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THE AGROFORESTRY APPROACH TO LAND DEVELOPMENT: POTENTIALS AND CONSTRAINTS

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THE AGROFORESTRY APPROACH TO LAND DEVELOPMENT: POTENTIALS AND CONSTRAINTS

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ABSTRACT

Agroforestry is a collective name for a broad range of land use systems and technologies in which woody perennials 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. In the Rwandan context there are many significant agroforestry potentials which could be developed.

As a relatively new field of applied scientific activity, however, agroforestry presently labours under a number of social, scientific and institutional constraints. In order to fulfill its institutional role as a catalytic agent in the promotion of sound agroforestry approaches to land development, ICRAF is endeavoring to develop and disseminate methodological tools for overcoming these constraints and to identify secure institutional niches for agroforestry research and development activities.

In the context of a broadly conceived "farming systems" approach to rural development, ICRAF's diagnostic and design methodology can provide a methodological basis for establishment of network of "midstream" R&D projects which integrate closely with improved extension methods emphasizing a two-way flow of information between responsible government agencies and their rural clients. Following a brief presentation of the main points of this methodology, a possible programme scenerio for agroforestry development in Rwanda is explored.

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THE AGROFORESTRY APPROACH TO LAND DEVELOPMENT POTENTIALS AND CONSTRAINTS

1. WHAT IS AGROFORESTRY?

Following the definition proposed by Lundgren (12), we may define agroforestry as an approach to land use in which woody perennials are deliberately combined on the same land management unit with herbaceous crops and/or animals, either in some form of spatial arrangement or in sequence. The concept of an agroforestry system implies both ecological and economic interactions among the components of the system.

A number of major ecological and socioeconomic potentials of agroforestry have been identified. The potential for integration of trees into production systems in fragile or marginal environments has received considerable attention (6,7,10,13). The role of trees in developing more productive and sustainable land management systems for these environments is particularly relevant where soil fertility is low and mainly dependent on organic matter, where the erosion potential is high, where soil dessication is high, or where rapid leaching of soils under high rainfall conditions degrades the system to a low level equilibrium once the natural forest vegetation is removed (12,14).

Even on high potential lands with adequate rainfall and high soil fertility, indigenous agroforestry systems have proven their value among the land use systems of choice by peasant farmers wherever conditions have placed a premium on maximally intensive use of land and labour resources to support high rural population densities, e.g. the home gardens and village forests of Java (3,24), the compound gardens of Southeastern Nigeria (11), and the tree-based island systems of the Pacific (2).

On both marginal and high potential lands, the agroforestry approach is deemed especially appropriate wherever lack of rural infrastructure (communications, markets, input supply) or such factors as restrictive land tenure systems or insecure markets have made it imperative for small farmers to produce most of their basic needs directly from their own production systems, often on a limited land base (12).

In many parts of the tropical and subtropical world today the main challenge to developers of new agricultural technologies is to find ways to support increasingly higher rural population densities through intensification of land use, without overshooting the sustainable carrying capacity of local ecosystems. This task is made doubly difficult by 1) the need to satisfy certain essential conservation requirements while simultaneously raising the productivity of the land, and 2) the reluctance of small farmers to adopt conservation farming practices whose long term production benefits acrue well beyond the limited planning horizons within which they are forced by present pressures to perceive their options (17).

It is here, perhaps, that agroforestry has its most unique contribution to make toward solving the land management problems of smallholders in the tropics. The preoccupation of agroforesters with multipurpose components and production systems is in part justified by the enormous design flexibility which these options allow in addressing location-specific needs and potentials in ways which awaken the adoption interest of local farmers. The conservation needs or future production requirements of the systems they operate often go unperceived or receive a low priority in the thinking of small farmers. By linking the solution of unperceived or low-priority conservation or future production problems to the solution of production problems satisfying presently felt needs (the "piggy back" effect), clever agroforestry designs incorporating multipurpose trees in multifunctional arrangements can play a major role in improving the productivity and sustainability of tropical landuse systems. The key to this role is the attribute of enhanced "adoptability" which well conceived designs may confer on agroforestry innovations (18).

These, in any case, are the main hypotheses as regards the general potential of the agroforestry approach to land development in tropical farming systems. But let us be clear about this from the outset: most of the technologies in agroforestry's current "bag of tricks" are of an undeveloped, preliminary or hypothetical nature. While most of the promising technological ideas can be supported on theoretical grounds by drawing on foundations laid by other disciplines, hard empirical proof-of-concept data is usually lacking at this early stage in the scientific development of the discipline, and agroforestry has a long road to pull before it possesses anything like a well-researched stock of proven technologies for the wide range of landuse applications which are deemed to lie within its eventual reach. This is not to say that extension of agroforestry concepts is completely out of the question at present, but that present day extension programmes must incorporate a substantial research component if they are to be successful in implementing agroforestry ideas in the field.

2. AGROFORESTRY POTENTIALS IN RWANDA

My colleague from ICRAF and coparticipant in this conference will dwell in greater depth on some of the more promising agroforestry technologies for Rwandan conditions (15), but the organizers of the conference have, quite rightly, asked us all to be specific in our discussion of potentials of relevance to Rwanda, so I will briefly outline the nature of the major technological thrusts within an agroforestry approach to the solution of land development problems in this country. I would ask the reader to bear in mind, however, when entertaining these preliminary technology suggestions the crucial methodological point that agroforestry research and development programmes should be based on a thorough pre-project field assessment of location-specific constraints and potentials.

At least one East African highland ecologist has predicted that when a thorough assessment is made of land use potentials in Rwanda, agroforestry will emerge as the dominant potential land use system in the country (1). Only time will tell if this prediction is correct, but certainly there are a number of significant agroforestry potentials in all three of the major ecological regions (semi-arid zone, central plateau, western highlands). Let us not be overly sanguine about our prospects, however the magnitude of the problems which call these potentials to mind is staggering. As stated in the ISNAR report to the government of Rwanda:

> Rwandan agriculture is now caught in a process of continuous degradation: overpopulation goes hand in hand with overcropping of fertile lands, the use of more fragile fringe areas around arable lands, shrinking of pasturelands, overgrazing, uncontrolled deforestation, etc. Labour productivity is decreasing. Ill-nourished crops grown on impoverished soils, moreover, become disease-susceptible. In sum, the country is suffering from deterioration of its plant canopy, which includes decreasing biological and genetic diversity, decreasing soil fertility, and soil losses due to erosion (9).

