PN AAE-335

64579

ICRAF Working Paper No: 36

LAND USE PLANNING WITH RURAL FARM HOUSEHOLDS AND COMMUNITIES: PARTICIPATORY AGROFORESTRY RESEARCH

Dianne E. Rocheleau

November 1985

Paper presented to the Networkshop on the Role of Sociologists and Anthropologists in Farming Systems Research

Sponsored by ARPT Zambia, and CIMMYT East Africa

Lusaka, Zambia

November 27 - 29, 1984

Land use planning with rural farm households and communities: participatory agroforestry research

by

Dianne E. Rocheleau

ICRAF

Nairobi, Kenya

Paper presented to the Networkshop on the Role of Sociologists and Anthropologists in Farming Systems Research

Sponsored by ARPT Zambia, and CIMMYT East Africa

Lusaka, Zambia

November 27-29, 1984

INTRODUCTION

Agroforestry is a form of land use and management familiar to millions of farmers and forest-dwellers throughout the world. Like any other production system, it has a social basis for existence, and the success or failure of future research efforts to improve that system will depend largely on the ability of researchers to serve the social ends of rural producers and to reconcile those ends with the demands of the urban markets.

Formally, agroforestry (AF) can be taken to include any system of land use in which woody plants are deliberately combined , in space or over time, on the same land management unit as herbaceous crops and animals. (Lundgren,1982). This applies to classical shifting cultivation, as well as to such variations as the Chitemene system in N.E. Zambia. It also refers to a variety of land use systems ranging from very intensive farming to extensive pastoral systems. These include: bush fallow farming systems; management of fodder trees in private or communal grazing lands; planting of trees and shrubs as live fences on farm and plot boundaries for fuelwood, small timber and other useful products; intercropping of hedges with grain crops, for leaf mulch/fertilizer (hedgerow intercropping) home gardens of all types where trees and annual crops are mixed; and many other systems where farmers and herders combine trees with field crops or animals.

RELEVANCE FOR EASTERN AND SOUTHERN AFRICA

Many such systems in eastern and southern Africa are in a process of rapid transistion due to population pressure on the land,

assimilation into the cash economy, new technologies, new markets, land tenure reform, large scale migration and resettlement, and new directions in national agricultural policy. Some traditional, stable AF systems are being replaced by high-input mono-cropping, while in other cases the traditional shifting cultivation systems are unable to keep up with the increasing demands without overtaxing the soil and forest resources on which future production depends.

In either case this transition can result in environmental degradation and declining production, or in sustainable, more intensive production from the agricultural and forestry sectors. The outcome has obvious implications for future food security in the region. There are many possible pathways to successful intensification of food production, many of which could include specific AF technologies, some of which could focus on AF land use systems.

Existing AF systems need to be improved and adapted to changing conditions. There is also a need to develop new AF practices and land use systems to stabilize or increase total production in cropping and animal production systems which have not included woody plants in the past. The woody plants may perform a direct service to the annual crop or herd, they may provide an indirect service by conserving soil, they may yield useful products directly (fruit, leafy vegetables, fodder, firewood, small timber, fiber) or ideally, they may do all three.

FARMING SYSTEMS APPROACH

The region is faced with a need for immediate action, and with the fact that small-scale farmers have not always benefited from the recent technological innovations in agricultural science. Many agricultural research programs in the region have responded by adopting (at least in part) a farming systems approach (Collinson, 1981; Kean and Chibasa, 1981) which also provides a better basis for future AF research.

Farming systems research and extension (FSR/E) is an approach to the development, evaluation and promotion of new agricultural technology. Although several varieties of FSR/E have been developed there are some characteristics common to all. Such programs usually serve small-scale farmers with limited resources. Most FSR/E programs focus on firsthand knowledge of farmers' situations through personal interviews and experiments on farms (to replace or supplement research station experiments). Interdisciplinary teams analise and treat the farm as a whole system, usually with a focus on a particular commodity or enterprise. The same biological and social scientists scientists that conduct farmer-oriented, agro-biological research are also engaged in related extension activities (Hildebrand and Poey, 1985).

Most FSR/E programs have concentrated on major cash and food crops, with less attention to animal production, soil and water management, and woody plants (other than major commodities). The farm household has been the unit of analysis most often used,

along with specific plot types, cropping systems, or farm enterprises.

DIAGNOSIS AND DESIG D&D) METHODOLOGY

The D&D method incorporates much of the experience and perspective of the farming systems approach (Chambers, 1981; Collinson, 1981; Hildebrand, 1981; Rhodes, 1981; Zandstra et al. 1981). This approach served as the basis for initial development of the D&D methodology for AF systems research (Raintree, 1983).

While an overall farming systems approach is an appropriate starting point, agroforestry research-for-development requires something more . Among those aspects which most demand a broader approach are the scope of the topic (whole-system), the variable scale of the land units involved , the variety of clients and land managers, the diversity of activities involved (including new categories of work), the combination of production and sustainability (environmental) objectives, the time factor involved in testing and growing trees, and the relative ignorance of researchers as to past and current use of woody plants by farmers and herders. All of these factors place heavy demands on the social science skills of research and planning teams.

Focus on basic needs

Agroforestry (AF) is a land use system, not a commodity. The range of potential AF interventions may apply to cash crops, subsistence crops, animal production, and gathered products, as well as to farm infrastructure and to the soil, water and natural

vegetation on the site. In contrast to single commodity production approaches, the D&D methodology focuses on problem-solving, with an emphasis on farmer's priorities for fulfillment of basic needs (Raintree,1983). The major needs categories are: food, water, fuel, cash income, shelter and infrastructure, savings/investment, and social production. Problems and priorities can be determined in informal surveys that rely strongly on ethnographic and oral history skills.

Production and sustainability

Farmers' concerns to maintain current production levels into the immediate future are an extension of the basic needs category, but require special consideration, including discussions of futures possible . The long term maintenance of the natural resource base (soil, water, vegetation) for future production requires more specific attention to history of land use and condition, and to potential improvements in soil conservation, watershed management, and management of range and forest lands (Rocheleau and Hoek,1984). The longer term issues may concern the researchers and national planners, more than the local client group, and solutions to these problems will need to be linked to the fulfillment of basic needs. The extent to which the client group does already recognize and address such problems is critical information for project design, choice of possible technologies, and research design.

