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CASE STUDIES IN AGROFORESTRY DIAGNOSIS AND DESIGN NO. 4

11

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

BY

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F O R E W O R D

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

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

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

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

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

J. B. Raintree
Case Studies Series Editor

INTRODUCTION

What has Landscape got to do with Agroforestry?

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

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

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

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

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

Why the need for a special approach?

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

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

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

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

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

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

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

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

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

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

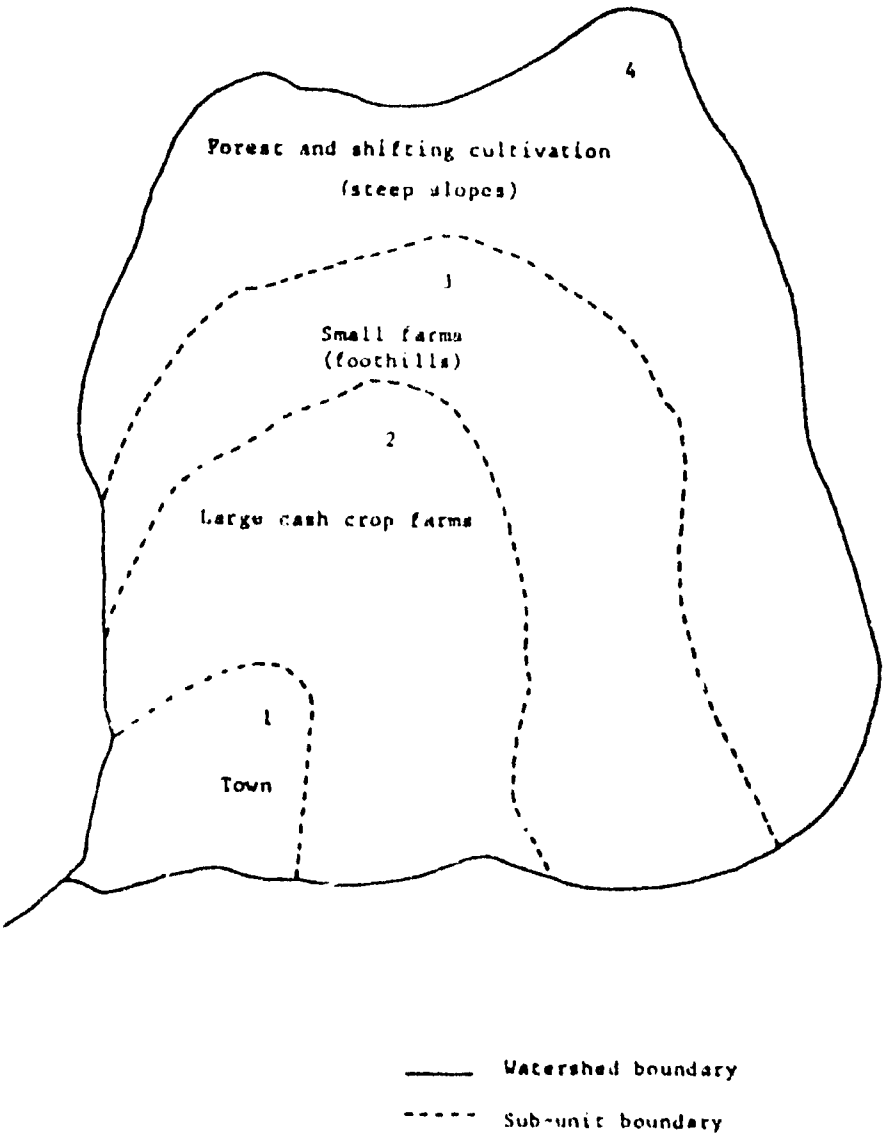

FIG. 1: GEOGRAPHICAL STRATIFICATION

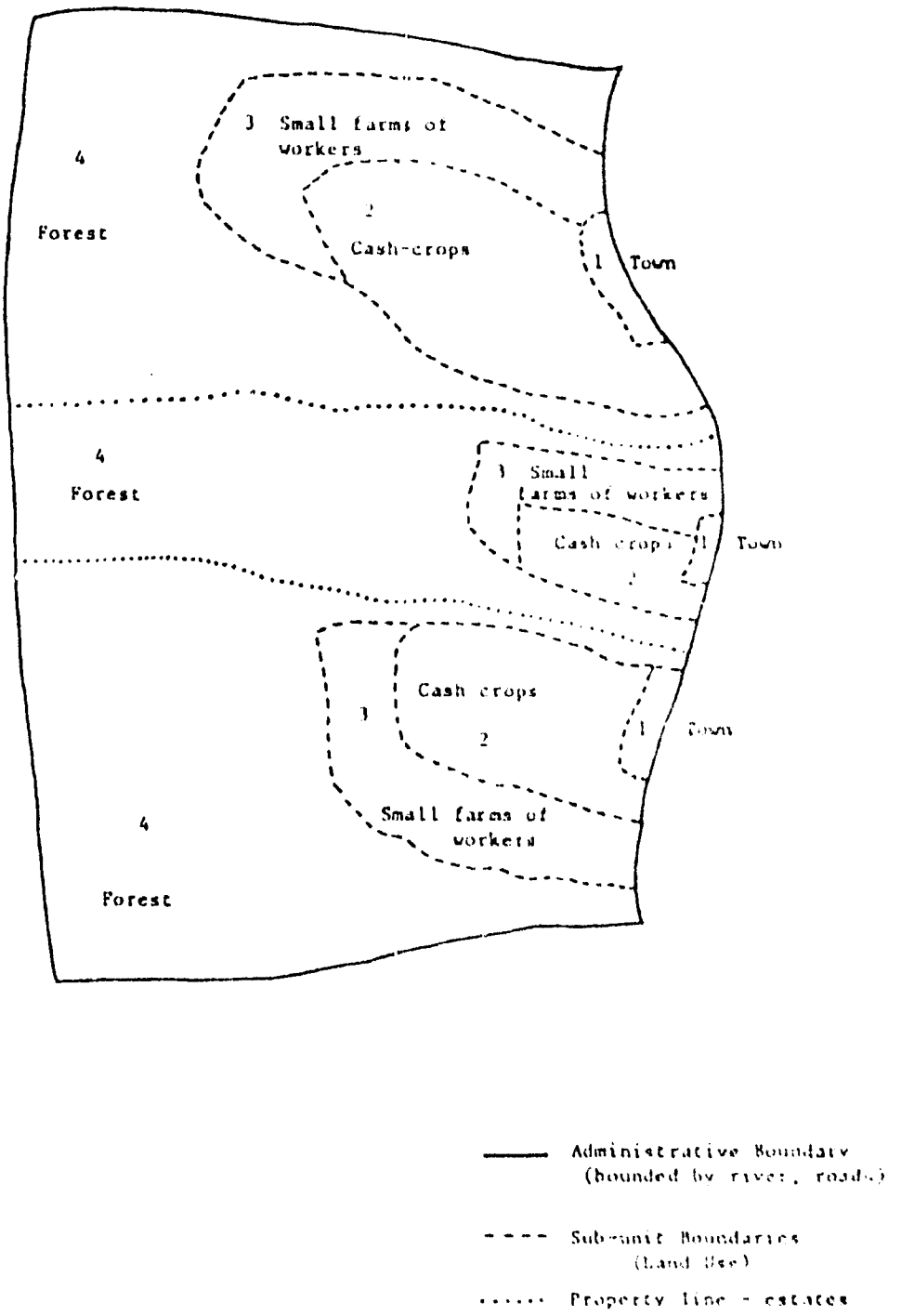

FIG. 2: STRATIFICATION BY FUNCTIONAL CRITERIA

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

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

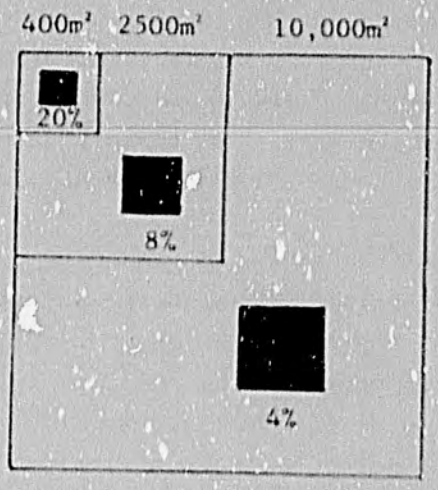

Fig. 3A: Square Sub-Divisions

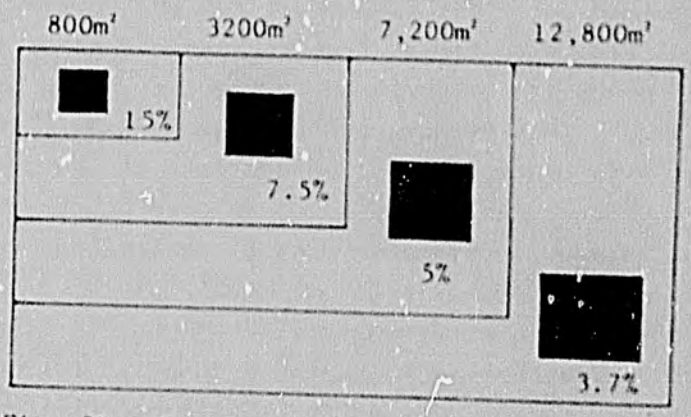

Fig. 3B: 1 x 2 Rectangles

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

Table 1 Relation of Boundary Area to Total Area

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

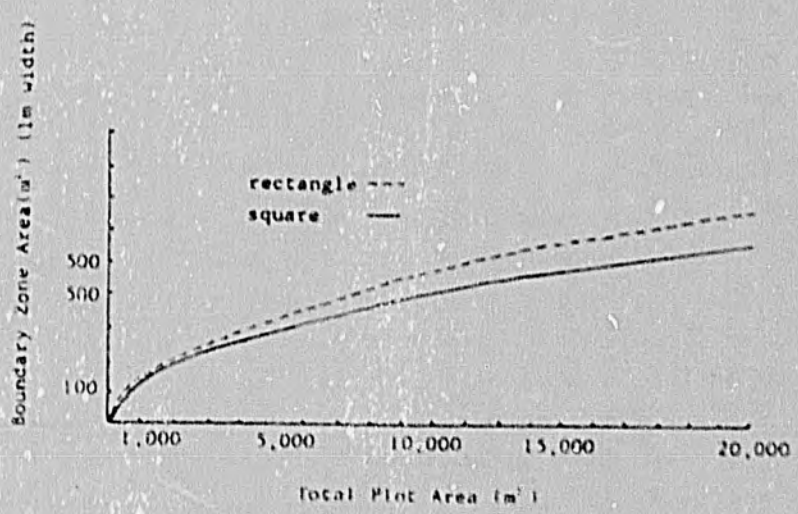

FIG. 4 GRAPH RELATING BOUNDARY AREA TO TOTAL AREA FOR SQUARES AND 1 x 2 RECTANGLES

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

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

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

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

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

Who would apply this method?

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

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

How do you systematically apply such an approach?

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

CASE STUDY EXAMPLE: KATHAMA RESEARCH SITE

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

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

Land.