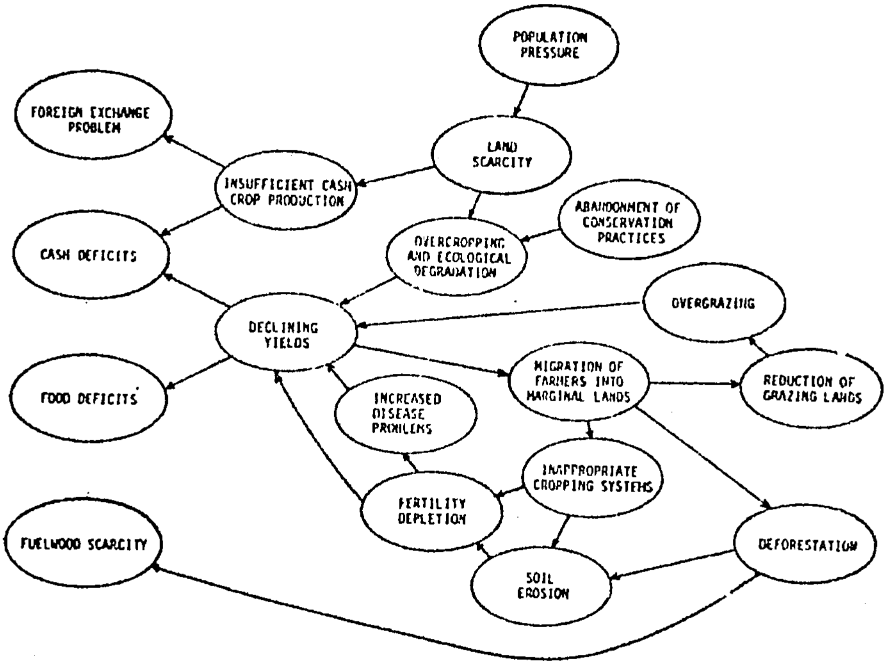

Figure 1. Generalized causal diagram of the Rwandan problematique

Figure 1 presents a generalized causal network model of the main elements of the Rwandan problematique based on the analysis contained in the ISNAR report. The progression from left to right is from problems to their causal antecedents. The main end-use problems, shown at the extreme left of the diagram, are deficits of food, cash and fuelwood as experienced at the household level and the foreign exchange problem at the national level. The driving variable in the degradation syndrome is population pressure. This results in land scarcity which leads to overcropping and ecological degradation with declining yields in the traditional farming systems. The processes of degradation are aided by the abandonment of conservation practices (contour grass strips) formerly enforced by the colonial administration. A conmitant effect of land scarcity is the emergence of competition for land between food crop and cash crop enterprises which, in the context of the priority placed by small farmers on maintaining subsistence food production, tends slowly to exacerbate the problem of insufficient cash crop production which contributes to cash deficits and the foreign exchange problem at household and national levels respectively.

One of the main responses of farmers to declining yields under the population-pressured degradation syndrome is migration into marginal lands with inappropriate cropping systems. The expansion of inappropriate traditional cropping systems into these fragile environments leads to rapid soil erosion and fertility depletion with a concommitant increase in desease problems on the degraded fields, all of which contribute to declining yields in the newly exploited marginal farming lands. An additional effect of the migration into marginal lands is a direct reduction of grazing lands in the semi-arid zone with a resulting tendency toward overgrazing and declining yields in the livestock sector. Deforestation, in the semi-arid zone as well but mainly on the newly opened slopes of the highland zone, exacerbates the soil erosion problem and contributes to an accelerating problem of fuelwood scarcity

This is not an unfamiliar syndrome. The fact which places the Rwandan situation in sharp perspective and underscores the magnitude of the problem is that all land ≤50% slope is already in cultivation! Figure 2 shows the major points in the system where agroforestry interventions could potentially play a role in solving or mitigating the identified problems.

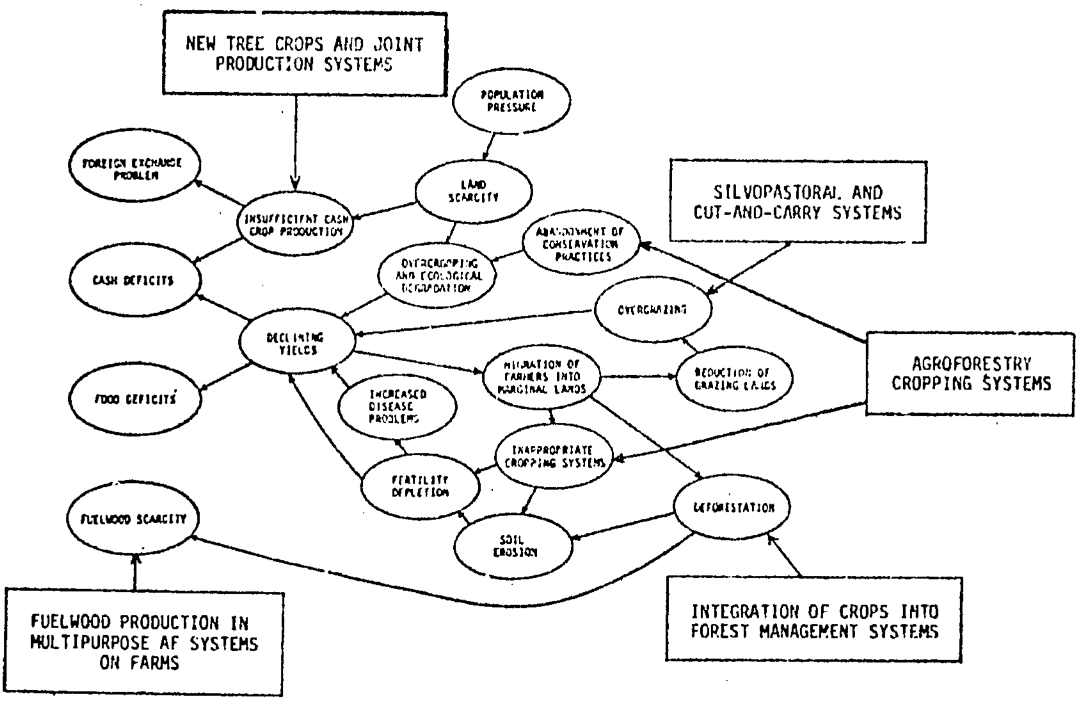

Figure 2. Some possible agroforestry interventions

<u>New Tree Crops and Joint AF Production Systems</u>

Following a careful assessment of production and marketing potentials selected tree crops might be introduced with the aim of increasing exportable crop production to increase household income and improve the national balance of trade. The potential for rural processing industries to create non-farm employment and add value to the export product (e.g. dried fruits, canned juices, essential oils, etc.) should be explored.

There may be a potential for integration of trees into existing cash crop enterprises to reduce dependence on external inputs (e.g. fertilizer and pesticides) by performing certain "service roles" (e.g. erosion control, fertility maintenance, insect repellence) within the existing production system.