Land and tree tenure

Trees are considered to be relatively permanent features on the landscape, and trees usually represent long term investments by

those who plant them. Relative to annual cropping , tree planting is far more constrained by formal land tenure and/or informal gaurantees of secure access and use. Past and current practices with respect to land tenure, land use rights, tree use rights and tree ownership (Fortmann, 1985; Raintree, 1985; Rocheleau, 1985a) are important indicators of problems and opportunities for new agroforestry technologies . Both de jure and de facto rules must be understood in order to make fair and feasible suggestions for new AF technologies and land use systems.

Time aspects

The time required to plant and test woody plants, especially trees, also places special demands on agroforestry research methodology. There is more of a need to plan ahead, and to anticipate potential future problems, since the experiments cannot be so easily repeated as in the case of annual crops. The same is true with respect to predicting markets, labour requirements for maintenance, and potential conflicts with other crop and animal production activities on the same or neighboring land units.

In addition to such precautions in the initial stages, project design, technology types and research design must all be subject to change, based on rapid response to feedback (reactions and suggestions) from farmers. This flexible approach extends to changes in species, placement, and management, based on observations and analysis by both farmers and researchers. It is especially critical to get farmers to screen new species and management systems, by their own criteria, at the same time as

researchers are screening them for biophysical and economic criteria. While any farming systems program can benefit from such a self-correcting approach, in agroforestry it is impossible to do otherwise, without sacrificing decades. Social scientists play a critical role in involving researchers and farmers as partners in such closely monitored, applied research.

Ethno-botany

There is also the fact that woody plants used by farmers are often unknown to researchers, in contrast to the relative familiarity of the major food crops. This relative ignorance may extend to the nature of the woody plant components, their interaction with soil, animals, and other crops, their uses, and their ownership and management. This adds a dimension of ethno-botany to the rapid appraisal and to the subsequent research effort.

Variable scale

AF addresses a wide ranging scale of land use units and production units. The physical units of land use include plots, farms, watersheds, communal holdings and public lands, while the managers may be individuals, households, communal sub-groups (clans, extended families), whole ethnic groups, cooperatives, communities or larger political units (e.g. the state representatives in reserve lands). This wider range of land use and production units applies to many other types of farming systems research and extension, but for AF it is an essential consideration.. More than any of the distinctive aspects of AF already mentioned, land use planning at multiple scales requires

social and ecological contributions to all phases of AF research and extension work.

Recent agroforestry research has devoted more attention to the division of labor, difference in interests, differential access to resources, and distribution of benefits within households and within communities. In the field tests of D+D the potential applications and the needs for agroforestry (AF) technologies have often extended beyond (and within) the farming system as a unit. The problems encountered thus far at the farm level and in rural development and watershed management projects have indicated the need for rapid appraisal, technology design and implementation at varying scales of analysis. Larger-than-farm analysis is particularly important for diagnosis and solution of: watershed problems (including conflicts in land and water use); soil and water degradation; development problems affecting the landless and near-landless; and problems with the use of common, public, and otherwise shared lands by farm households. On the other hand, intra- household (within household) analysis is needed to deal with environmental and production problems that affect household members differently based on age, sex, kinship and marital status.

For cases where the farm household has been identified as the main focus, there is a need to identify and act upon farming systems opportunities and limits that reside (or originate) in the next larger systems of which they are a part, or in sub-units of the farm household. A brief look at the next level (up or

down) in the hierarchy can indicate whether the external constraints on farming systems are changeable, and whether the household sub-systems and/or the larger system can support such changes if introduced. Such constraints may be ecological or socio-economic. In the case of farming system dependence on opportunities within the larger system (abundant labour, free fuel, abundant water) the sustainability of these resources and their future availability to the farm household must be considered. The mixed management of "free" goods such as water and fuel, with owned land, cattle and equipment, and the combination of family, communal and paid labour in many rural production systems requires a scale of analysis beyond the farm. Changes in farm technology may affect the larger systems and then reflect back indirect impact on the farm household in the form of changing prices, availability or quality of basic resources (fuel, water, food, shelter, raw materials) or availability of production inputs (agro-chemicals, labour, equipment). The results may also be a change in demand for farm products. Both production and sustainability of farming systems are subject to such feedback (return) effects from technology change.

The interdependence between household members and the farming system is equally important. Intra-household units may vary according to circumstance, distinguishing between: men, women and children; wage-earners and non-wage earners; heads of household and "others"; producers and dependents. For example, women, men, and children in the same household have different knowledge, interests and responsibilities with respect to specific land units and landscape features, specific plants and animals, and

particular activities. The differential demands of existing and new technologies on these groups, their distinct knowledge and skills, and the variable returns for their respective contributions will influence the welfare of the entire household and the farm as a whole.

Family composition affects both household and individual needs and priorities for AF interventions. Among households there are distinct types; a woman-headed household with young children cannot be treated the same as a household with several adults (men and women) and school-age children. Neither will a given household remain static; future developments must be considered in AF technology design (e.g. land sub-division, marriage, out-migration, re-distribution of labour and control between men and women, or by age group).

There is, in fact, little doubt that we need to treat intra-household, community and ecosystem issues within agroforestry research for rural development. What is not so clear is just how to do this in a way that is practical, frugal and yields useful results for rural people. A first approximation of variable scale D+D is emerging from observation, analysis and participation in field research projects in Kenya (Rocheleau,1985 b,1984 a and b; Arap-Sang,1984; Buck,1984; Mwendandu,1984) and elsewhere.

THE KATHAMA CASE STUDY

The most direct source of ideas, questions and results has been the continuous contact with farmers and the surrounding community in Kathama sub-location, Machakos District, Kenya. The Kathama project is a small methodology development project initially based on farming system surveys and on-farm trials of agroforestry innovations (Raintree, 1983; Vonk, 1983b). The project has continued (on a limited scale) as a vehicle for testing implementation approaches and variable scale D&D (Rocheleau,1985b; Rocheleau and Hoek,1984).

This case illustrates the evolution of the methodology in general (Figs. 1 and 2) and the self-correction of the project and technology designs in response to social, economic, biological and physical performance criteria. The experience in this community also illustrates the general importance of social factors in existing production systems, and in the planning, testing and dissemination of new technologies. In particular, the project has called our attention to the need for designs that transcend the household and the individual farm (both within and without), according to both social and ecological criteria. More importantly, this case has provided the stimulus and the opportunity to refine diagnoses and to re-design technology trials to reflect intra-household and community level criteria within an AF systems project. The experience from both the original trials and the variable-scale follow-up are presented in order to demonstrate the empirical and practical basis for the methodological and research policy conclusions which follow.