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

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

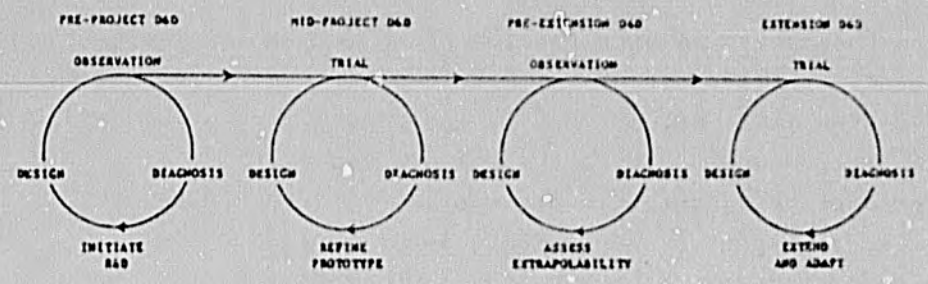


FIG. 5: D&D AS AN ITERATIVE PROCESS IN THE PROJECT CYCLE
(Source: Raintree, 1983; ICRAF, 1983)

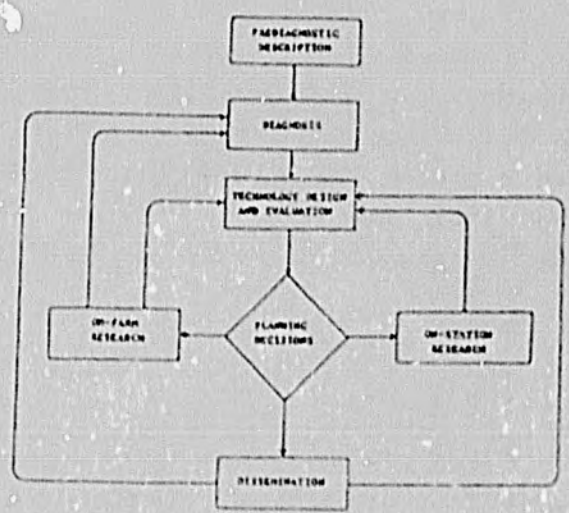


FIG. 6: DIAGNOSIS AND DESIGN (D&D) PROCESS
(Source: Raintree, 1983; ICRAF, 1983)

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

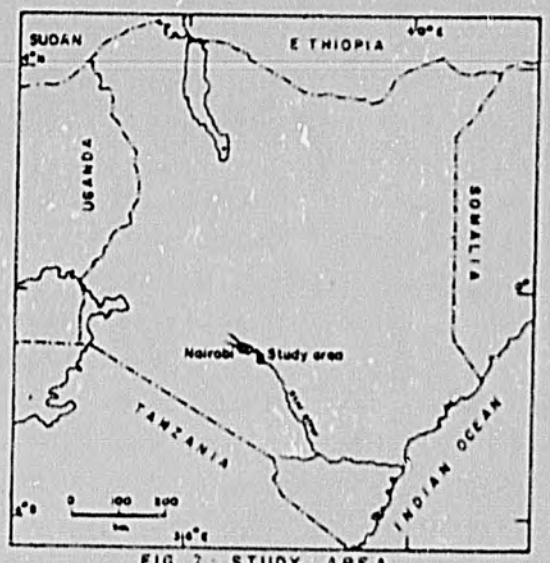


FIG 7 : STUDY AREA

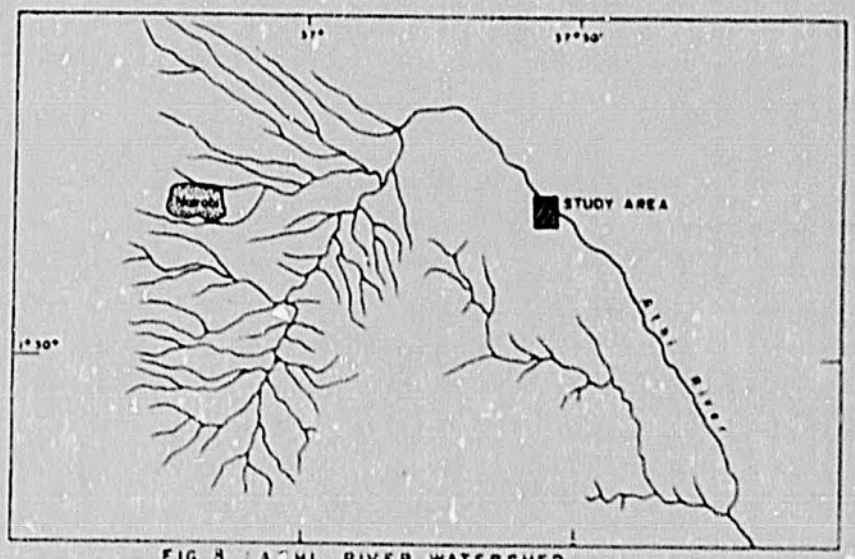


FIG 8 : ATHI RIVER WATERSHED

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

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

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

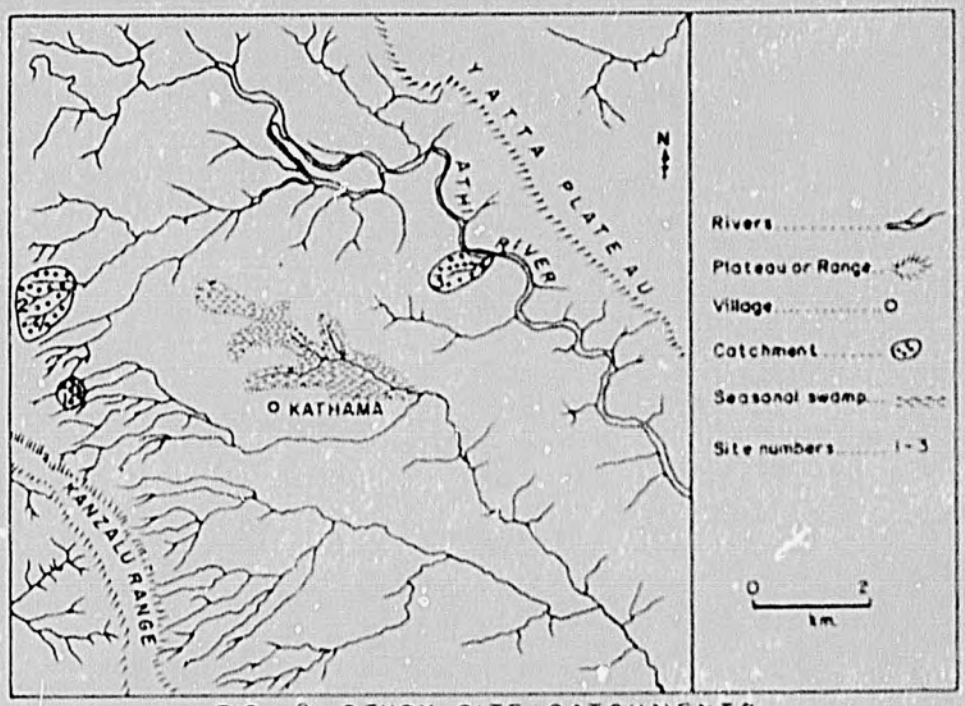


FIG. 9: STUDY SITE CATCHMENTS

(Hoek, 1983)

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

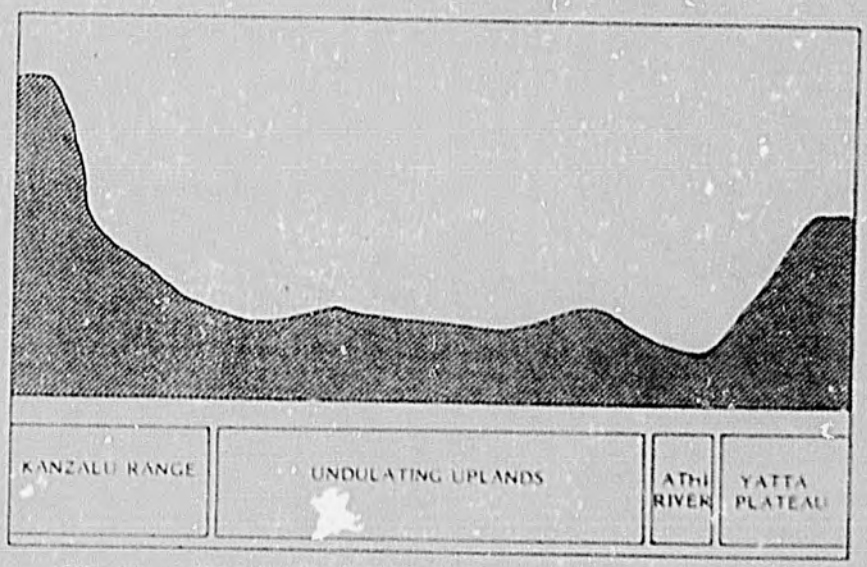


FIG. 10: TOPOGRAPHIC PROFILE WITH LAND UNITS

(Hoek, 1983)