Also, by choosing trees and cropping systems with a potential for joint production of desired subsistence goods (e.g. food, fuelwood, etc.) it may be possible to reduce the level of competition between cash crops and subsistence crops in integrated land use systems emphasizing complementary production.

Sylvopastoral and Cut-and-Carry Feed Production Systems

As an alternative or concommitant strategy to unpopular de-stocking measures, agroforestry feed production systems aimed at increasing the sustainable carrying capacity of the land could be considered.

Sylvopastoral systems of grazing land improvement making use of pod producing and browse trees would seem the most appropriate strategy for the semi-arid zone.

In the higher potential lands where population density precludes an effective grazing strategy, cut-and-carry or pen feeding systems making use of feed materials from multipurpose trees which can be integrated into improved cropping systems on farmland would seem a good alternative to consider in designing sustainable mixed farming systems.

Multipurpose Agroforestry Cropping Systems

Hedgerow intercropping or "alley cropping" systems might be considered for high density areas of the Central Plateau in order to prevent soil erosion and restore sustainable levels of fertility with a minimum of external inputs. There are a range of options for such systems from erosion control and green manure production to fully developed minimum tillage mulch farming systems, but research would be needed to develop and adapt the appropriate technologies.

In the lower density savanna areas where hedgerow intercropping systems might prove too labour-intensive for adoption in the short run, planted fallow systems might be developed which could provide additional incentives in the form of by-products added to the essential conservation functions which they perform. Phased sequences of intensification could be built into the design for such systems which would allow them to respond to future increases in population pressure (17).

On steeply sloping land in the highland areas where a permanent vegetation canopy is considered necessary for watershed protection, multistorey, multipurpose agroforestry systems which mimic the protective characteristics of the forest while providing production opportunities for hillside farmers might be the wisest land use alternative.

Integration of Agricultural Crops into Forest Management Systems

As a variant of the last mentioned alternative in highland areas where forest production is deemed a priority land use objective, various models for integration of agricultural production into managed forests could be explored. One such model, just to mention an example, is the "forest village" scheme in Thailand (20). This modified "taungya" system has been adapted to allow farmers to grow both annual and perennial food and cash crops together with the forest trees and has proven successful not only in reducing farmer pressure on forests but actually recruiting the farm population as active partners in the forestry production process.

Opportunities for introduction of shade tolerant understorey agricultural crops into forests have hardly begun to be explored, but the hypothetical potential would seem to justify a research effort in this direction--again to reduce land use conflict between agriculture and forestry by identifying viable joint production alternatives.

Fuelwood Production on Farms

A fuelwood production system for domestic needs can be added to most farms almost immediately by planting hedgerows, border plantings, stickwood fences, etc., on "marginal" or inte citial lands within existing farms.

In designing such systems, attention should be given to the potentials of multipurpose trees and arrangements designed to accomplish additional conservation or production functions on the farm (e.g. erosion control, fertility maintenance, fodder production, etc.).

3. CONSTRAINTS ON THE DEVELOPMENT .. NEW AGROFORESTRY SYSTEMS

It is often said that agroforestry is an age old land management practice but a new field of organized research and development. As such it must overcome a number of constraints which tend to retard the development of new agroforestry systems. Some of these are common to research and development of other types of agricultural technology, some are more-or-less unique to agroforestry. For convenience we may classify these constraints in three categories: social, scientific and institutional.

Social Constraints

In saying that agroforestry is an ancient type of landuse this does not mean that it is practiced everywhere or that there are no difficulties in promoting the acceptance of new agroforestry technologies. On the contrary, the novelty of a truly integrated approach to land use which is implied in the concept of an agroforestry system does impose constraints on the implementation of agroforestry designs in traditional land use systems; although, of course, this constraint is more severe in areas where trees do not play a significant traditional role in the system. In general, the novelty and potential complexity of agroforestry systems places a heavy burden on research and development institutions to come up with genuinely adoptable designs.

One of the most important social factors to consider in the design of agroforestry systems is that of the differential socioeconomic impact of specific agroforestry technologies on different members of the rural society. Not every one is equally benefited by a given technology.

Different classes of people in a society have different needs, different resource endowments, and different management skills. This means that there is no such thing as a "socially neutral" technology. To avoid unanticipated negative effects, particularly on the poorer members of the community, it is necessary to assess the social impact of candidate technologies and to design compensatory alternatives for those who may be adversely affected by agroforestry innovations. Generally speaking, socioeconomic differences must be considered together with biophysical variations within the project area in order to adequately define the various land management systems present in the area. This stratification can then serve as the basis for identification of system-specific needs and potentials.

Situational constraints play an important role in determining the appropriateness of specific technologies for different members of the community. In addition to differential access to resources (land, labour, working capital, etc.), such factors as restrictive land tenure systems, poor marketing facilities and inadequate infrastructure may limit the adoptability of any specific agricultural innovation. Given the relative permanency of agroforestry technologies and yet the generally lower requirement for external inputs, land tenure constraints are perhaps more important for agroforestry innovations than limited input supply infrastructures. Of course, each candidate technology must be assessed in terms of the situational constraints which may be operant in each system-specific application(12).

Attitudinal constraints on the adoption of agroforestry technologies may also be important in some locations. Many farmers share the conventional attitude of many agricultural researchers that trees have no place on the farmer's fields. Patient demonstration of the potential benefits of trees in well-designed agroforestry cropping systems is the only sure way to overcome this constraint. Another, possibly more significant constraint is the attitude of small scale farmers to conservation farming practices. Even where there is no residual bad feeling about conservation technologies left over from the colonial heritage, traditional farmers are often reluctant to incur the added costs of conservation measures whose benefits are not immediately apparent. Agroforestry is perhaps better equiped to overcome this constraint that other technologies insofar as "low-priority", long-term conservation functions can be introduced as part of multipurpose technological package which is sold to the farmer primarily on the basis of its immediate production benefits (e.g. contour hedgerows of fast-growing fuelwood species which also aid in the control of erosion). To the extent that agroforestry systems can be made to address felt needs and provide early returns, they will stand a better chance of adoption.

Attitudes toward work may constitute another set of attitudinal constraints on new technology. Generally speaking, farmers in areas with a long history of population pressure and intensive agricultural practice will have a more positive attitude toward the adoption of labour-intensive agroforestry technologies than farmers accustomed to the lower labour requirements of more extensive farming systems (4). If a high rate of adoption is the goal of agroforestry research and extension programmes, it becomes imperative to focus R&D efforts on developing technologies with the appropriate degree of labour intensity for the target farming system. Otherwise, the resulting technologies will not be likely to awaken much adoption interest. In some cases a phased approach to land use intensification may be possible by designing a succession of agroforestry technologies each of which is compatible with its successor and appropriate to the level of acceptable labour intensity at its own stage in the progression (17).