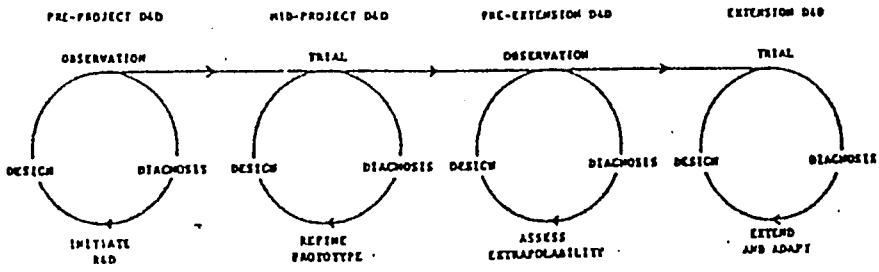

FIG. 1 : D&D AS AN ITERATIVE PROCESS IN THE PROJECT CYCLE
(Source: Raintree, 1983; ICRAF, 1983)

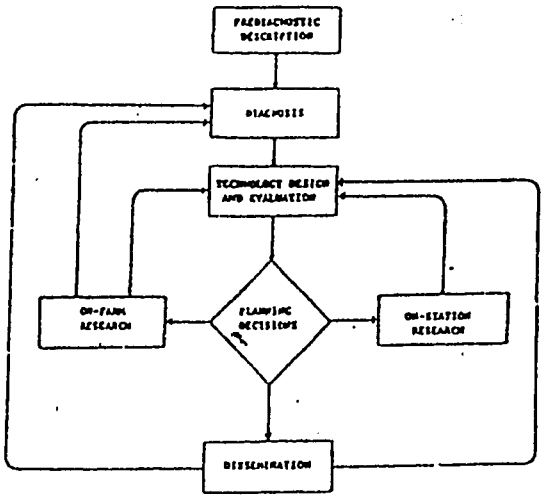

FIG. 2 : DIAGNOSIS AND DESIGN (D&D) PROCESS
(Source: Raintree, 1983; ICRAF, 1983)

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

D&D at the Farm Scale

Initial Surveys and Farm Trials

The initial diagnostic exercise identified farm-level potentials and problems that could be addressed by agroforestry. The highest priority problems were food shortage and inadequate income, both in turn caused by low soil fertility and soil moisture, and by low animal production. The latter was attributed mainly to lack of fodder during the dry season. The farmers' objectives, basic household needs, current strategies for problem-solving, and available resources guided the design of promising agroforestry technologies (Raintree, 1983; Vonk, 1983 b and c). Ten farmers agreed to test these best-bet options on their farms.

The technology trials included preliminary trials of promising multipurpose (exotic) tree species; methods of tree establishment in cropland and grazing lands: intercropping of *Leucaena leucocephala* and *Cassia siamea* with maize and pigeon pea to improve soil moisture and fertility, through use of leaf-mulch (hedgerow intercropping); and small lots of multipurpose trees to produce fuelwood as well as high quality dry season fodder. The study incorporated monitoring of labour inputs for establishment and farmers' reactions and suggestions during establishment and early growth. The changes suggested by farmers reduced labour for land preparation and provided a simple low-input alternative for rehabilitation of individual plants in small plots of grazed woodland (Vonk, 1983a). As information began to filter back from the continued monitoring of the 10 farm trials, there were also

strong indications of interaction between AF technologies on the farm, and management of the surrounding environment.

Issues Raised by Farm Trial Results

Importance of access to water

Three of the participating farmers attempted to propagate (raise) their own new seedlings for independent continuation and expansion of species trials, fodder lots, and hedgerow intercropping. Two of the three failed (and others refrained from trying) due to water shortage and difficulty of access to permanent water sources. The one participating farmer who succeeded in growing his own seedlings has had prior experience with a home citrus nursery and has a permanent water source on his property. For most families, however, access to water involves use of public sources.

While the hillside springs and the nearby Athi River are considered public domain, ease of access is influenced by location of owned property and means of transport. This implies a need to consider such differences between farms in planning for plant propagation, which may in turn influence AF technology designs and/or choice of species. Alternatively, plant propagation for some or all of the farms might be organized at the group or community level, near water sources, on either a private or public basis.

Intra-Household Distribution of Labour

Further discussions with farmers also raised the issue of intra-household distribution of labour for plant propagation. While men were the main participants in the farm trials, women were required to collect and transport the water for seedlings in the farm nurseries. The women were unwilling to continue this extra task when water shortage forced them to obtain the domestic water supply from the Athi River (2-5 km distance), carrying water on their backs in containers. This demonstrates the need to involve women as individual beneficiaries and clients, and to consult them about feasibility if they are to play the role of water-bearers for plant propagation.

Importance of Shared Resources and Cooperation

Other issues of major importance that surfaced in farm trials included pest control, browsing damage by domestic and wild animals, and the need for protected fodder reserves. As in the case of water for nurseries, fodder production and animal management involves use of off-farm resources and the cooperation of other farmers (control of herds and more careful management of gathering). Any interventions of this type would require a closer consideration of land tenure, use rights and terms of access to land, water and plants.

While most of the land in the study site was adjudicated over 10 years ago, exclusive use by one household applies only to cropland (permanent, terraced), home compounds and small grazing plots. Woodlands and large holdings of wooded grazing land are

controlled by single households but are perceived as conditionally available to the larger community or to sub-groups thereof (Cantor, 1984). Many smallholders depend heavily on this system of discretionary common use of private land. They obtain most or all of their fuel, fodder, timber, thorn-fencing and minor forest products from sources outside their own farms (off-farm) (Wijngaarden,1984b). Access is unevenly distributed between households and also varies with seasonal and periodic drought, the latter being an emergency and considered just cause for granting broader privileges than usual. Use of such lands and terms of use vary considerably.

Gathering rights for fuelwood are seldom compensated. Most commonly the practice is referred to as "borrowing", with the understanding that "borrowers" take deadwood, small stickwood, and the least desirable species. Some gathering without permission also occurs in the denser, more remote woodlands (Cantor, 1984). Many larger landholders also grant dry-season grazing and browsing rights to several other households based on kinship or other social ties or in exchange for cash or services. When the cropping season ends, 'social fences' fade and roadside, woodland and gully sites provide grass, shrubs, and high-protein pods to supplement on-farm fodder. Changes in animal management for fodder tree protection would necessarily involve the community-at-large. Enrichment planting in public lands and common-use private lands would also require group decisions and maintenance.