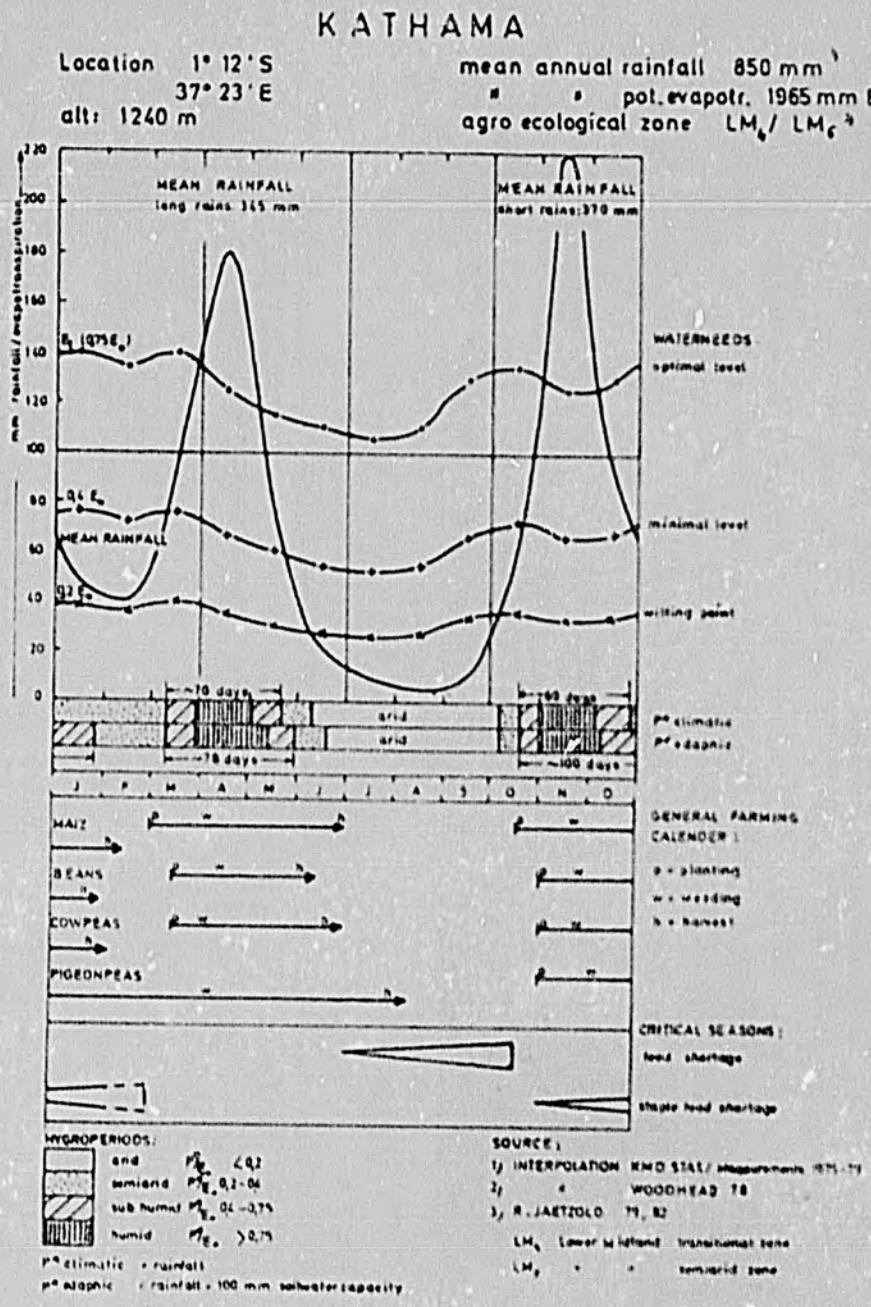
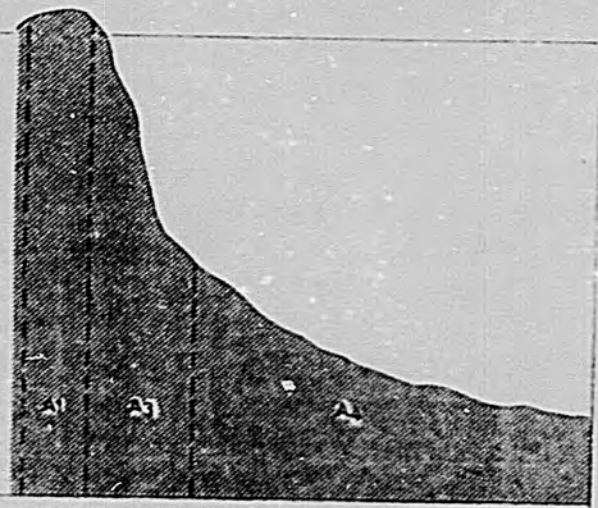


FIG. 11: CLIMATE SUMMARY FOR KATHAMA

(Darnhofer, ICRAF)

FIG. 12A: LAND UNIT DESCRIPTION

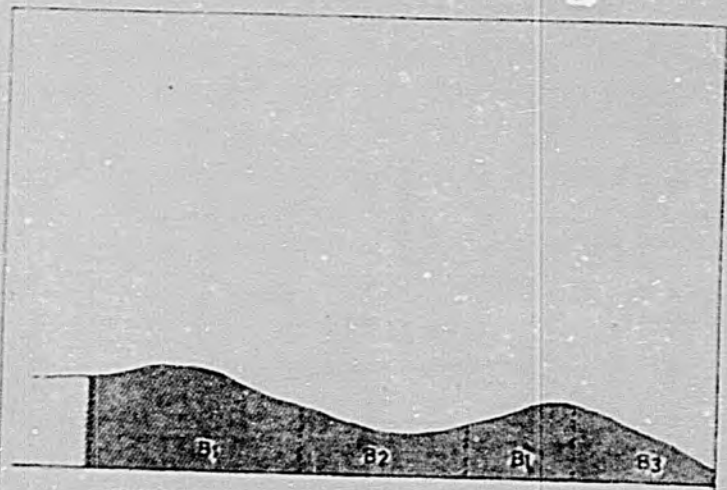


	ridge	Steep slopes with rock outcrops	Rolling footslopes
Slopes	A1.1 flat to very gentle	A3.1. steeply sloping	A4.1. moderately sloping
Drainage	well drained	well drained	in places imperfectly drained
Soils		shallow stony soils	reddish brown clay ultisols
Landuse	road - shambas[1]	bushland used for grazing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

(Hoek, 1983)

1. 'Shamba' farm

FIG. 12B: LAND UNIT DESCRIPTION



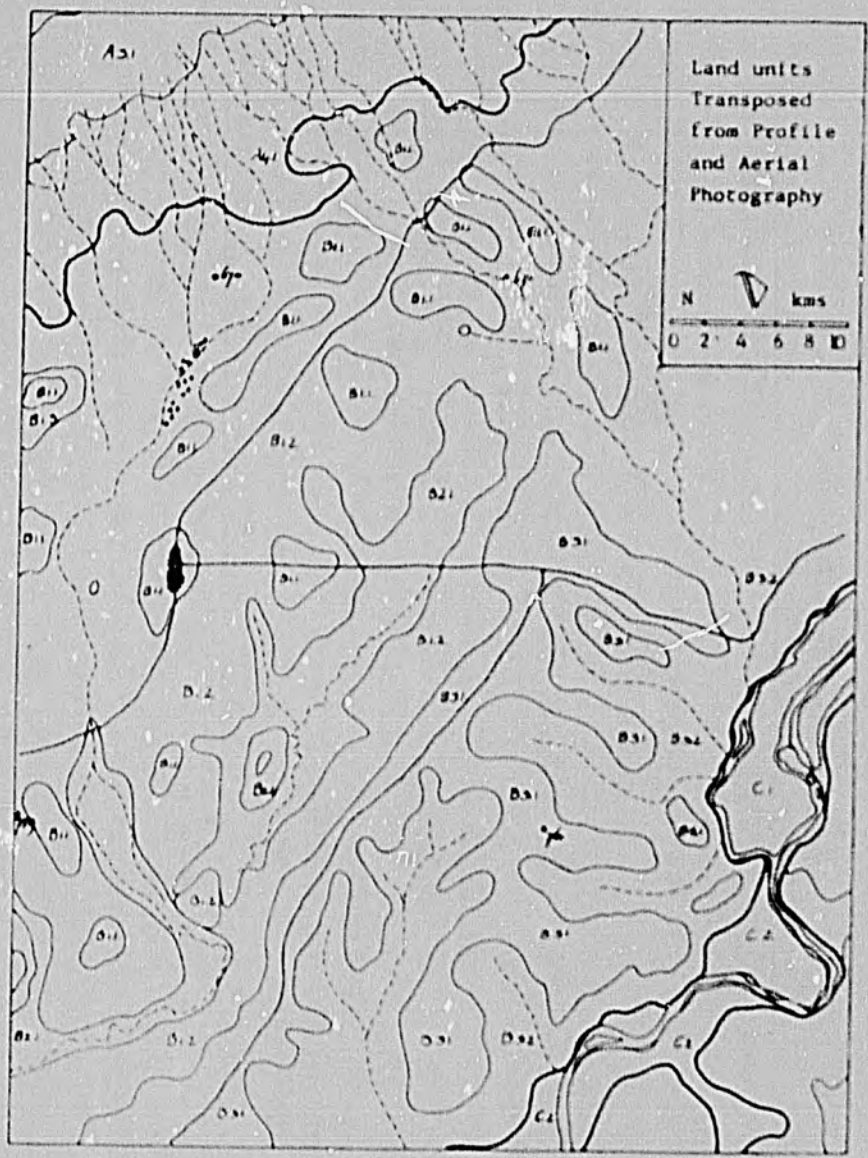
	undulating uplands	flat/almost flat depression	rolling slopes
Slopes	B1.1. flat to very gentle B1.2. gently sloping B1.3. moderately sloping	B2.1. flat to very gentle	B3.1. flat to very gentle B3.2. moderately sloping
Drainage	well drained	badly drained seasonal water-logging	well drained
Soils	red compact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

(Hoek, 1983)

LEGEND TO LAND UNIT DESCRIPTION

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

FIG. 13: PLAN VIEW OF LAND UNITS*



*See legend p.23

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

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

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

People.

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

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

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

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

Excerpted from Vonk, 1983

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

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

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

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

4. Most households have 10 goats, up to 7 cattle; 1 animal unit = 5 goats; 1 adult cattle; 2 cattle < 1 year; 1.3 cattle 1 - 3 years (Rukandema, et al. 1981).

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

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

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

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

Land use

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

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

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

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

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

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

Land Tenure, Use Rights and Water Rights

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

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

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

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

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

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

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

Government Services and Organization.

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

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

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

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

DIAGNOSIS AND DESIGN

Farming Systems Problems and Potentials.

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

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

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

KATHAMA
MACHAKOS DISTRICT
KENYA

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

SYSTEM DESCRIPTION	LAND USE SYSTEM DIAGNOSIS		AGROFORESTRY POTENTIALS
	HOUSEHOLD SUPPLY PROBLEMS	PRODUCTION CONSTRAINTS	
Climate Semi arid-sub-humid **Soils** Sandy loams over sandy clay loam to sandy clay; imperfectly drained in places **Farming System** Mixed farming **Crops** Maize, beans, pigeon peas, cowpeas **Livestock** Zebu cattle, goats and sheep **Economy** Subsistence farming **Population Density** 171/Km^2 **Growth Rate** 3.4%	**Problems in Basic Needs Supply Sub-Systems** FOOD - Seasonal staple food shortages normal, must purchase; drought related crop failure on avg. of once in every five years; low milk and meat production due to dry season feed shortage for livestock FUEL - Insufficient production from own land, must purchase fuelwood for household and cottage industry uses; lack of large trees for brick burning. SHELTER - Lack of construction quality timber and poles, must purchase; lack of large tree for brick burning; lack of fencing and shade trees. RAW MATERIALS FOR HOUSEHOLD INDUSTRY Must purchase fuelwood for brick making. CASH - Low net household income due in part to cash outflow for staple foods, fuelwood, and construction wood; savings and earning potential of livestock enterprise limited by dry season feed shortage **CONSERVATION PROBLEMS** Erosion Declining Soil Fertility Degradation of grazing land vegetation	**Antecedent Causal Factors** **Crop Land** 1. Low fertility and declining yields 2. Lack of manure 3. Low available moisture 4. Oxen too weak for dry season ploughing/planting; hence inefficient use of limited soil moisture. 5. Soil erosion and water loss due to heavy runoff. 6. Waterlogging on low spots 7. Labour bottleneck at ploughing and weeding time. 8. Insect pests. **Grazing Land** 1. Small grazing area 2. Insufficient dry season feed production. 3. Insufficient production of fuelwood **DESIGN CONSTRAINTS** Low capital Low available labour Long dry season, frequent droughts Termites & other pests	**Specific Problem-Solving Agroforestry Potentials** 1. Elimination of dry season feed gap by planting of multipurpose fodder trees in grazing areas and as hedgerow in cropland with concomitant erosion control effects and fuelwood and mulch coproduction possibilities; improved feed situation should allow dry season ploughing/planting. 2. Cut-and-carry fodder trees for increased pen feeding and usable manure production. 3. Alley cropping/mulch farming with leguminous and other trees to control erosion, increase water infiltration, conserve soil moisture, improve soil fertility and structure, reduce the need for tillage and lessen the labour requirement for weeding, insect repellence 4. Hedgerows and living fences of high-yielding fuelwood species and fruit producing thorn bushes (as a hedge against famine in bad years, for supplementary livestock feed in average years). 5. Multistorey fruit trees with undersown grass-legume pasture.

