizations that might not otherwise be prepared to undertake joint endeavors.

On the international scene, it is fair to say that the collaborative role of most research centres tends to be limited in scope by their commodity focus. The broad scope of agroforestry technology poses fewer limitations in this regard and may qualify ICRAF as a less biased institution to integrate the efforts of international centres around common land use problems.

6 LOOKING AHEAD TO LARGER NETWORKS

Up to now, ICRAF has been able to gain experience with land use systems in a wide variety of environments and to establish a track record of institutional collaboration by taking a somewhat opportunistic approach to the selection of institutional partners within an ecological and geographical framework. The time for solving urgent development problems is running out, however, and a more comprehensive strategy is needed to promote research on the scale required to solve accelerating land management problems. To meet this need ICRAF has developed a networking strategy (Torres 1985) and is in the first stage of applying this strategy to the development of an Agroforestry Research Network for Africa (see AFRENA below).

ICRAF's Networking Strategy

Why networks? The rationale for networking in agroforestry can be summarized in three points:

1. Given the disciplinary nature of existing research institutions and the scarcity of resources, inter-institutional networks within and between countries could help assemble the multidisciplinary "critical mass" required for effective technology-generating research.

2. Countries sharing a common agroecological zone may also share common land use problems with similar agroforestry needs and potentials. Between-country networks could provide the organizational means of sharing in the work of technology generation, avoiding undue duplication of effort and making better use of scarce resources.

3. A zonal approach to training of national cadres within a region would provide a wider spectrum of land use problems, case studies and project sites for on-the-job training and comparison of alternative approaches to land use problems.

The principal objective of ICRAF's networking strategy is to *strengthen the capability of national institutions* to evaluate land use systems and identify their realistic agroforestry potentials, derive research plans from such evaluations, and carry out a coordinated programme of on-farm and on-station research aimed at meeting the country's need for various forms of agroforestry technology. In addition, the strategy calls for ICRAF to play a direct implementing role, together with selected IARCs, in the screening and development of improved woody components and prototype technologies (spatial arrangements and management practices) which can then be adapted to fit location-specific circumstances.

Programmes developed to achieve these objectives will be guided by the following principles.

1. *An ecozone scope for technology generation*, increasing the probability of matching agroecological circumstances and the possibilities for sharing of technological components;

2. *Inter-institutional cooperation at national and zonal levels*, providing the required multidisciplinary inputs and avoiding duplication in the use of scarce resources;

3. *In-service training of national cadres* on methods for the planning and implementation of agroforestry experiments;

4. *A systematic approach to the development of technologies*, based on an understanding of the agroecological and socioeconomic circumstances under which land use systems operate and on the identification of roles for agroforestry in overcoming prevailing land use problems.

A four phase plan is proposed for the development of zonal networks, incorporating the elements shown in Figure 2.

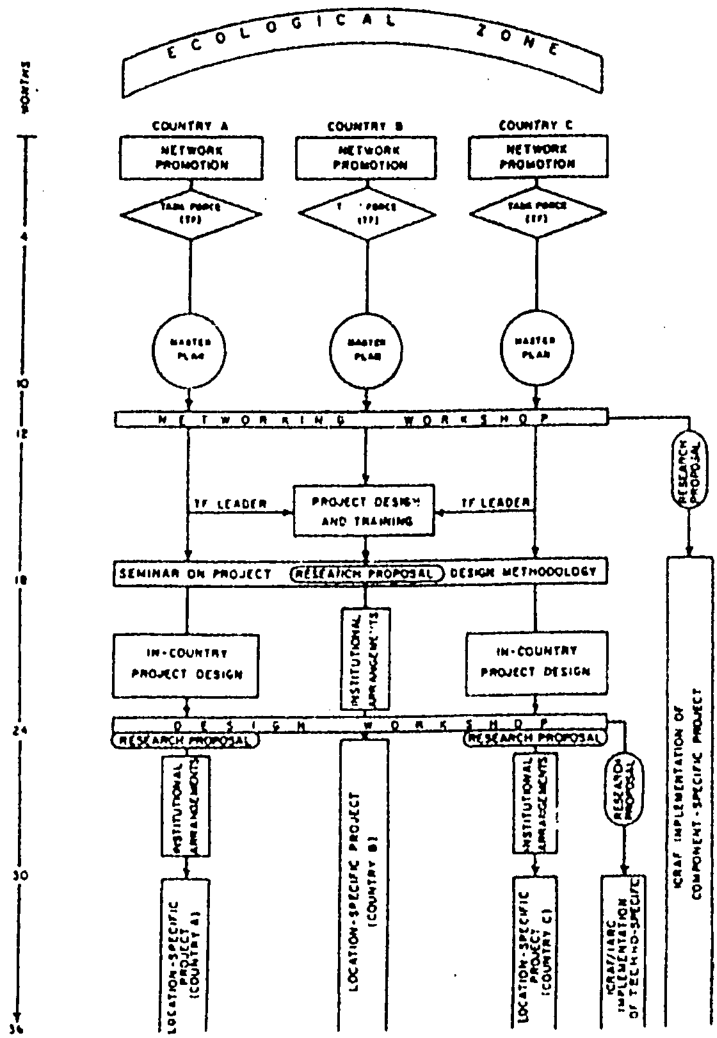

Figure 2. Strategy for the development of agroforestry research networks.