While fodder and fuelwood are almost 'free goods', fencing material, timber and charcoal trees are perceived as commodities to be purchased directly. In some cases charcoal makers may rent access to land for tree harvesting and burning (Hoek, 1983). The favoured species for charcoal and timber also produce pods and/or leaf fodder, so these commercial activities impinge strongly on actual carrying capacity of shared lands for domestic animals and on the production of gathered food, fibre, medicines and fuelwood.

D&D for the community

Diagnosis of watershed problems

Based on the issues which surfaced during the farm trials, the D+D for the community and surrounding watershed was initiated as a separate, parallel study during the third year of the project. It identified excessive runoff and soil erosion as major problems limiting individual farm production as well as threatening water supply and road networks throughout the area (Rocheleau and Hoek, 1984). Overharvesting of valuable multipurpose trees (*Acacia tortilis*, *Terminalia brownii*) for single-purpose exploitation (charcoal) has also depleted shared sources of fodder and forest products for the community-at-large. Overgrazing, overstocking, and lack of alternatives for cash earnings and savings/investment also contribute to economic hardship and ecological instability throughout the Kathama sub-location.

Soil and Water Management Problems

The drainage network emerged as the predominant structural landscape feature in need of stabilization; it formed the basis for further stratification and detailed study at the Kathama site. A more detailed qualitative analysis, including informal interviews, cartographic analyses, aerial photographic interpretation and detailed field observation, was conducted in three small catchment sub-units. The detailed landscape analysis identified the major sources of excessive runoff, critical points in the drainage network, and sites of sheet and gully erosion (see Hoek, 1983 and Rocheleau and Hoek, 1984 for detailed maps, discussion and technology designs).

Most residents are aware of these problems and their causes. Some have constructed small structures to prevent or contain gully erosion, and most farmers have terraced their croplands; much of the construction (on and off-farm) has been carried out by self-help groups. Gully and drainage control structures appear on private, public, and boundary lands, usually at or near the site of damage to roads, paths, homesites, or cropland. In spite of interest and awareness, the overall drainage work is *ad hoc* and represents the cumulative (and often unanticipated) effect of many separate decisions and actions. Groups and individuals living upslope affect land and water resources (private and public) immediately downslope.

Combining conservation with production

The watershed level D+D exercise indicated additional production needs for multipurpose trees as well as a need for better planning of soil and water conservation. Discussions were held with individuals and group interviews were conducted with women's groups about fuelwood and fodder availability and management. Both surveys revealed that smallholders rely very heavily on off-farm fuelwood and fodder sources and many consider fuelwood supply to be a problem. The current role of gully sites as off-farm grazing lands and fuel wood sources for many households, further strengthened the case for maintaining these productive functions at such sites under a sustainable system.

Other critical sites for application of AF with soil and water conservation technologies included: the degraded hillslope grazing lands (sources of excessive runoff and sources of fuelwood and fodder for many households); the roadsides and boundaries (often under-utilized, and also key features in the drainage network); soil conservation structures on croplands (often unstable and/or unproductive); and home compounds (major sources of runoff, convenient for closer management/protection of plants). The resulting integrated landscape design in cross section view (Fig. 3) shows the fit of these technologies into a productive, sustainable agricultural landscape.

Initial Evaluation of Proposed Technology

In order to better evaluate the feasibility and probable effects of the proposed design, a parallel ecological and spatial

FIG. 3 : INTEGRATED AGROFORESTRY SOLUTIONS NESTED IN THE LANDSCAPE

Tree, shrub and grass combinations

on the farm

on boundaries, in gullies and along roads

Landscape Niche Affected:

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

(Hook, 1985)

analysis was conducted to quantify some of the existing conditions and potential changes in a representative small watershed on the Kanzalu Range. Results included areas of different land use and land cover categories, the total length and area of various linear landscape features (as potential planting sites); and the relationship of various land cover types (including linear features) to runoff, erosion and production problems and potentials (Rocheleau and Hoek, 1983). One of the more significant results of this analysis was the estimated proportion of fuelwood and fodder demand that could be produced by planting woody plants and grasses along boundaries, roads and drains (including gullies, streams and soil conservation structures). Approximately forty percent of the fodder and sixty percent of the fuelwood needed by the residents could be grown in these under-utilized spaces (Rocheleau and Hoek, 1984).

The analysis also extended to the functional relationships between various structural landscape features, land uses, land tenure and family composition. The results proved to be crucial for choice of technologies for further trials and for design of extension strategies. Household surveys (Cantor, 1984) indicated a marked division of labour, control and interests within and between households, with respect to present and future management of fuel and fodder supplies and the wooded grazing lands in general. Based on qualitative and quantitative analyses of the survey (Rocheleau and Cantor, forthcoming) two major criteria differentiated the households with respect to needs, priorities,

and available resources for AF technology development: size and quality of landholdings (eg. land value and productive potentials) and household composition (male vs. female-headed, male vs. female-managed, and number of resident family members of working age).

Land Owners and Land Users

The land size and quality was closely related to the division between 'borrowers' and 'lenders' of fuelwood and grazing land. There is a general division of interests between the two groups, with the former needing to integrate subsistence production of fuel and fodder into intensified food and cash crop production on their limited smallholdings, and the latter tending toward conversion of lands currently used by borrowers into crop production or private lots for fodder and small timber production (all semi-commercial enterprises).

Gender and Household Composition

Cutting across this land-based division of interests are three types of households with labor-based differences. Within this watershed 33 percent of the households are headed by women, 47 percent are headed by men, and another 20 percent are managed by women.In the latter case the male head-of-household lives and works away from home, returns at intervals ranging from monthly to annually, and retains varying degrees of decision-making authority in the household. The women are farm managers and make most or all of the day to day operational decisions, but consult or defer to the men in planning decisions (such as new

cropping systems or land use) .These types of households would usually be designated "male-headed", but have very distinct needs, constraints, and resources compared to households with resident male heads. With few exceptions , woman-headed and woman-managed households have less labor available than those headed by men, have different priorities for allocation of labor (subsistence vs commercial; domestic vs whole-farm; group vs farm),and have different types of labor exchange and other reciprocal arrangements for use of grazing land, fuelwood, and draft power.

Smallholder households headed or managed by very young or very old women present both a challenge and a special opportunity to AF research and extension in this area. These women are extremely limited by labor (often only their own) but even more so by lack of mobility and time. Mothers of very small children, and older infirm women were particularly interested in concentrating fodder and fuel resources (currently gathered outside the farm) on croplands, home compounds, small lots, and boundaries. The additional real labor for establishment and management (including fodder lopping) would be more than compensated by the accommodation of their mobility and time constraints for activities outside the farm.