Apart from attitudinal constraints, learning constraints may affect the rate and acceptability of agroforestry innovations. Traditional agricultural technologies are passed down from generation to generation by traditional education mechanisms. How will agroforestry projects meet the educational requirements implied by the introduction of novel technologies? This is another aspect of project development which requires serious consideration if agroforestry projects are to achieve "take off" with respect to the adoption and dissemination of promising new technologies.

Scientific Constraints

Scientists, like farmers, are differentially susceptible to innovations in technique. One of the factors which makes for an uphill struggle in promoting the agroforestry approach to land development is the traditional disciplinary specialization of researchers. Agroforestry is, by definition, an integrated approach to land use which requires a high degree of interdisciplinary activity in the generation of new technologies. ICRAF's experience has been that the required degree of interdisciplinarity is not always easy to achieve. Education at technical and professional levels is almost always along traditional disciplinary lines and even where scientists are mandated by their institutions to work in multidisciplinary teams with a systems approach, workable models of interdisciplinary synthesis are often lacking (12). Another constraint is the traditional orientation toward academic rather than truly applied research. Success in the former is, to a large extent, measured in terms of publications, while in the latter it must be assessed in terms of impact on the landscape of rural development. These are really two very different kinds of research activity. To effect successful applied research programmes a change of attitude may be needed which can only be accomplished by a change in the incentive structures by which scientists are rewarded for relevant efforts. Another important implementation requirement is for methodologies capable of guiding research programmes toward the requisite degree of interdisciplinary synthesis.

Institutional Constraints

Problems at the scientific level are reflected at the institutional level where administrative structures tend to reinforce rigid disciplinary patterns of over specialization (12). While strong disciplinary programmes will always be needed, these need to be complemented by new structures created specifically to answer the need for interdisciplinary approaches to integrated land use. At the present time, agroforestry suffers particularly from the lack of institutional niches with sufficient scope to implement an integrated approach to research and development at the national level (12,22). Competition between technologically specialized agencies (agriculture, forestry, livestock etc.) for scarce resources and even for exclusive legal jurisdiction over land exacerbates the difficulties of launching an integrated agroforestry programme in many countries. Where would R&D on agrosilvopastoral land use systems fit into such a structure? On what land and under whose jurisdiction would an agrosilvicultural approach to land development be effected?

One of the most limiting institutional constraints to an impact-oriented programme of agroforestry research and development is the traditional, but nevertheless artificial, administrative separation of research and extension activities. Not only does this tend to result in a hit-or-miss approach to technology generation which follows from the traditional paradigm of a one-way, top-down flow of information from scientists to extensionists to farmers, but it also fails to take advantage of the enormous manpower potential of extensionists and participant farmers who could contribute substantially to the achievement of applied research objectives under the more cybernetically adequate paradigm of a two-way flow of information in the research and development chain. Certainly, if early testing and development of promising agroforestry technologies is to be a goal of government programmes, an institutional capability for integration of research and extension activities will have to be developed.

A related set of constraints also operates at the level of international aid agencies. In spite of the fact that many of the donor agencies are today espousing the concept of agroforestry as an integrated approach to land development, funds still tend to be channeled through technologically specialized departments (agriculture, forestry, livestock, etc.) and support is still hard to find for some of the research planning steps and methodological approaches which we are now finding necessary to the development of integrated national agroforestry R&D programmes which embody a strong applied bias (12).

All of these constraints imply an approach to agroforestry programme development activities which can be aided by and built around appropriate methodological tools. The next section describes one such tool which ICRAF is endeavoring to develop, in Kenya and through application in collaborative projects around the world, which is specifically tailored to the needs of agroforestry programme development.

4. THE ICRAF DIAGNOSTIC AND DESIGN METHODOLOGY

With a mandate to promote agroforestry research and development worldwide, and yet with a limited capacity to generate agroforestry technology to meet the varied needs of location-specific applications in widely different environments, ICRAF is implementing an institutional strategy which places a major emphasis on developing methodologies to be used by collaborators around the world (8,21). The major methodological thrust to date has been the development of a "Diagnostic and Design Methodology" for agroforestry projects, This methodology has been described elsewhere (16) and will be the subject of a forthcoming manual, so the treatment in this paper will be restricted to a presentation of the main structural and logical elements of the methodology and a discussion of how it can be used as a basis for project activities at different stages in the agroforestry R&D/Extension cycle. With this as our objective considerable use can be made of diagrams to quickly convey the main ideas of the methodology.

Aim and Scope of the Methodology

We begin by defining the aim and the scope of the Diagnostic and Design (D&D) methodology. The aim, in a word, is good agroforestry design. In the context of an impact-maximizing rural development strategy "good agroforestry design" means productive, sustainable and adoptable agroforestry land management systems and technologies. In agreement with the pragmatic philosophy of Farming Systems Research (19), the most effective and reliable route to the development of designs which embody these three essential attributes is felt to be that of a diagnostic or problem-solving approach. D&D is an iterative process which is repeated throughout the project cycle to home in on an optimized agroforestry system. (We will return to this concept in Fig. 8.). The purpose of the initial "project formulation" application is to get the R&D process moving along relevant lines toward an eventual technological synthesis which embodies the three attributes of good design in a site specific design for a problem-solving land management system.