Phase 1: Institutional Organization

In order for the envisaged inter-institutional cooperation to become functional, institutional "niches" are needed to promote network activities within and among countries as well as between countries and external agencies. Given the realities of scientific and institutional specialization and competition for scarce research resources, we believe that the development of the desired cooperation should be based on the principle of *integrated planning but independent implementation* of components of the overall research plan by the specialized institutions. Integration of research planning within a country would be the responsibility of a "National Committee" composed of representatives from ministerial and academic institutions dealing with agriculture, forestry, livestock, research, extension, rural development and training. The National Committee will be responsible for developing an agroforestry "master plan" for the country. Cooperation among countries within the ecological zone will be discussed by decision makers of collaborating institutions at a workshop at which the country master plans will be presented.

Phase 2: Land Use Planning

Activities of this phase include a kind of "macro-level diagnosis" and preliminary design exercise, based on existing knowledge of land use systems in the country with supplementary reconnaissance visits by members of the national "Task Force" appointed by the Committee to develop the master plan. The specific objectives of this planning exercise are:

1. To identify and describe the main land use systems within the selected ecozone of the country;

2. To make a first assessment of the nature and severity of problems in these systems;

3. To evaluate the potential of agroforestry to assist in solving these problems; and

4. To appraise on-going agroforestry research in relation to the assessed problems.

It is envisaged that the National Committees and Task Forces will take primary responsibility for activities 1, 2 and 4, while 3 will be the joint responsibility of ICRAF and the national team. To the extent decided by the collaborating institutions, national plans may be combined into a zonal plan of research at the proposed zonal workshop.

Phase 3: Formulation of Research Projects

Activities in this phase are systematically coordinated with the training of national cadres. As project implementation activities are initiated, personnel development activities will evolve from training on research planning to training on experimental methods and techniques of field research in agroforestry. The coordination of project design and training objectives is achieved through the following sequence of activities:

1. *Case Study Development*
This is the pilot for the project design exercises (see 3 below) undertaken by multidisciplinary teams within the network. The team for this exercise is composed of the task force leaders of each of the national teams and the exercise is developed, with the full support of ICRAF's experienced D&D team, as a case study for use in training the national cadres to carry out similar exercises on their own. The methodology for this step is based on adapted versions of the D&D field survey procedures described in ICRAF (1983a, b).

2. *Seminar on Project Design Methodology*
Featuring the previously developed case study and carried out at the case study site with the participation of all teams from the participating countries, the purpose of the seminar is to develop wider capability to apply the D&D methodology, which will be used for subsequent project development throughout the network. The seminar will be organized by a joint team of ICRAF staff and the country task force leaders.

3. *Project Design Exercises*
To be carried out by the national teams at each of the in-country sites designated by the respective master plans, with backstopping from ICRAF staff.

4. *Design Workshop*
With the participation of ICRAF and all country teams the purpose of this workshop is to discuss the projects designed in the previous step, identify common problems and compare proposed agroforestry interventions with a view to discussion of potentials for inter-country collaboration on "technology-specific" (see below) research projects of relevance throughout the zone.

5. *Research Proposals*
To be finalized by country Task Forces following Workshop discussion and submitted for approval to national research systems and, if appropriate, to external assistance agencies for funding.

Phase 4: Technology Generation

Three types of technology-generating research proposals are expected to emerge from the activities outlined above:

1. *Component-specific research*, derived from the macro-level land use planning activities of phase 2 and aimed at providing essential biological components for the location- and technology-specific projects in the ecozone;

2. *Technology-specific research*, producing information on prototype technologies, i.e. widely applicable component combinations, plant arrangements and management practices, which address common agroecological and socioeconomic problems and potentials of the zone;

3. *Location-specific research*, addressing land use problems which arise from a particular combination of land use circumstances specific to sites within participating countries; though not of direct significance to other countries in the network, such research activities may be important for solving land use problems in the concerned country and in providing a meaningful framework for the integration of national institutions around agroforestry research.

All of these projects will be carried out at sites within the participating countries of the network. The location-specific projects will be the responsibility of the relevant national institutions and should normally include both on-station and on-farm trials, in accordance with the principles discussed in this paper. Component- and technology-specific research projects will be carred out at national research stations, but it is expected that they will receive more substantial inputs from ICRAF and other international research institutions.

The Agrororestry Research Network for Africa (AFRENA)

Development of a network along the lines of the strategy outlined above is already under way in Africa. Four broad ecozones have been identified for networking purposes in intertropical Africa: 1) the subhumid unimodal highlands of southern Africa, 2) the subhumid bimodal highlands of East Africa, 3) the humid lowlands of West Africa and 4) the semiarid lowlands of northern Africa south of the Sahara. Currently, Phase 1 institutional arrangements are being developed in the first three ecozones with the following countries: Malawi, Tanzania, Zambia and Zimbabwe in zone 1; Burundi, Kenya, Rwanda and Uganda in zone 2 ; and Cameroon, Ghana, Ivory Coast and Nigeria in zone 3. Subsequent activities are also planned with countries in the zone 4.

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