These household types are more than academic categories; they imply distinct sets of technology designs and landscape niches at the farm level, and set the context for reconciliation of conflicting interests at the community level in watershed scale

designs, land use plans and project organization. While men-headed largeholder households want timber, cash crop trees, and living fences (hedges), to better protect their croplands and grazinglands, the small-holder women-headed households want fodder and fuel close to the home and low-input cash crops that can combine with food crops and that can also be consumed on-farm. The first group may well lead the way in grazing land improvement, sylvo-pastoral technologies (trees and shrubs combined with pasture), and development of commercial tree crops. The latter group are the logical choice to pioneer intensive production of fodder and fuel in croplands and on boundaries and introduction of multi-purpose cash and food crops into subsistence cropping systems. These two contrasting groups with conflicting interests illustrate the potential for design of complementary technologies at the watershed and community scales. Recognizing that the conflicts may not always be easily resolved, and that new ones may develop later, the survey information was used for grouping clients, stratifying designs, and integrating research and project management to serve the groups separately, within a larger context of landscape design.

Group trials within selected watersheds

While the potential benefits of the AF designs were estimated during the first cycle D+D (Rocheleau and Hoek, 1984), several questions remained as to practical feasibility and distribution of costs and benefits, given the existing conditions and practices in Kathama. The second cycle of the larger scale D&D

addressed these questions through on-site trials with self-help groups and selected households.

A small pilot project was initiated within the Kalama catchment (small watershed)to further explore the research methods, technologies and organizational activites necessary to implement the landscape design within the D+D context. The exercise also provided a practical context in which to test and evaluate the method, the overall design and the specific technologies for application in similar environments in Machakos District (ranges and hillslopes, agroecological Zone 4). The specific objectives of the pilot project were: 1. to develop AF methods suitable for implementation, monitoring and evaluation of watershed and community scale group projects; 2. to build rapport with the groups and assess their organizational and technical capabilities and potential; and 3. to modify AF designs and implementation plans to fit "2".

Labour requirements and labour availability

The implementation consisted of weekly work sessions with five self-help groups at two sites chosen by the team and the groups respectively. An analysis of the time and labor required to implement the original design revealed a vast discrepancy between group capabilities within the public works context, and the demands of the overall plan. Based on the existing work schedule and rate of performance, the groups would take more than ten years to complete the necessary soil conservation structures and planting.

Private objectives of group work

However, the entire emphasis on public works was repudiated by the qualitative information from observation of, and participation in, group work sessions. The groups were found to be small associations of individual households (20-50) engaged in exchange and rotation services and pooling of resources for the benefit of individual members and their households. While the results of the household survey confirmed the importance of group labor for individual management, they also revealed a de facto exclusion of some types of households from participation in group activities and benefits. Women heads of small households (usually very young or elderly women) who were isolated geographically from relatives and/or the community -at-large, reported being unable to attend group activities due to limited mobility (due to sole responsibility for child care and domestic work,or due to ill health). By contrast, some of the wealthiest and/or largest households found group membership unnecessary. The self-help groups are thus not fully communal in either objectives or in composition. As in other AF studies (Dove,1983) the difference between communal groups and associations of independent households proved critical to project and technology design.

Implications for project design

The groups requested changes in the work schedule, organization and choice of sites, because too much time was being spent on the property of non-members. Even on members' farms the groups cannot spend several consecutive sessions at the same site, but must

maintain some semblance of rotation. While they might undertake gully repair at any site that impinges on members' lands or at sites where public roads and schools are threatened, the groups still find continuous long term investment at any one site unacceptable. Moreover, the group leaders insisted that future activities be limited to one or two groups, rather than the combination of five groups as was the arrangement for the first season. They blamed much of the problems in the group trials on inter-group rivalries (R. Mwendandu, personal communication). Subsequent activities were organized with individual self-help groups, in order to avoid this problem.

Implications for technology performance

During the course of the group work the participants requested seedlings for their own farms and negotiated group soil conservation labor as an exchange for 15 seedlings (sampler package, multiple species) for each member. Farm planting results showed that while most people planted all of the trees they were issued, they reserved the cropland sites and special care for fruit and fodder trees. Timber and shade trees planted on the home compound also received special care in some cases. Trees planted at soil conservation sites were protected, if at all, by property owners, not by the groups as such. Since one of the two sites was badly degraded, poorly protected, and traversed by water collection and cattle paths, most of the planted seedlings died. However, the small water- harvesting structures made by the groups did foster improved growth of the natural vegetation (especially grasses and small *Acacia tortilis*

trees). The property owners also managed to protect some of the planted grasses and seedlings located close to the home. At the other site the owner took full responsibility for planting and protection and converted a small plot just adjacent to the group site into an individual farm trial of AF for fodder and wood production and rehabilitation of a gullied grazing land. On-farm and group follow-up during the subsequent planting season (no public works at that time) resulted in requests for a switch to nurseries for individual groups (located near water, at a member's home), to supply seedlings for group members' farms.

The results from this first cycle of group tree planting influenced the choice of species and planting sites for the seedlings produced in the group nurseries the following season. After the focus of the group activities shifted to plant propagation for members' farms, two more self-help groups asked to join the project. Some groups also recruited new members interested specifically in seedlings and grasses for their farms, including one farm trial participant who expanded his fodder lot. While some groups continued to ask for advice on placement and construction of soil conservation works, they gave priority to nursery construction and plant propagation activities (fruit trees and a mixture of fodder, fuelwood and timber trees). While the soil conservation problem was still of concern, it was treated indirectly through work on individual farms and through development of group capabilities in AF for future application in their limited public works activities.

Integration of group and farm trials

Although it was not originally planned, the farm trials and group activities became closely linked as a result of actions and decisions taken by the individual farmers and the groups themselves. They established complementary domains of group-based and household-based AF activities (tree propagation and planting is a new class of work) and they set limits on the scale of community-level group collaboration (one nursery per group, with some joint training and evaluation activities and occasional joint public works activities with tree-planting and soil conservation). This, in turn, established the social terms of reference for the further development, testing and dissemination of AF technologies in the area.

Broader base of participation

Farm trials combined with group activities had several advantages. It allowed the farmers (especially women) to speak more freely as part of a majority, when dealing with researchers or with their own families. It also stimulated new ideas and sharing of new technologies suggested by group members.