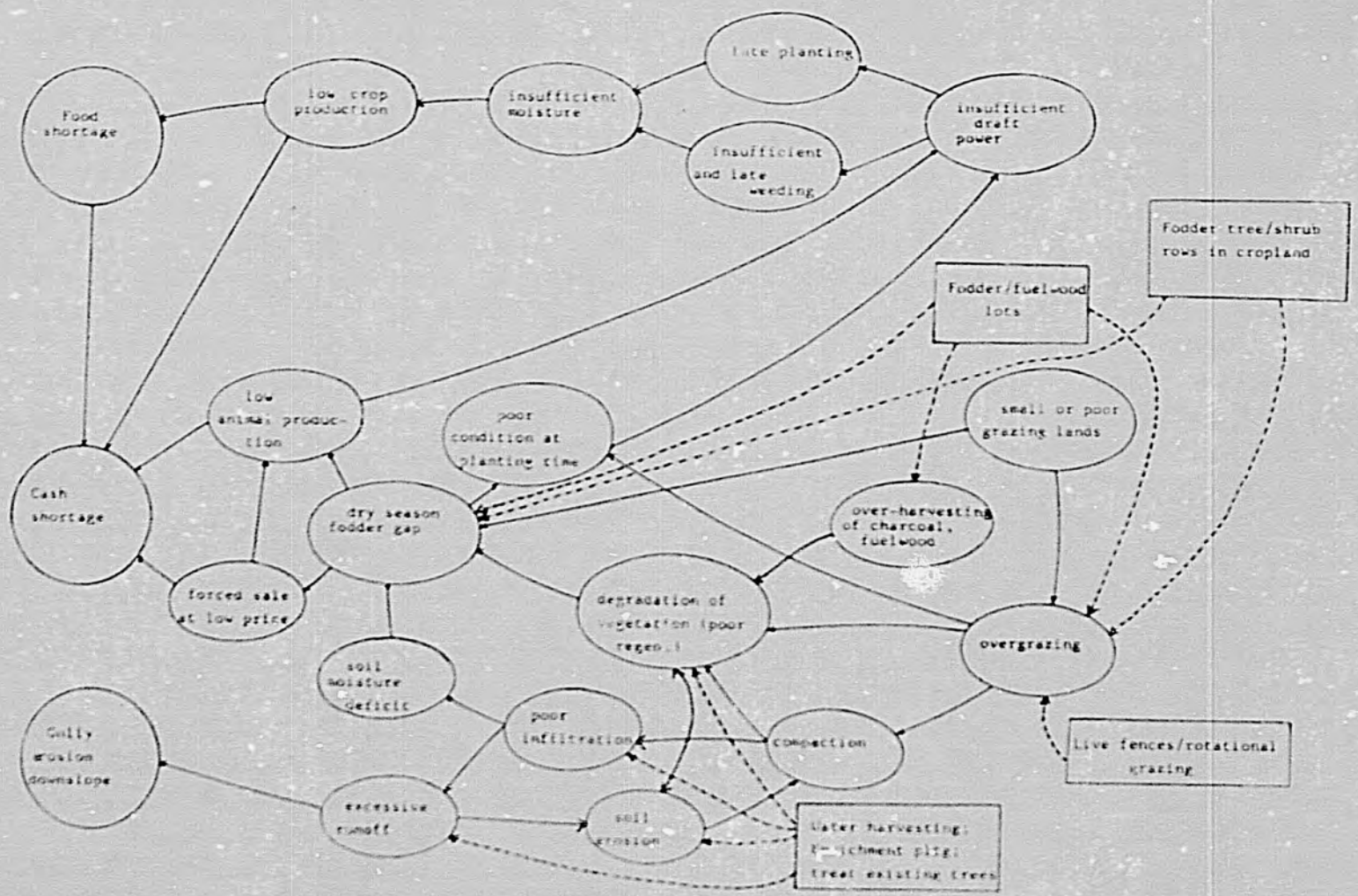
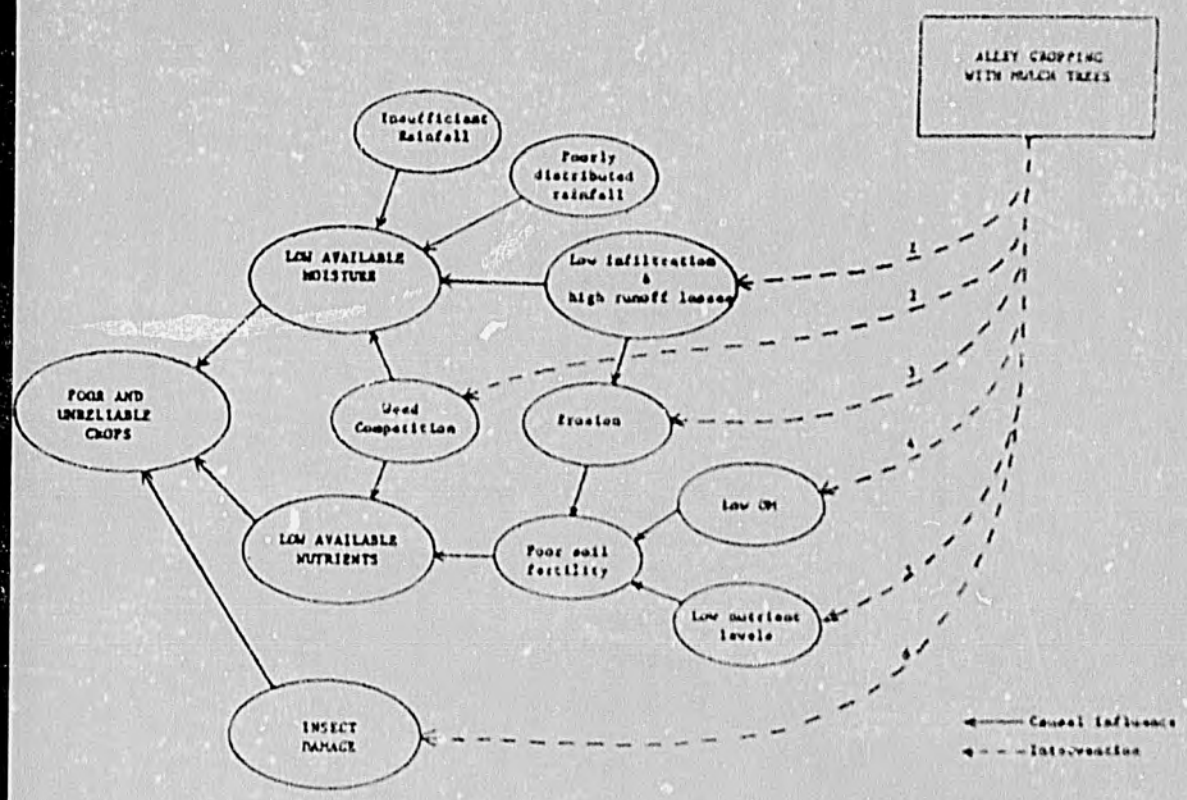


FIG. 16: CAUSAL DIAGRAM OF ANIMAL PRODUCTION
WHICH AFFECTING FOOD AND CASH SHORTAGES

(Adapted from Kung, 19..)



Potential Mulch Trees

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

Potential Interventions

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

FIG. 15. DIAGNOSIS AND DESIGN - CAUSAL DIAGRAM

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

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

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

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

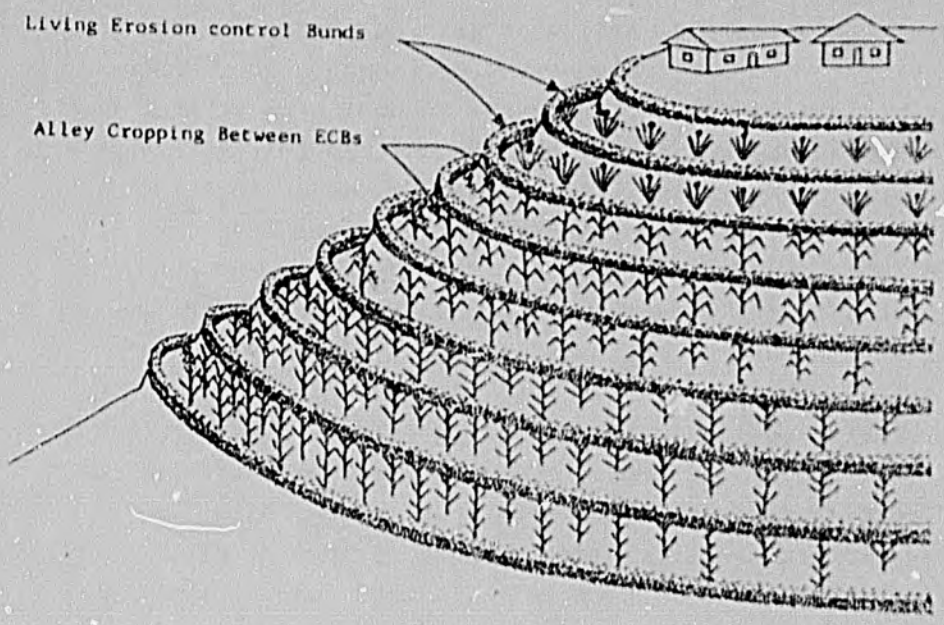


FIG. 16 A HILLSIDE ALLEY CROPPING SYSTEM

(Source: Raintree, 1983;
ICRAF, 1983)

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

	Paraguay	Burundi	Burkina Faso	Canada	Costa Rica	Chile	Cuba	Dominican Rep.	Ecuador	Ethiopia	Fiji	Gambia	Guatemala	Haiti	Honduras	Indonesia	Jamaica	Kenya	Malawi	Mexico	Nicaragua	Nigeria	Philippines
Leucaena leucocephala																							
'K8'	•	•	•	•	•	•	•	•	•			•	•				•	•	•	•	•	•	
'K28'	•	•	•	•	•	•	•	•	•			•	•				•	•	•	•	•	•	
'Peru'	•	•	•	•	•	•	•	•	•			•	•			•	•	•	•	•	•	•	
Cassia siamea	•	•	•	•		•			•	•				•		•	•	•		•	•		
C. glauca	•	•			•				•								•			•	•		
Albizia lebbeck	•	•			•			•	•							•				•	•		
Sesbania sesban	•	•			•	•	•		•			•	•							•	•		
S. grandiflora	•	•			•		•		•				•			•				•	•		
S. bispinosa	•				•		•		•				•							•	•		
S. rostrata	•	•			•		•		•			•				•				•	•		
Stylosanthes scabra		•			•				•			•		•	•		•	•		•	•		
Zizyphus mauritiana	•	•			•	•	•		•		•	•	•							•	•		
Prosopis chilensis	•	•	•		•	•	•	•	•		•	•	•							•	•		
P. juliflora	•	•	•		•	•	•	•	•		•	•	•							•	•		
P. nigra	•	•	•		•	•	•		•				•							•	•		
P. pallida	•	•	•		•	•	•		•				•							•	•		
Grevillea robusta	•	•	•	•				•	•					•						•			
Acacia albida	•	•	•		•	•	•	•	•		•		•							•	•		
A. tortilis	•	•			•		•	•	•		•				•	•				•	•		
A. holosericea	•	•			•		•						•			•	•			•	•		
Pithecellobium dulce	•	•			•	•	•		•		•	•	•			•				•	•		
Croton megalocarpus	•	•	•	•								•				•				•			
Jacaranda mimosifolia	•	•	•																				
Tamarindus indica	•				•	•	•				•	•	•										
Azadirachta indica	•	•	•	•				•	•	•				•	•	•							
Melia azederach	•	•	•	•				•	•	•				•	•	•							
Acrocarpus fraxinifolia	•			•																			
Casuarina equisetifolia	•	•	•	•	•				•							•							
Melaleuca cajuputi	•	•	•		•	•	•	•	•		•				•	•							
Moringa oleifera						•									•								
Samanea saman	•	•	•	•	•	•	•	•	•			•	•		•	•							

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

Excerpted from Vonk, 1983.