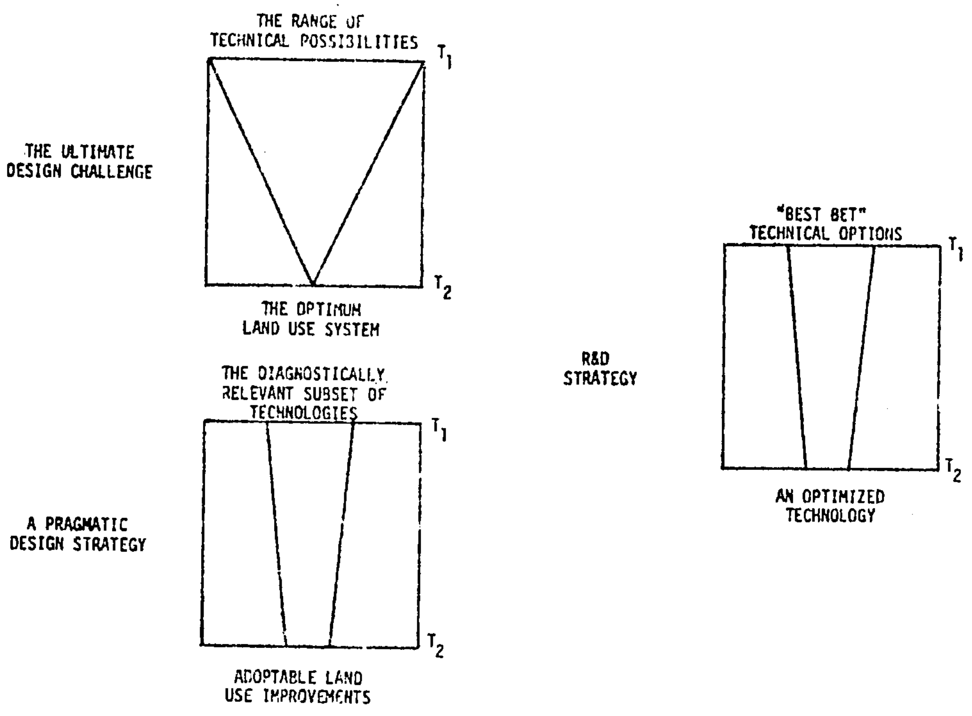

FIGURE 3. THE STRATEGY BEHIND A D&D-BASED APPROACH TO R&D

Figure 3 attempts to convey an idea of the strategy by which the D&D methodology approaches this objective. It is virtually impossible to evaluate the entire range of technical options and come up with a design for the optimum land use system. So we aim, instead, to define the diagnostically relevant subset of technologies and on this basis to design an improved land use system. This design serves as the basis for defining "best bet" technical options with which to start off the R&D process. The R&D process, in turn, aims to test and refine the best bet prototypes and generate an optimized technology package.

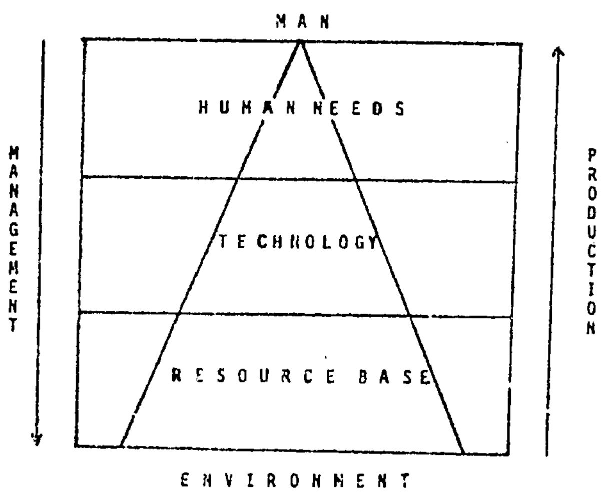

FIGURE 4. FOCUS ON THE HUMAN ECOSYSTEM

The subject of all this attention is, essentially, a human ecosystem. Figure 4 depicts the basic features of this system in schematic form. The square represents the entire Man-Environment system while the central triangle represents the production system, which is organized by man to exploit the resource base through the mediation of technology in order to satisfy human needs. Resources are culturally and technologically defined. Few, if any, human cultures exploit the full resource potential of their environment. This fact is indicated by the environmental area which lies outside the culture's resource base. Likewise, not all human technology is directed toward the exploitation of environmental resources (e.g. communications technology) and not all human needs are satisfied by the production system (e.g. social needs). Management flows down from Man and production flows up from the Environment. In the course of this interaction problems arise. Hence, the need to diagnose problems and design solutions.

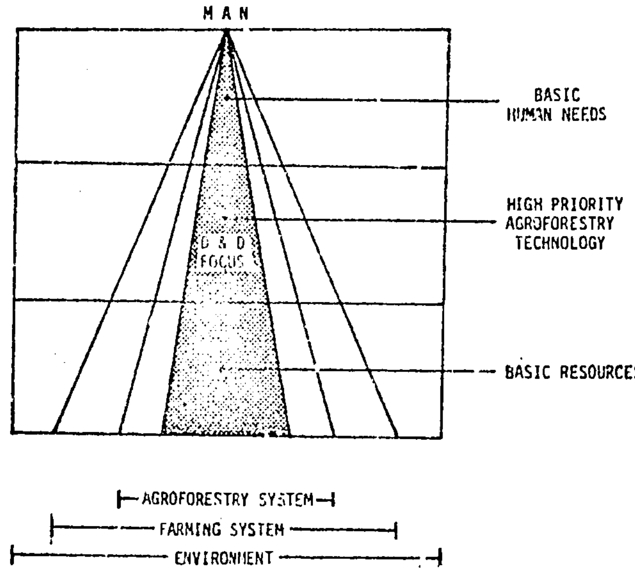

FIGURE 5. SCOPE AND AIM OF THE D&D METHODOLOGY

Figure 5 elaborates this concept to illustrate the scope and aim of the D&D methodology. The potential agrof- ... system is part of the total farming system. Many facets of farming system research and development lie outside the scope of agroforestry per se (e.g. genetic improvement of annual crops and livestock). The D&D methodology focuses on the central core of the agroforestry system, i.e. the potential role of high priority agroforestry technologies to make efficient use of basic resources (soil, water, woody plant material, etc.) to satisfy basic human needs (food, fuel, shelter, raw material for processing industries, and cash).

This concentration on basic human needs is a focusing strategy to simpligy the D&D problem to a manageable level which can be rapidly accomplished in order to have a timely effect on project planning activities. Without some such economizing strategy, systems analysis can go ever on and yet have little impact on crucial planning decisions. The adoption of this pragramatic analytical strategy places the basic D&D methodology squarely within the framework ... rapid rural apprais... " methodologies and makes full use of the principle of "optimal ignorance" (5) as an economizing tactic.

The focus in the initial D&D application on that part of the production system which is responsible for the satisfaction of basic human needs (including cash for the satisfaction of needs going beyond mere subsistence - rural development needs floors but not ceilings) gives priority to those agroforestry potentials which are of fundamental importance, and thus serves to orient agroforestry R&D toward the generation of relevant and adoptable technologies. Needless to say some less fundamental agroforestry potentials will be missed by this rapid appraisal approach, but this is a small price to pay for enormous gains in the economy and efficiency of the D&D process. In any case, what is missed in the initial rapid appraisal application can be picked up in subsequent D&D applications later on in the project cycle (see Fig. 7).