The nursery activities served to train individual farmers in the full cycle of plant propagation, and at the same time provided a forum for training and discussion re: tree planting, choice of species and sites, and management of AF technologies on-farm. The farm trials, on the other hand, provided a kind of AF "sampler" that allowed farmers (individually and in groups) to observe and discuss results within the realistic context of a neighbor's

farm. People were better able to choose species (indigenous and exotic) and to consider alternative planting arrangements and management techniques, once they could see what the new trees and shrubs looked like, and how these and indigenous trees performed in new niches on-farm. The group members also contributed to the farm trials by their honest appraisal and constructive criticism of the trials; they often helped to elicit suggested modifications from the more timid or biased individual farmers.

Changes in Research Topics and Priorities

Out of this consultation and testing came a suggested change of emphasis from hedgerow inter-cropping for mulch, to hedgerow inter cropping for fodder and fruit, with wider spacing between hedgerows. To improve soil fertility most farmers prefer concentrated mulching of cattle pens (pre-composting) with tree biomass from fencerows and dispersed trees in grazing land. A few farmers are still interested in widely spaced hedgerows for mulch. The groups and project team also began a search for indigenous wild fruits and exotic drought-resistant marketable fruit compatible with food cropping systems and/or hedges (on inside of boundary hedges (living fences) or on internal plot boundaries). Both groups also initiated a search for tree-based pesticides available in the area, with the help of foresters and local herbalists. The relationship of these and other research lines to the original D + D are outlined in Tables 1 and 2. Aside from these specific prescriptions for research, several general conclusions can be drawn from this experience.

COMMUNITY LEVEL	DESIGNS	RESEARCH PRIORITIES
Cash Problems		
No facilities for plant propagation marketing, and farmer training to support farm level technology tested (above) at farm level	Provision of "sampler" seedling packages (13 species) and some training to group members in soil conservation projects	Follow-up to seedling distribution on 60 farms, re: survival and placement by species; quarterly follow-up at 30 farms re: performance, damage, maintenance, farmer assessment, farmer learning.
Degradation of grazing lands	Involvement of groups in establishment of fodder and timber species upstream of gully sites	
Net purchase of construction wood from other communities		
Food		
Inadequate storage, credit and marketing facilities at community level	Low priority	Not pursued
Degradation of gathering sites	No design (see survey, below)	Interviews with groups re: wild fruits and other foods, to determine preferred species, and dwindling species (amount or access)
Fuel		
Depletion of favoured species for fuel and charcoal; uneven distribution of what remains	Distribution of sample fuelwood species No design (see survey below)	Follow-up of sample seedlings as above, special attention to fuelwood species re: survival, willingness to plant more, and planting location.
Savings Investment		
Need community-level support for improved savings mechanisms; alternative investments lacking	Low priority Involvement of groups in mixing AF (fodder and fuel trees with grasses, and living structures) into public soil conservation works.	Informal polling of groups re: alternative investments, group savings, preferences of farmers
Disinvestment in land resources and infrastructure at community scale: degradation of grazing and gathering lands, water supply, roads and paths	No design:	Pilot survey on use of off-farm resources (water, fodder, fuel) group labour, raw materials)

Table 1. Original D&D

FARM LEVEL DIAGNOSIS CASH PROBLEMS	ORIGINAL DESIGNS	RESEARCH PRIORITIES/PROGRAMS
Poor animal production due to dry season fodder gap:	Enrichment planting in grazing lands	Establishment trials, several species; various site preparation planting, and management techniques.
High seasonal cash outlays for staple food purchase	Fodder and fuel lots (cut and carry) on small unused plots	Same as above; different spacing and land preparation techniques
Off-season animal sales due to both of above	Multistorey fruit tree stands over grass and legume cover (fodder)	(Low priority)
FOOD PRODUCTION PROBLEMS		
Low yields and crop failures: soil capping: late tillage: poor soil moisture: poor soil fertility; soil erosion.	Hedgerow intercropping for mulch with Nitrogen and organic matter additions and protective cover for soil improvement and small fuelwood as by-product	Cassia siamea and Leucaena leucocephala at 2.5 m between-row and 0.5 m in-row with maize and pigeon pea, on cropland.
FUELWOOD SHORTAGE		
High dependence on off-farm sources: fuelwood purchase, purchase of trees for charcoal making.	see above, plus: Hedgerows and living fences with fruit bearing species and high-yielding fuelwood species	Species trials along fencelines and in lots (low priority)

Table 2. Revised D&D

Feedback D&D

From farm trials

- Hedgerow intercropping is still risky mainly due to apparent water competition with pigeon pea, but farmers are interested in mulch.

- Pest control, water harvesting and browsing damage problems on grazing land left most farmers with management of existing trees as best option.

- Water supply for on-farm nurseries poses a problem for most individual farmers, public supplies or access to others' private supplies is needed for nurseries (if seedlings used).

From Groups

- Groups are not public works or purely communal in orientation; they are associations based on exchange/rotation of labour on members' lands to benefit individual members and families.

- Follow-up of "sampler" seedlings indicated greatest interest in fruit trees and fodder trees, both on croplands (for best soil and protection)

- Group requests for nursery project, participation and results show need for training plus simpler, cheaper methods of plant propagation, and pest control. Confirms fruit and fodder priority: would consider local wild fruits.

- From Surveys plus Interaction of Groups and Individual Farms:

- There are 3 main design client-groups:

1. labour-short, land-poor, limited mobility families;
2. largeholders interested in investment over long term, and
3. medium-small holders interested in mixing fruit trees, fodder, improved practice into cropland.

- Subdivision of lands is a critical issue, as is land conversion; we need to plan present placement and spacings of trees accordingly.

- Use of boundaries is especially important to smallholders, as is use of gullies; roadsides are also heavily utilized by same, but lack definition re: rights of use (for example, for new trees). Women and poor men may be able to use gullies and fencerows. Most are willing to start with fencerows (for fuel, timber).

- Some members have tried boma-mulching (pre-composting with tree biomass in corrals) and some have pits for rough-composting; other group members interested in increasing 'manure' yield from corrals.

Table 2. (cont'd)

Changes in Research Programs and Priorities for Farms and Groups.

Priority 1: fruit trees in cropland and internal fencerows. Research questions: species? spacing? combinations? markets? processing or storage? multiple uses? food, cash, fodder and fuelwood by-products?

Priority 2: fodder trees in cropland, intercropped or in small plots (one bench terrace)

Research questions: species? spacing? location on farm? fodder production? effect on crop production? cut fodder vs. once-a-year browse?

Priority 3: Use of tree biomass for pre-composting ("boma mulching") and composting (combine with fuelwood production).

Research questions: fencerow or dispersed trees? best species? timing? quantities? labour input? nutrients and organic matter content? effect on soil? yields? farmer assessment.