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

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

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

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

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

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

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*Multipurpose trees.

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

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

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

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

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

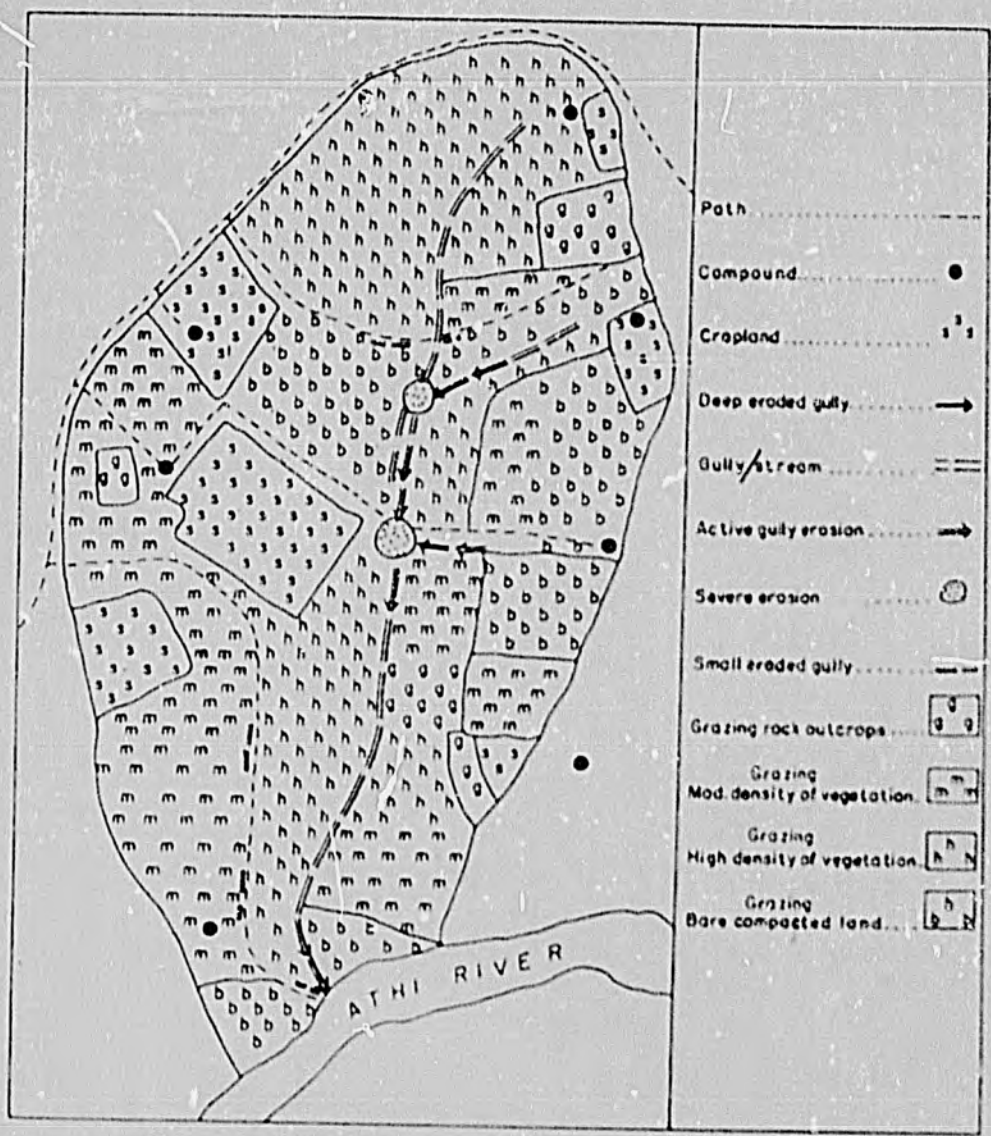


FIG. 17 ULAANI CATCHMENT (3) DRAINAGE AND LAND COVER
(Hoek, 1983)