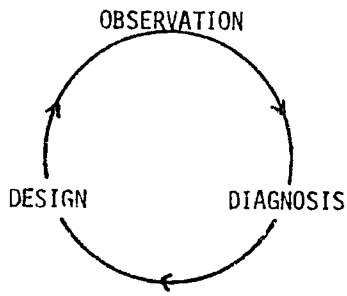

FIGURE 6. THE CYCLE OF DIAGNOSIS AND DESING

The Process of Diagnosis and Design

The basic elements of the D&D cycle are depicted in Figure 6. The ability to solve a problem begins with the ability to define what the problem is (21). This is the fundamental diagnostic idea and is analogous in many respects to the rule of practice in the medical profession that "diagnosis should preceed treatment." The ability to diagnose a problem begins with observation of the system in question, i.e. a process which is analogous to the physician's examination of the patient. In respect to land use systems, the observation step provides basic information on the structure (anatomy), function (physiology) and performance (health) of the system. This sets the stage for a diagnosis, by means of trouble-shooting proceedures, of the problems and constraints which limit the performance of the system in producing outputs to satisfy basic human needs. Both present and future states of the system are examined (the latter by extrapolation) to evaluate the productivity and sustainability of the present land use system. The analysis of problems and constraints leads to the identification of problem-solving/constraint-removing technological potentials. This, in turn, provides a basis for derivation of design specifications for appropriate technological interventions in the system, which enter the design process as an input from the diagnostic phase of the cycle.

The nature of this input is essentially a definition of the functional attributes of problem solving technologies, together with an appreciation of other relevant design parameters of the system (e.g. land suitability constraints, resource constraints, management limits, relevant system interactions, etc.). The function of this input is to channel the technological imagination toward relevant problem-solving designs. In the course of the design process the members of the multidisciplinary D&D team first brainstorm the range of conceiveable technological options and, then evalute the most promising options to arrive at a design which incorporates the present "best bet" options. In most cases, at this stage in development of agroforestry, there will be few, if any, entirely adequate "off-the-shelf" solutions. The next step, therefore, is to assess the state-of-the-art and formulate a research design to develop or adapt technologies to fill the identified gaps in the current stock of technological options. This leads to an R&D project in which the best bet prototypes, if any are available, are subjected to on-farm trials with backup from on-station research.

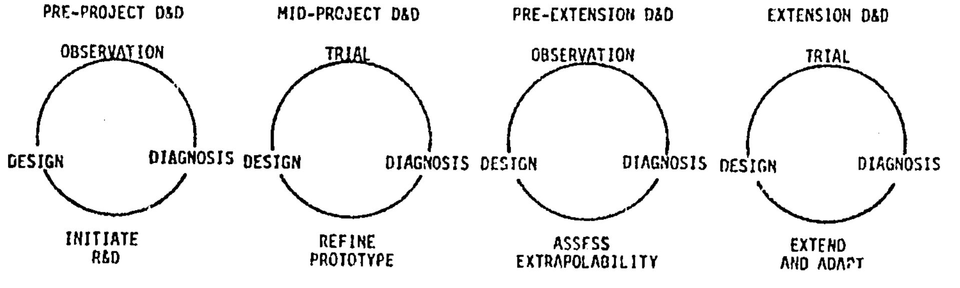

FIGURE 7. D&D IS AN ITERATIVE PROCESS IN THE PROJECT CYCLE

D&D, as previously stated, is an iterative process which is repeated throughout the project cycle for different purposes at different stages (Figure 7). In the initial, "pre-project" (or project formulation) application the process just described is carried out in order to initiate the R&D project and set it moving along generally appropriate lines. At the next, i.e. "mid-project" stage, the D&D process is repeated, either at intervals or more-or-less continuously, to deepen the diagnosis and refine the design. This takes place in the context of on-site research in which the "observation" phase takes the form of more in-depth study of system characteristics and farm trials of the best bet technology prototype(s). This latter activity can be conceived as a "perturbation experiment" designed to probe system response to the technology intervention. The experiment yields information which is used to refine the initial rapid appraisal diagnosis and suggest modifications in the technology to make it specifically appropriate to the system in question. Freed from the constraints of the initial rapid appraisal approach, which is no longer needed at this stage in the project cycle, the on-site research team is able to explore the finer points of diagnosis and design and gradually home in on an optimized design for the site.

Eventually this process will result in technologies which are considered ready for extension to a wider set of recipients throughout the recommendation domain, which is composed of sites of a similar biophysical and socioeconomic nature with the same basic problematique. But first it is necessary to assess the extrapolability and define the boundaries of the recommendation domain. A modified D&D format which incorporates an expanded land evaluation exercise may be used for this purpose. Once the recommendation domain is known, a new set of on-site trials may be initiated which uses another form of D&D process to extend the technology throughout the recommendation domain and adapt it to site-specific conditions.

The advantage of the D&D approach to technology generation might be clarified by means of an analogy. If you will permit a martial semile, the difference between an R&D project with and without a D&D component is analogous to the difference between a guided missile and a conventional ballistic shell. The missile continuously alters its course to track a moving target in response to continuously improved information on the location of the target, while the latter depends entirely on the accuracy and continued validity of the original information and obviously leaves much more of the outcome to chance. While it may be repugnant to think of human ecosystems as "targets", it may be easy to acknowledge the advantage of an approach to R&D which incorporates an "internal guidance system."

Figure 8 shows the steps in the basic D&D process in a little more detail. The approach to gathering and evaluation of relevant information is hierarchical and progressive. Assuming that a general potential for an agroforestry approach has been previously established, the sequence starts with the collection of pre-diagnostic background information on the project area guided by a checklist of what is relevant and useful to know about the area at this stage. This sets the stage for a diagnostic field survey conducted by a multi-disciplinary D&D team which focuses in part on identifying supply problems at the household or unit management level and trouble-shooting the production system to identify antecedent causal factors in the land management system.

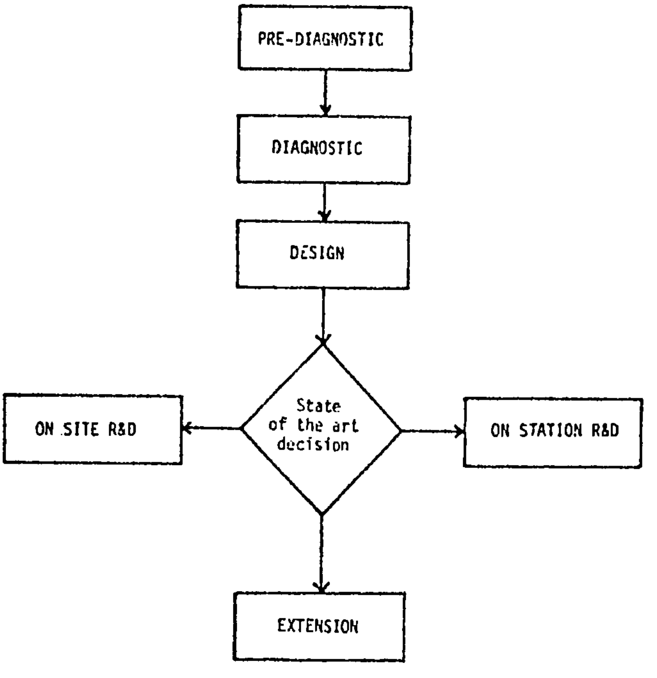

FIGURE 8. STEPS IN THE D&D PROCESS (PRE-PROJECT STAGE)

Interviews with representative farmers and qualified informants (e.g. extension agents, local officials, articulate farmers, researchers familiar with the area, etc.) are supplemented by direct observation of landscape processes and problems. Analysis of all the relevant information leads to a diagnosis of the main problems and identification of the associated causal syndromes. The result is a more detailed and site-specific version of the type of causal diagram shown in Figure 1.