Priorities for related systems research (support)

Priority 1: Propagation methods with and without nurseries (e.g. cuttings, direct seeding, and bare-root and stumping)

Priority 2: Pest control for propagation, establishment (local resources).

Priority 3: (Serves 1, 2, and 3: should be included in each case) Landscape planning with families and groups, accounting for access to, and ownership of, different places within-farms and within-communities.

Research questions: Time-series planning to account for tenure and access shifts; land subdivision and land use conversion at farm/community level; develop and propose various components, mixture, arrangements and social organization options; determine with clients most acceptable avenues to pursue, then monitor performance as-per-usual.

Priority 4: (serves main priorities 1,2,3 and related research priority 3 (landscape). Training and Extension approaches: assessment of alternative approaches and techniques (for Kathama and other similar areas), decision points, and decision criteria (usable by research, development, and extension field personnel).

Lessons From Kathama

Both farm and watershed (group) activities converged on the gap and false dichotomy between treatment of farm and larger-scale units. These social themes were common to both activities:

1. the need to mobilize group labor, group skills, group learning and shared access to land and water, to support productive AF technologies on-farm (for the benefit of individual members and households);

2. the need to better integrate women into the initial D+D and farm trials and to better serve their interests in technology design and in organization of group trials/activities;

3. the need to better address questions of shared use and sustainability of farm production and to consider the production benefits to individuals from off-farm, public and shared lands;

4. the need to adjust technology designs for different production objectives and different levels of access (within households and between households) to the means and fruits of production (on and off-farm);

5. the need to plan with farm families and community groups for technology and landscape designs that can adapt to land subdivision, labor pool fluctuations, land use conversions, migration, and other aspects of household and community developmental

The implications of point four are critical for AF design. One approach would be to design separate AF options for each group with a different level of access to resources and different domain of control. Another solution would be to integrate complementary resources of different groups, whether at farm or larger-than-farm scale. Feasibility of separate versus integrated designs will vary, depending on the existing distribution of resources, control over them, and access to them.

Point five also warrants special attention from social scientists directly involved in technology design. Not only can AF technology be adapted to existing household and community development cycles, but it can be purposely used as an agent of change or of stabilization. In many cases the technology and landscape designs can also help to determine the future of the system by stabilizing development cycles, particularly with respect to land subdivision and land use conversion.

The Kathama Project experience demonstrates the empirical and practical basis for the inclusion of social science theory, methodology and practice in AF research and extension. Social science skills can help solve problems for both clients and researchers, both with respect to AF technology per se, and to the way in which it is tested, evaluated, modified, and disseminated.

The example cited refers to a mixed farming system practiced by a sedentary population, in an area where land adjudication (by household) has already occurred. However, the suggested combination of land-use planning with AF research and extension can apply to any tenure situation, provided that there is interaction of public (or group) and private resources in AF production for indivuals, farm households, and the community. Such an approach may be even more important in cases where the community ,rather than the household, directly manages some aspects of agricultural (or AF) production.

The development of a sliding-scale AF/FSRE approach for the 'communal lands' of eastern and southern Africa presents a special challenge to interdisciplinary AF researchers, particularly to social scientists. The mixed pastoral and agricultural systems of the semi-arid and sub-humid zones, and the shifting cultivation and bush-fallow systems of the humid areas are both changing rapidly in response to population pressure, land allocation , national economy and new technologies. AF technologies for transition to sustainable intensified systems should build on existing local organizations and institutions for management of trees, crops, animals, water,and land.

Farming systems researchers have documented the distinct objectives and conditions of communal farmers for cattle (Avila,1984 ; AP , RU,1983; Hayward,1984;) crop production (ATIP,1984; Kean,1983; Mugabe,1984; Qasem,1984). and land and

water management (Peters,1980; Roe and Fortmann,1982;Silitshena,-1983;Harris,1981; Castelli Gattinara,1984). In addition to the differences in resource base and objectives, the basis of control and ownership (Peters,1980; Roe and Fortmann,1982), and the codes of group decision-making in 'communal systems' contrast sharply with large-scale commercial farm management. Issues of community re-source management impinge heavily on individual behaviour re:management of animals, fodder, fuel and water collection, land preparation and demarcation, and seasonal migration.

While the extensive grazing systems are the most widely recognized examples of communal tenure and management, similar issues arise in the management of water-harvesting, small-scale irrigation, contouring, dry season fodder banks, tree crops, and introduction of new crops and practices. On-site work in communal systems will require interdisciplinary expertise, and an approach that goes beyond household-based research to treat community and intra-household questions of tenure, water rights, grazing and collecting rights (fuel,food, fodder, fibre, dung). Experimental variables would include alternative organizational models (tenure, distribution of labor, extension methods), as well as economic, biological and ecological variables. This rather global approach need not be stretched too thin, but could best be used to address a single problem with a few 'best bet' technologies as the focus ,within a long-term, integrated plan.

National production goals and local development need to build on the strengths of existing communal area production systems and the social organization that guides them. Senior research

administrators and policy makers have indicated that legislation and other controls will be needed for future development of communal farm resources, such as land, water, and government services. The challenge is to develop compatible technical and social innovations that are sustainable, and that serve a reasonable mixture of individual, community and national objectives. Social scientists have a major role to play in that process, as members of interdisciplinary research and extension teams, and as advisors to policy makers.

References

APRU (Animal Production Research Unit) (1983) Livestock and Range Research in Botswana 1981-82. Gaborone: Ministry of Agriculture.

ARPT(Adaptive Research Planning Team) (1983) Chilanga, Zambia: Annual report 1982-83. Mount Makulu Research Station.

ATIP, (1984) Annual Report 1983-84, Agricultural Technology improvement Project, Gaborone: Ministry of Agriculture.

ATIP, (1984) "Annual Report No. 2 Aug 1983-Aug 1984", Agricultural Technology Improvement Project (ATIP). Mid-American International Agricultural Consortium (MIAC), Dept. of Agric. Res., MOA, Botswana, Interim internal draft document, 130 pp.

Arap-Sang, F.M (1984) Annual Report. Dryland Agroforestry Project. Nairobi: KARI (Muguga) and IDRC.

Avila, M (1984) Monitoring and Evaluating the Effectiveness of On-farm Research Trials. Harare: Ministry of Agriculture.

Boer, Edu (1984) Measuring Stickwood Increment in Grazed and Non-grazed Woodlands, Kathama. Draft report for practical field pr oject. Netherlands: Forestry Dept. Wageningen University.