* See Fig. 9 for Location

** Sketch, not to scale

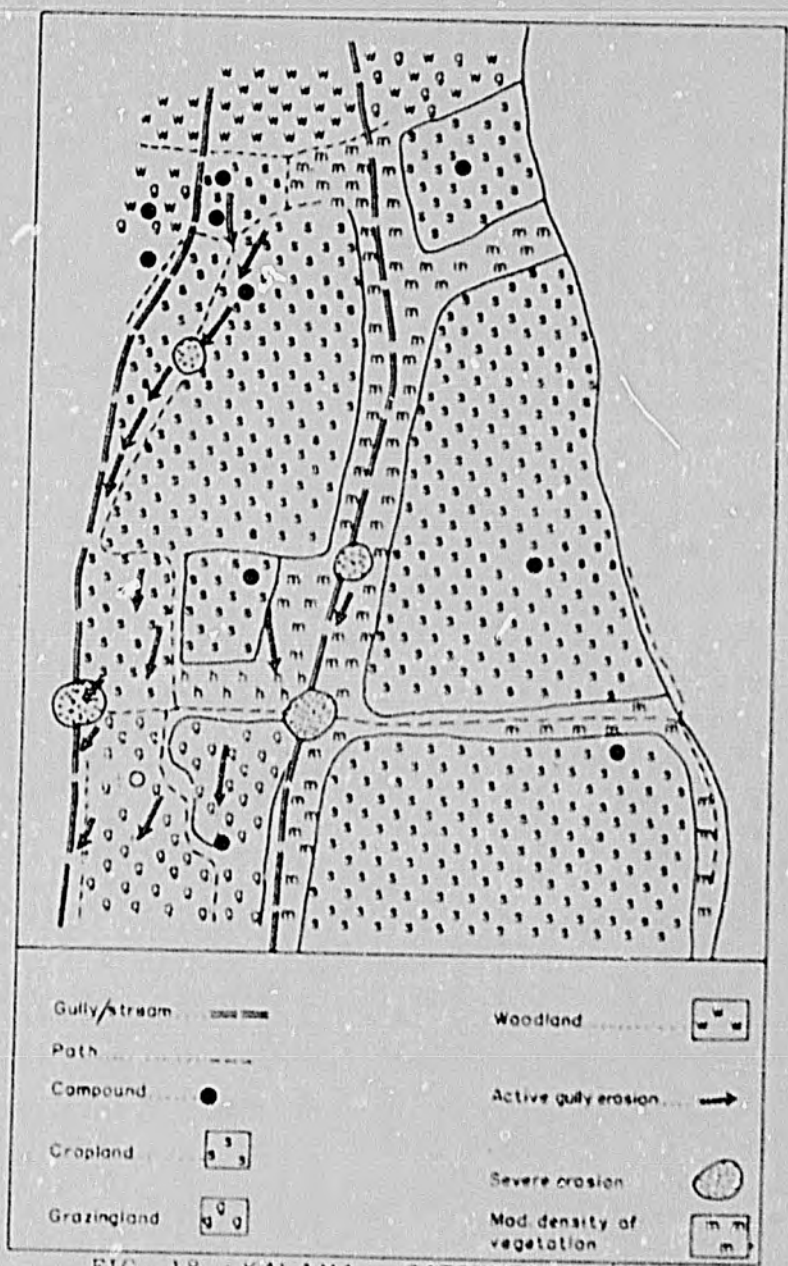


FIG. 18 : KALAMA CATCHMENT (I)*
DRAINAGE AND LAND COVER

* See Fig. 9 for Location
** Sketch, not to scale

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

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

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

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

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

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

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

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

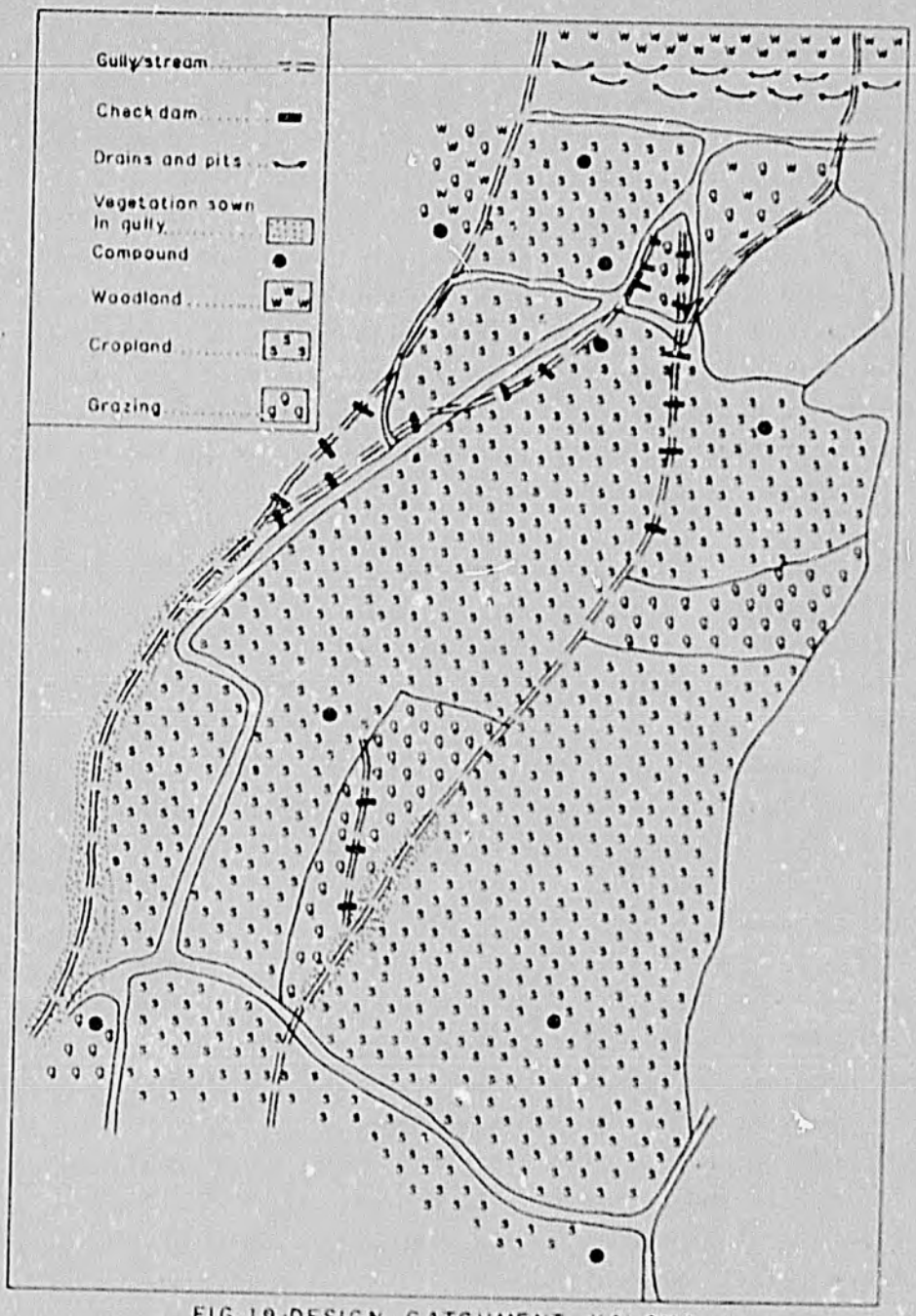
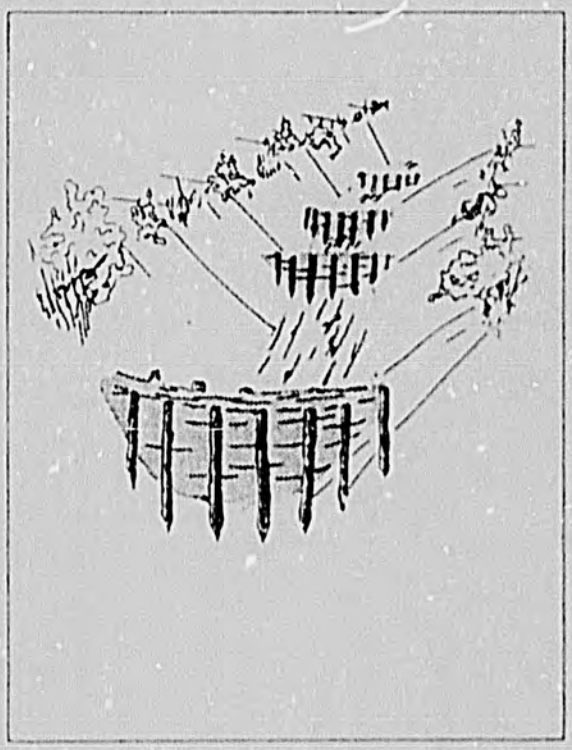


FIG 19:DESIGN CATCHMENT KALAMA I

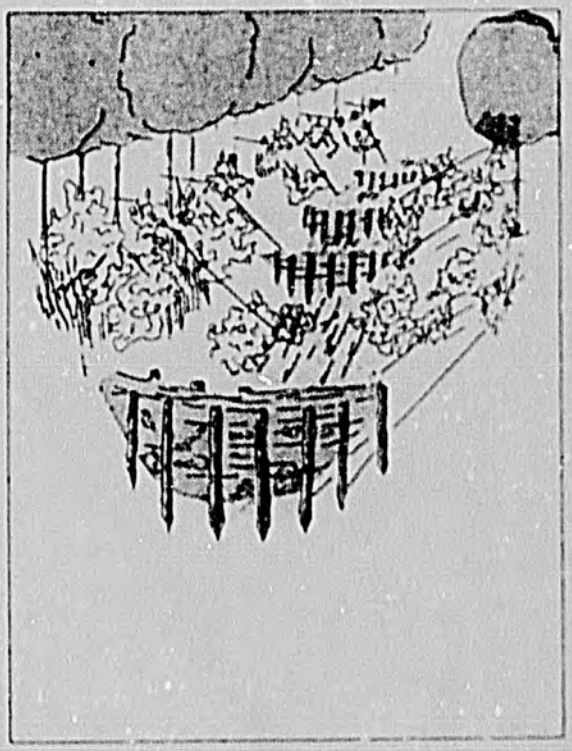
(Hoek, 1983)

FIG.20: PRODUCTIVE GULLY RECLAMATION DESIGN

(Hoek, 1983)



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



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

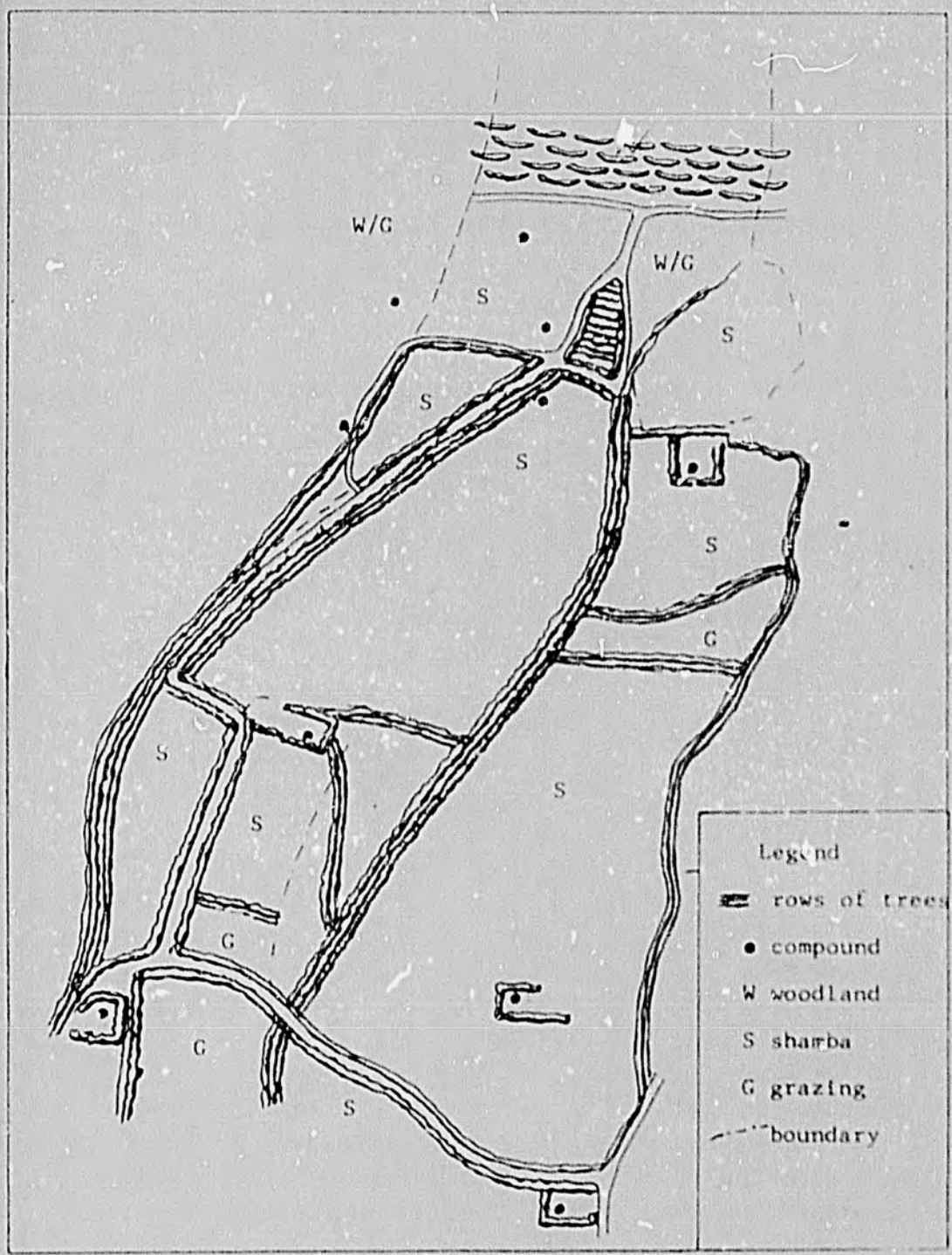
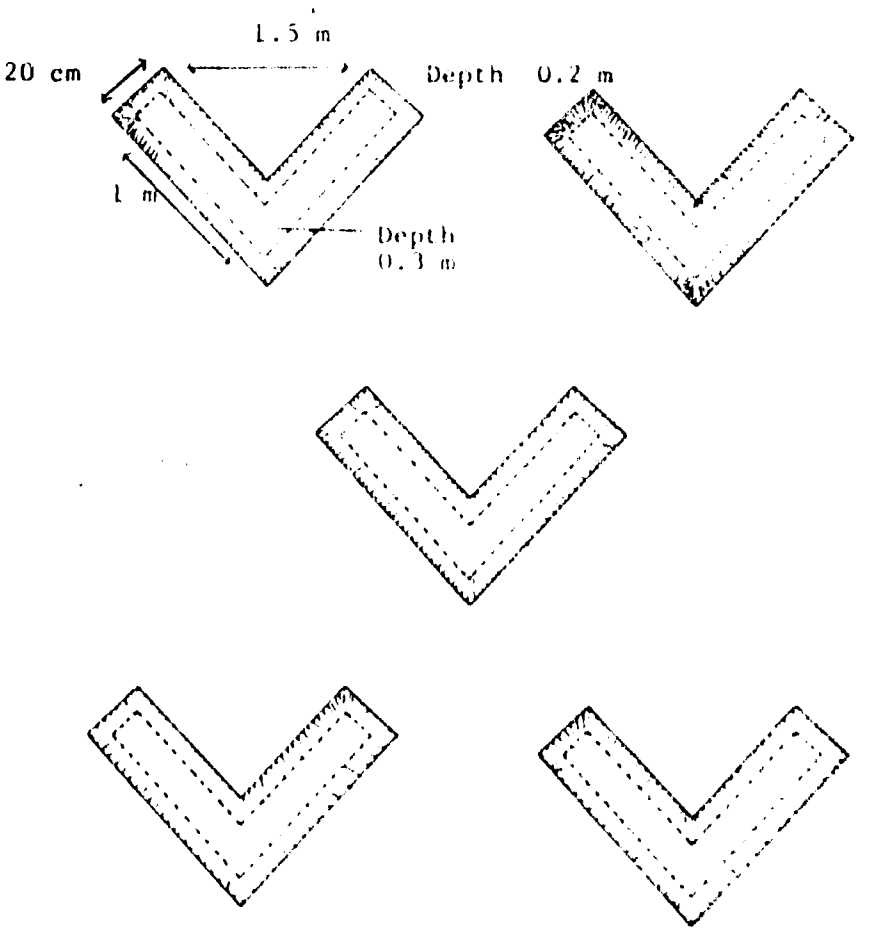


FIG. 21 DESIGN FOR PLANTING, KALAMA CATCHMENT

(Hoek, 1983)

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

Approximate dimensions suitable under conditions in Kalama catchment:



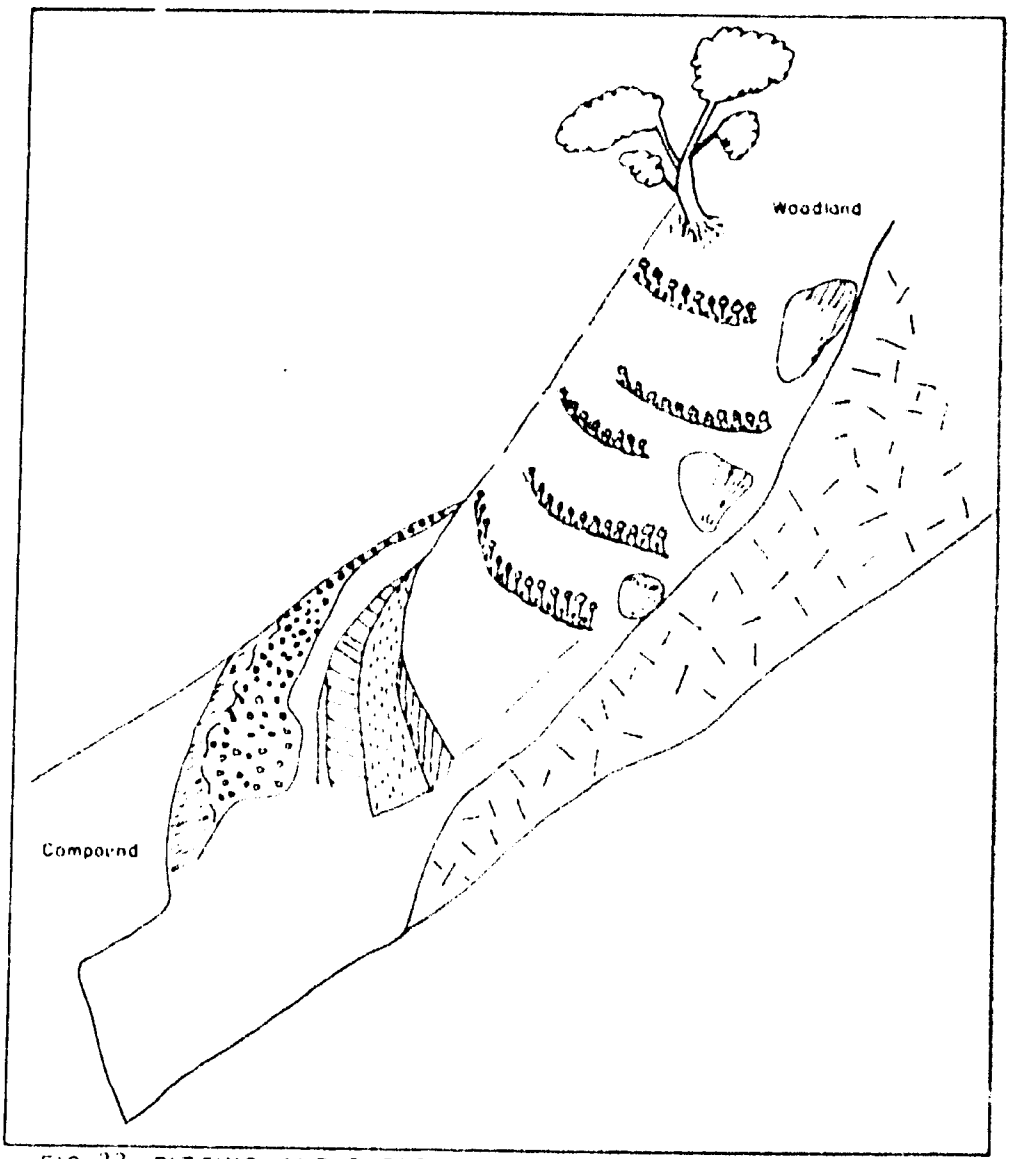
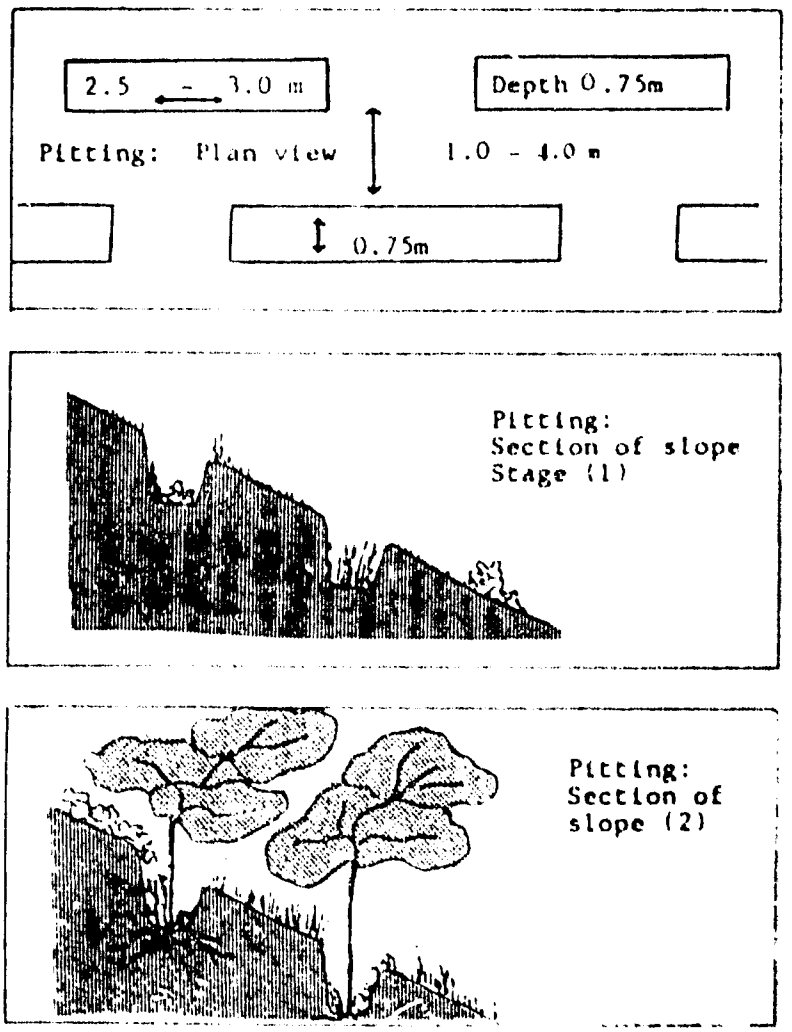


FIG 23. PITTING AND CUTOFF DRAINS DISCHARGING WATER FROM HILL SLOPE

(Hoek 1983; Wenner, 1980)

FIG: 24: DETAIL

PITTING FOR WATER HARVESTING,
INCREASED PRODUCTION ON SLOPES

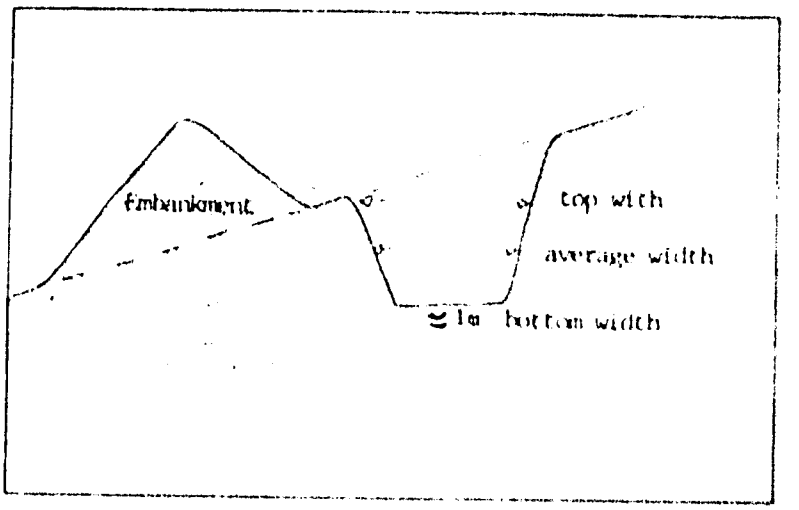


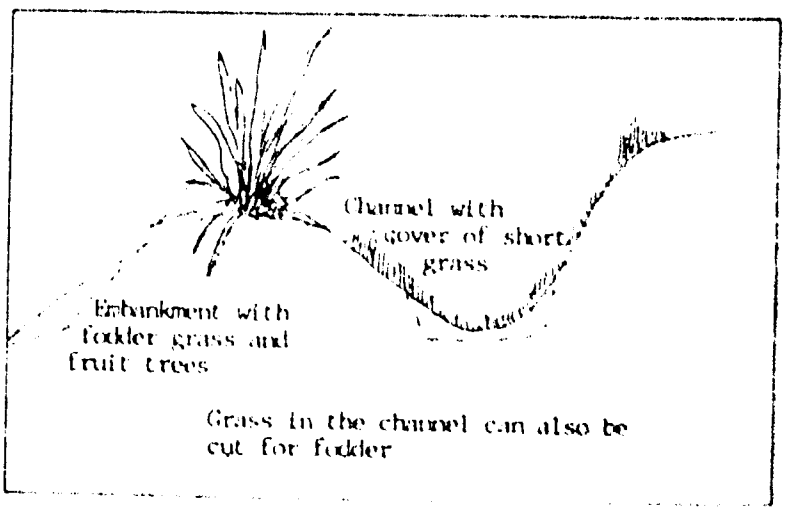
(Hoek, 1983)

FIG. 25: DETAIL: CUT-OFF DRAIN

Stage 1. Structure

Stage 2. Planting





(Hoek, 1983 · Wenner, 1980)

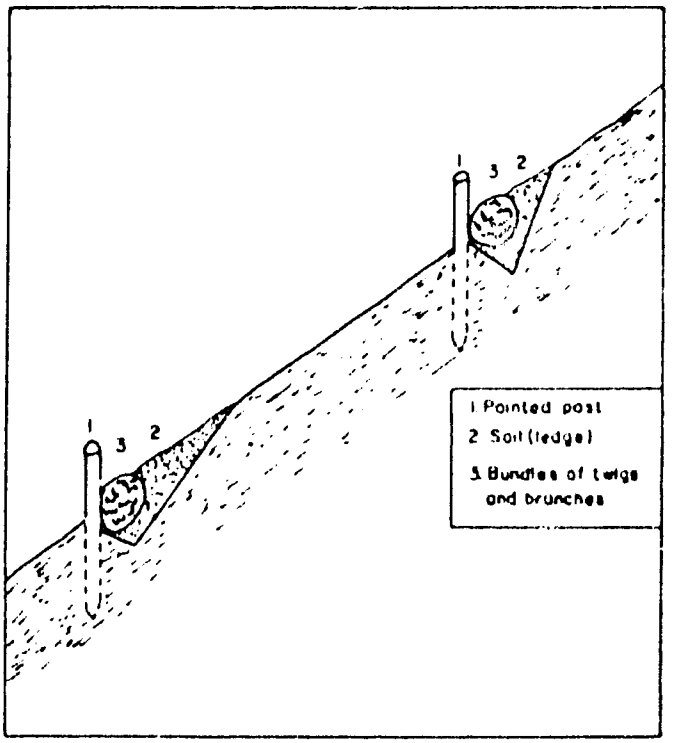


FIG. 26 CONTOUR WATTLING

(Hoek, 1983)