At the design step the multidisciplinary D&D team, in consultation with other technical experts as needed, brainstorms the technical options (both of an agroforestry and non-agroforestry nature), evaluates the alternatives and focuses down to a set of "best bet" options for R&D. Next comes a state-of-the-art evaluation to determine whether any of the identified technologies are ready for direct extension to the target area, or whether research is first needed to develop or adapt the candidate technologies before entering into the extension stage. The type of research which is needed will depend on the state of readiness of the technologies. "Notional" or purely hypothetical technologies which are judged too immature to take to the farmers even on an experimental basis are referred to the research station for prototype development. "Preliminary" technologies which have sufficient empirical support to warrent farmer input into the process of prototype refinement are referred to the project staff at the site for farm trials. "Developed" technologies whose feasibility and appropriateness has been previously established by farm trials in similar environments elsewhere might be considered for immediate "extension trials" and adaptive R&D on site.

In practice, research on a given technology might be simultaneously initiated both on farms and at the research station. On-farm research would be oriented mainly toward monitoring the impact of prototype technologies on the farming system and obtaining feed-back on the farmers' response, while on-station work would take place in a more controlled experimental environment and would employ different experimental proceedures to evaluate alternative components and investigate interactions between components under systematically varied management treatments in order to refine the prototypes and establish design curves which would make it possible to develop more precisely optimized designs for varied site conditions.

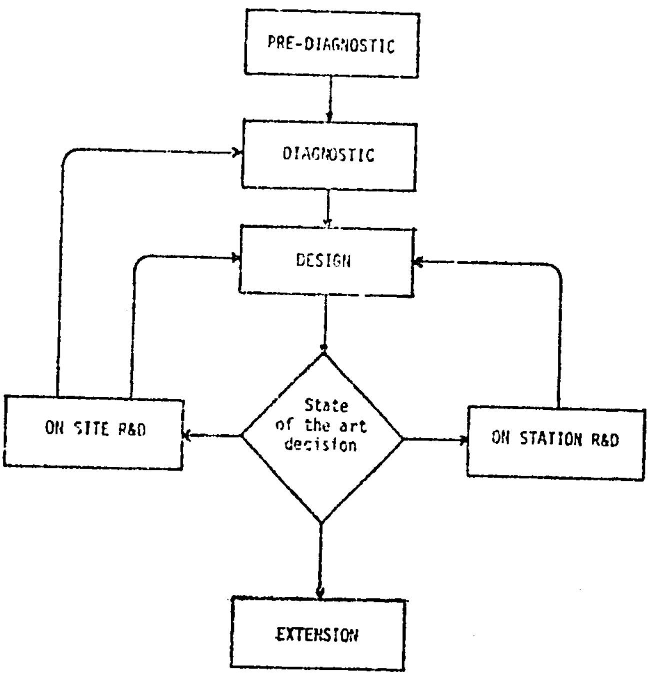

FIGURE 9. D&D IN THE CONTEXT OF "MIDSTREAM R&D"

Figure 9 shows the full set of interactive relationships between the continuing D&D process and the on-farm and on-station research work in the active R&D stage of the pilot technology generation project. On-farm R&D provides feedback on both the diagnosis and the design. On-station R&D provides feedback on the design. Following the accepted nomenclature in Farming Systems Research which distinguishes between "upstream" prototype development and "downstream" adaptive research (23), the deliberate incorporation of the above mentioned feedback linkages in an integrated approach to R&D would suggest the term "midstream R&D" to described this particular R&D paradigm. One advantage of this paradigm is that it explicitly acknowledges the possibility that prototypes may originate in the on-farm R&D and be referred to the research station for further testing and refinement, whereas the established paradigm more-or-less implies that prototypes can only originate on the station.

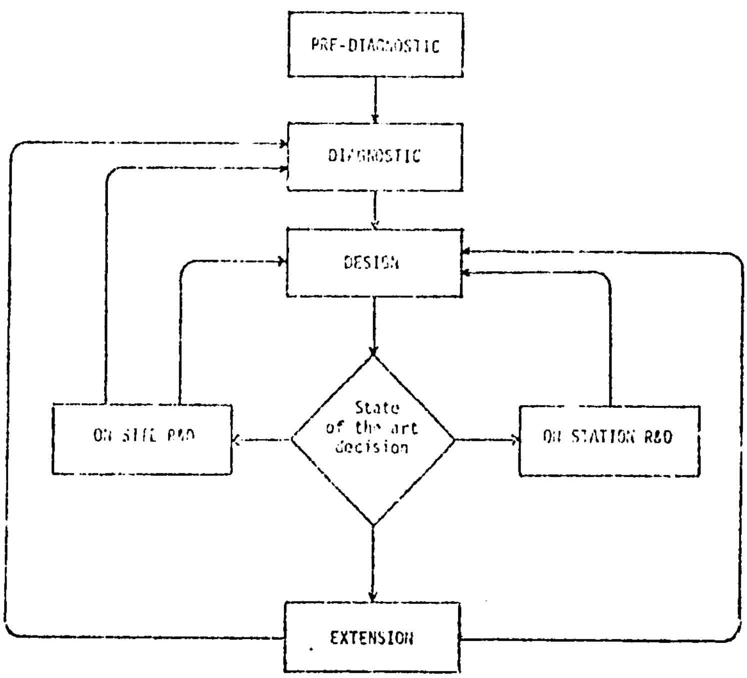

FIGURE 10. FEEDBACK LINKAGES IN "EXTENSION R&D"

Figure 10 shows the additional feedback linkages which occur when the technology moves into the extension stage. Adaptive R&D continues in the form of on-farm trails and adjustment of the technology to fit specific extension sites. New information arising from these extension-and-adaptation activities is part of the R&D learning process. The term "Extension R&D" is suggested as a name for this integrated paradigm for adaptive R&D at extension sites.