Buck, Louise (1984) Siaya Agroforestry Project. Proposal; Training Manual; Project Documents. Nairobi: Care-Kenya.

Cantor, Jill (1984) Survey of Off-Farm Land Use by 31 households in Sample Watershed, Kathama Sub-Location, Machakos District, Kenya. Raw data and Summary. Mimeo Nairobi: ICRAF.

Caplan, Donna (1984) Survey of Off-farm Land Use by Households in Kakuyuni Watershed, Katangi Sub-Location, Machakos District Kenya. Raw Data. Mimeo. Nairobi: ICRAF.

Castelli-Gattinara, G.C (1984) Basotho Culture and Lesotho Territory; The Development of Land Use Planning Institution(s) for Rural Areas, Lesotho. Lesotho: FAO, SIDA, Ministry of Agriculture.

Chambers, R (1981) Rapid Rural Appraisal: rationale and repertoire. Public Administration and Development 1: 95-106.

Collinson, M.P (1981) A Low Cost Approach to Understanding Small Farmers, Agricultural Administration 8, 433-450.

Dove, M.R (1983) Theories of Swidden Agriculture, and the Political Economy of Ignorance. Agroforestry Systems, 1, 85-10.

Fortmann, L (1985) The Tree Tenure Factor in Agroforestry, with Particular Reference to Africa. Agroforestry Systems 2, 229-251

Harris, J (1981) A Conceptual Framework for the Study of Migration in Botswana. Working Paper No. 42, Boston: African Studies Centre, Boston University.

Hayward, J.W (1984) Drought and Communal Areas: Agricultural Extension Priorities. Harare, Ministry of Agriculture.

Hildebrand, P.E (1981) Combining disciplines in rapid appraisal: the sondeo approach. Agricultural Administration 8, 423-432.

Hilderbrand, P.E and F. Poey (1985) On-Farm Agronomic Trials in Farming Systems Research and Extension Boulder: Lynne Rienner Publishers, Inc.

Hoek, Annet van den (1983) Landscape Planning and Design for a Watershed in the Kathama Agroforestry Project, Kenya, Master's Project Report, Wageningen: Department of Landscape Architecture and Planning.

Hoekstra, D.A (1984) Agroforestry Systems for the Semi-arid Areas of Machakos District, Kenya, Working Paper No. 19, ICRAF. Nairobi: ICRAF. 28 PP.

ICRAF.(1983) Guidelines for Agroforestry Diagnosis and Design, Working Paper No. 6, Nairobi: ICRAF.

ICRAF. (1983) Resources for Agroforestry Diagnosis and Design, Working Paper No. 7, Nairobi: ICRAF.

Kean, S and W. Chibasa, (1981) Institutionalising Farming Systems Research in Zambia. Chilanga. Zambia: Research Branch, Department of Agriculture.

Mwendandu, Richard (1984) Report on Farm Trials and Nursery at Kakuyuni, Dryland Agroforestry Project. Muguga (Kenya): KARI.

Qasem, M.A (1984) Pilot Schemes and Studies for the Development of Settler Irrigation in Zambia. Zambia: FAO/Ministry of Agriculture, National Irrigation Research Station.

Raintree, J.B (1983) A diagnostic approach to agroforestry design. Paper submitted to the International Symposium on Strategies and Designs for Hinkeloord, Wageningen: (Holland) Sept. 19-23, 1983.

Rhoades, R.E (1982) The art of the informal agricultural survey. International Potato Center. Lima.

Rocheleau, D (1984a) Progress Report (through April 1984) ICRAF Collaboration in the Care-Kenya Siaya Agroforestry Project. Mimeo. Nairobi: ICRAF.

Rocheleau, D (1984b). Outline Proposal: Potential of AF technology and land management innovations for treatment of off-farm and interstitial lands used by women of farm households. Nairobi: ICRAF.

Rocheleau, D (1985a) Criteria for Re-Appraisal and Re-Design: Intra-Household and Between-Household Aspects of FSRE in Three Kenyan Agroforestry Projects. In Flora, C.B (ed.) Proceedings of Kansas State University's 1984 Farming Systems Research Symposium: Implementation and Monitoring. Manhattan: Kansas State University.

Rocheleau, D (1985b) Women, Trees and Tenure: Implications for Agroforestry Research and Development. In Raintree, J.B (ed.) Proceedings of the International Workshop on Tenure Issues in Agroforestry, 26-30 May, 1985. Nairobi: ICRAF.

Rocheleau, D and A. Hoek. (1984) The application of ecosystems and landscape analysis in agroforestry diagnosis and design: A case study from Kathama Sub-Location, Machakos District, Kenya. Working Paper No. 11. Nairobi: ICRAF.

Rocheleau, D and J. Cantor. forthcoming. Women, Trees and Off-Farm Land Use: Preliminary Findings in Kathama Sub Location. Working Paper. Nairobi: ICRAF.

Roe, E and L. Fortmann, (1982) Season and Strategy: The Changing Organization of the Rural Water Sector in Botswana. Special Series on Resource Management, Ithaca: Cornell University.

Silitshena, R.M.K (1983) Intra-Rural Migration and Settlement Changes in Botswana. Research Report No. 20, Leiden, The Netherlands: African Studies Centre.

Vonk, R.B (1983a) A study on possible agroforestry tree species for the Kathama area, M.Sc. thesis for the Department of Silviculture. Wageningen: Wageningen Agricultural University.

Vonk, R.B (1983b) Report on a methodology and technology generating exercise. Wageningen: Wageningen Agricultural University.

Vonk, R.B (1983c) The effect of different mulch treatments on the growth of maize and beans in a mixed cropping system. M.Sc. thesis for the Department of Tropical Crop Science. Wageningen: Wageningen Agricultural University.

Vonk, R.B (1984) Care-Kenya Siaya Agroforestry Project. Paper Prepared for the End of the Women's Decade "Pre-Workshop", Nairobi: Jan. 18, 1985.

Vonk, R.B (1984) Report on Siaya Agroforestry Project. Nairobi: Care-Kenya.

Wijngaarden, J. van (1983a) Agricultural self help groups and their potential role in agroforestry. Draft Report. Wageningen: Agricultural University.

Wijngaarden, J. van (1983b) Patterns of fuel gathering and use M.Sc. Thesis for the Department of Forestry Management. Wageningen: Wageningen Agricultural University.

Zandstra, H.G., E.C. Price, J.A. Litsenjer and R.A. Morris, (1981) A methodology for on-farm cropping systems research. Los Banos, Philippines: IRRI.