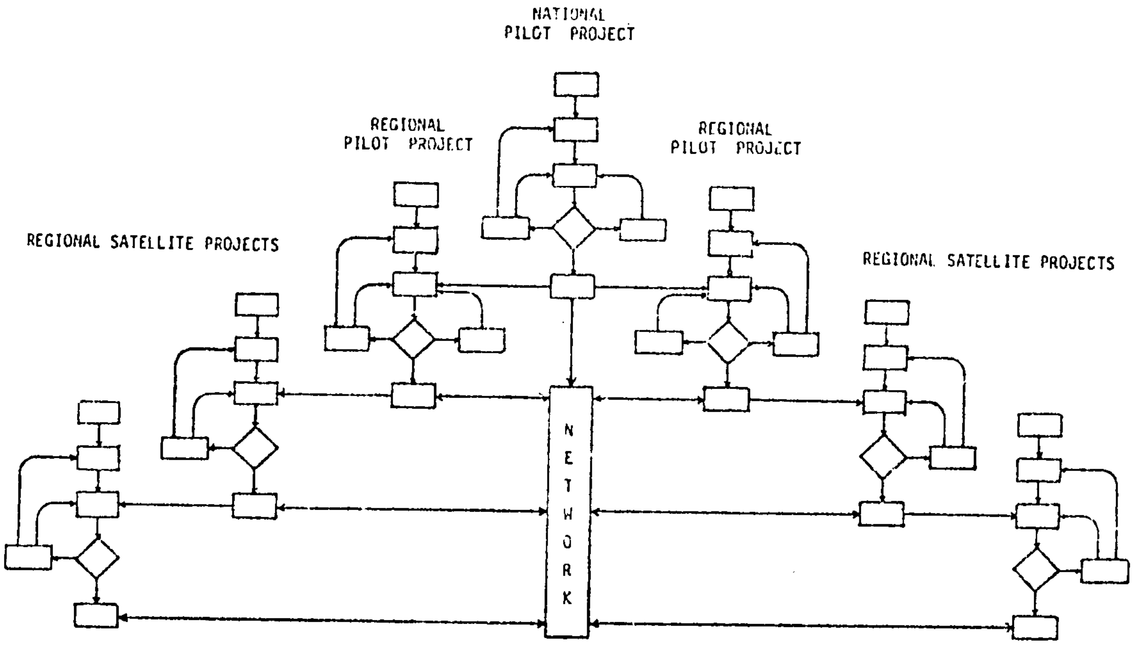

FIGURE 11. SUGGESTED MODEL FOR A NATIONAL AGROFORESTRY R&D NETWORK

Figure 11 illustrates the concept of the "project multiplier effect" by which the D&D-based R&D paradigm can serve as the basis for a cascading series of post-pilot R&D and extension projects to multiply adapted technologies throughout a wider area. Note that the on-station component drops out once the programme reaches the level of purely site-specific adaptive research, although the on-farm R&D cycle persists throughout. The key to the successful utilization of this multiplier potential will be the incorporation of a deliberate training component into the site-related R&D programme in order to increase the amount of trained manpower available to establish satellite projects.

To make best use of the project multiplier effect, a networking mechanism will obviously be needed to coordinate exchange of relevant information between R&D projects at all levels, as suggested by the schematic representation in Figure 11 of what a national programme of agroforestry R&D might look like.

5. A POSSIBLE AGROFORESTRY PROGRAMME SCENERIO FOR RWANDA

Subject, of course, to revision by authorities better informed about Rwandan institutional potentials and programme priorities, the following tentative suggestions are made for an implementation scenerio which incorporates the foregoing considerations vis-a-vis the elements of an idealized agroforestry research and development programme.

The proposed reorganization and strengthening of the national agricultural research system outlined in the ISNAR report to the Government of Rwanda (9) would seem to be a prerequisite for implementation of an agroforestry programme along lines outlined above. In particular, the proposed addition to ISAR of a Department for Research on Agricultural Production System would provide a natural base for coordination of a national network of agroforestry R&D projects. As noted in the ISNAR diagnostic report, additional measures to strengthen relations between research and extension work are also indicated, particularly if the previously discussed extension of an agroforestry R&D network to subregional extension-cum-adaptive R&D sites is to be implemented. Presumably this would entail some formal relationship with the Ministry of Agriculture and Livestock to incorporate some of the Ministry's enormous field extension staff into the manpower base for Commune level Extension R&D activities. Other arrangements to draw on the manpower resources and technical expertise of the UNR, the OPROVIA and the OCIR (the latter two to develop an industrial and marketing capability for potential agroforestry export crops) might prove necessary to s'pport the activities of the agroforestry R&D programme.

Three levels of programme organization would seem to be required:

At the National Level

1. A central Coordinating Group for the national agroforestry R&D programme to coordinate and support the national network. This group could most effectively be housed within the proposed Department for Research on AGricultural Production Systems at ISAR.

2. A central Research Station to provide joint services, laboratory facilities and scientific backup for on-station research activities at the regional stations and to carry out some of the more fundamental and widely applicable aspects of on-station research on agroforestry prototype technologies.

At the Regional Level

1. Regional D&D teams to carry out pilot surveys, formulate R&D project proposals and provide technical backup to local field teams.

2. Regional Experiment Stations to support the efforts of local field teams with the on-station research necessary to develop and refine regionally important prototype technologies.

At the Local Level

1. Local field team or "verification and testing units" composed of junior researchers and local extension staff to carry out site-specific adaptive R&D projects (with the cooperation of administrative authorities at the Prefecture and Commune level).

The suggested sequence of steps in developing a national agroforestry programme would include:

1. An initial D&D application-cum-training exercise carried out by members of the interdisciplinary national Agroforestry Programme Coordinating Group to develop a national D&D pilot project located in one of the regions.

2. Expansion of this process to other ecological regions in the country.

3. Formation of a national network of agroforestry projects, to coordinate information exchange within and between regions, to hold seminars and workshops, etc.

4. Development of subregional Extension R&D projects to adapt and disseminate the emerging agroforestry technologies to a wider group of potential adopters.

Possible Forms of Support from ICRAF

1. Application and transfer of the ICRAF D&D methodology through participation in a D&D exercise to formulate the initial regional R&D project (i.e. the national pilot project).

2. Training support and technical backup to the development of pilot projects in other ecological regions.

3. Consultation on technical, organizational and management aspects of project and programme development.

4. Other forms of training, information services and technical assistance.

Such support would be carried out through arrangements with the relevant Programmes within ICRAF (Systems, Technology, Information, Training) under the overall coordination of ICRAF's Programme on Collaborative and Special Projects and with support from ICRAF's Advisory Unit. Given financial support, ICRAF stands ready to assist the Government of Rwanda to meet the challenge of developing viable agroforestry systems for a secure and productive future.

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