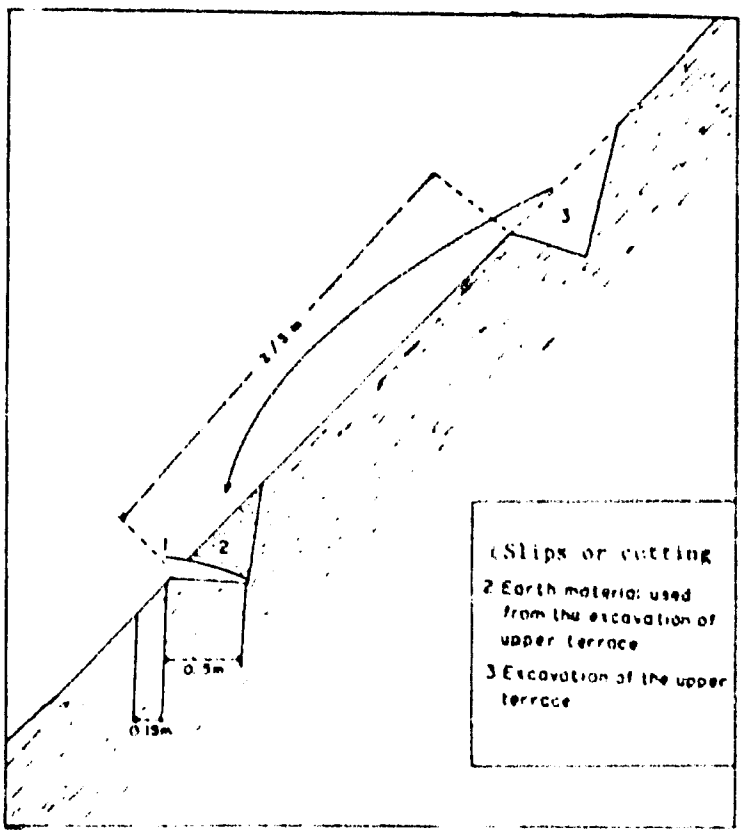
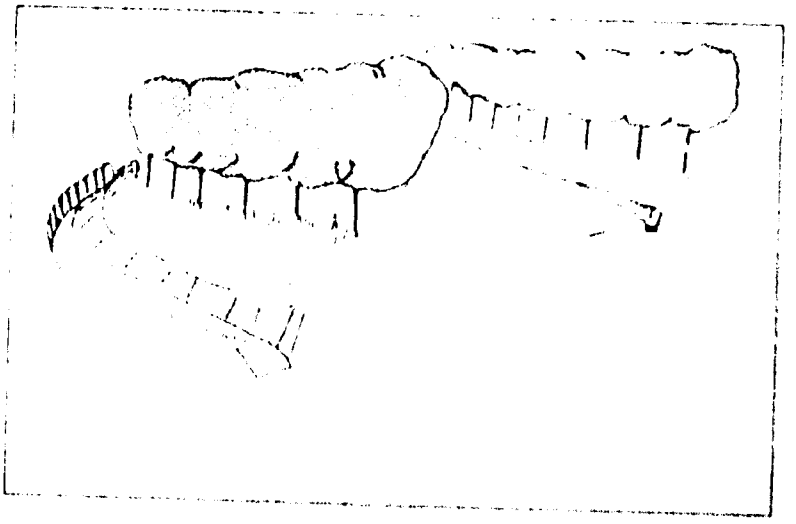


FIG. 27 : CONTOUR PLANTING
(Hoek, 1983)

FIG.28: FANYA JUU TERRACING



Grass and trees onthe benches, grass in drains

(Hoek, 1983)

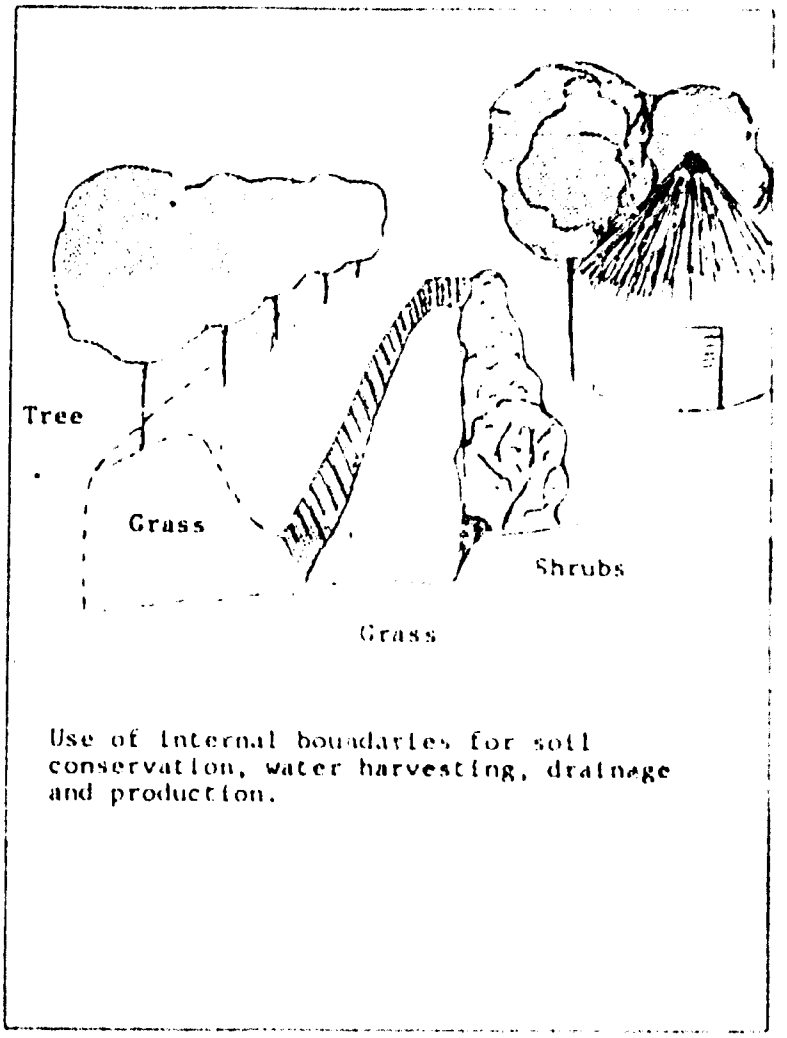


FIG. 29: DRAINAGE AND PLANTING AROUND HOME COMPOUND FOR FUELWOOD AND FRUIT PRODUCTION

(Hoek, 1983)

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

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

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

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

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

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

FIG. 30: INTEGRATED AGROFORESTRY SOLUTIONS NESTED IN THE LANDSCAPE

Tree, shrub and grass combinations

on the farm

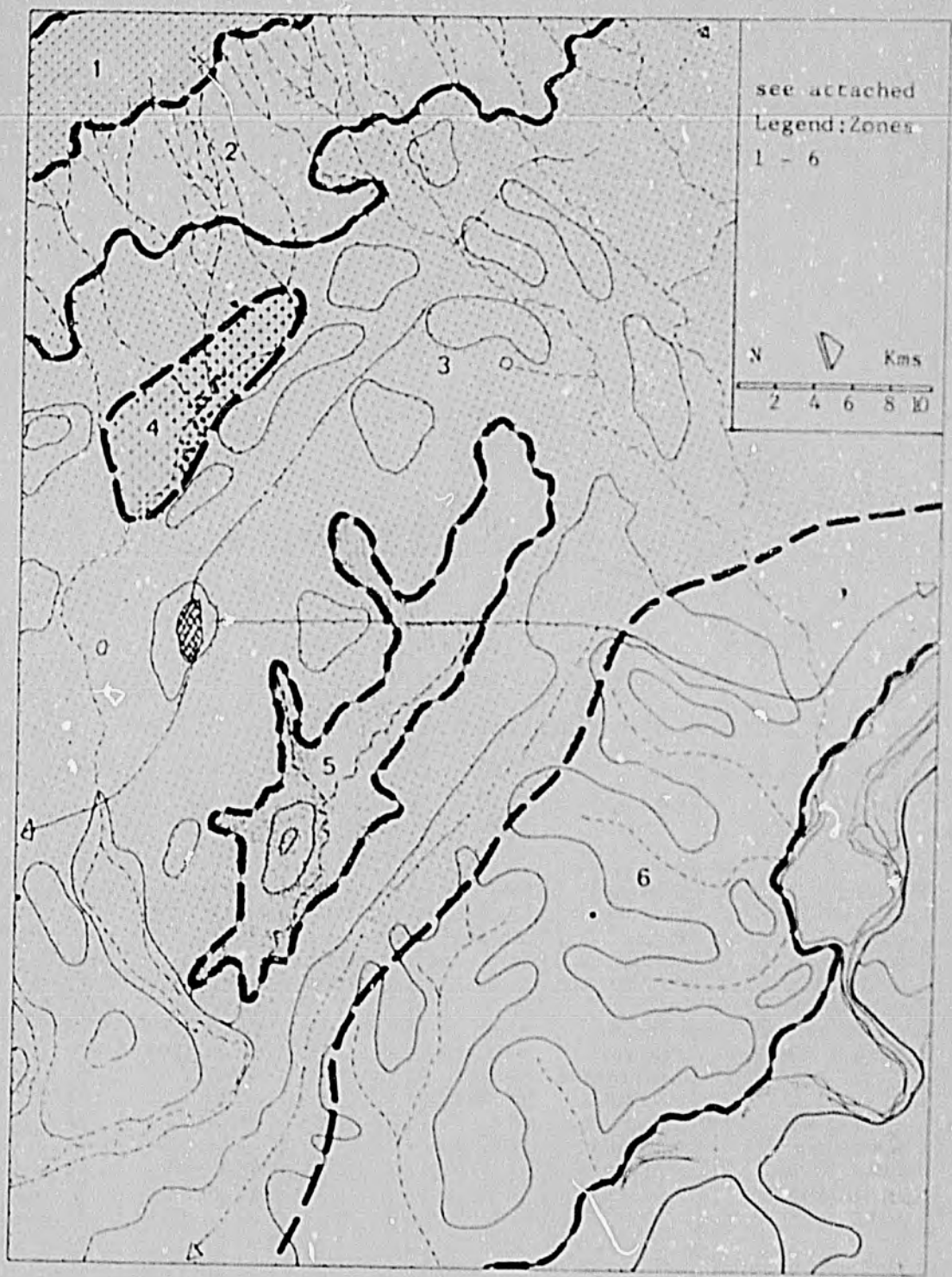
on boundaries, in gullies and along roads

Landscape Niche Affected:

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

(Hoek, 1983)

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



(Hoek, 1983)

LEGEND, FIG. 31

1. Woodland Kanzalu Range, Upslope:

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

2. Gullied Mid and Lower slopes:

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

3. Undulating Uplands:

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

4. Depressional Area:

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

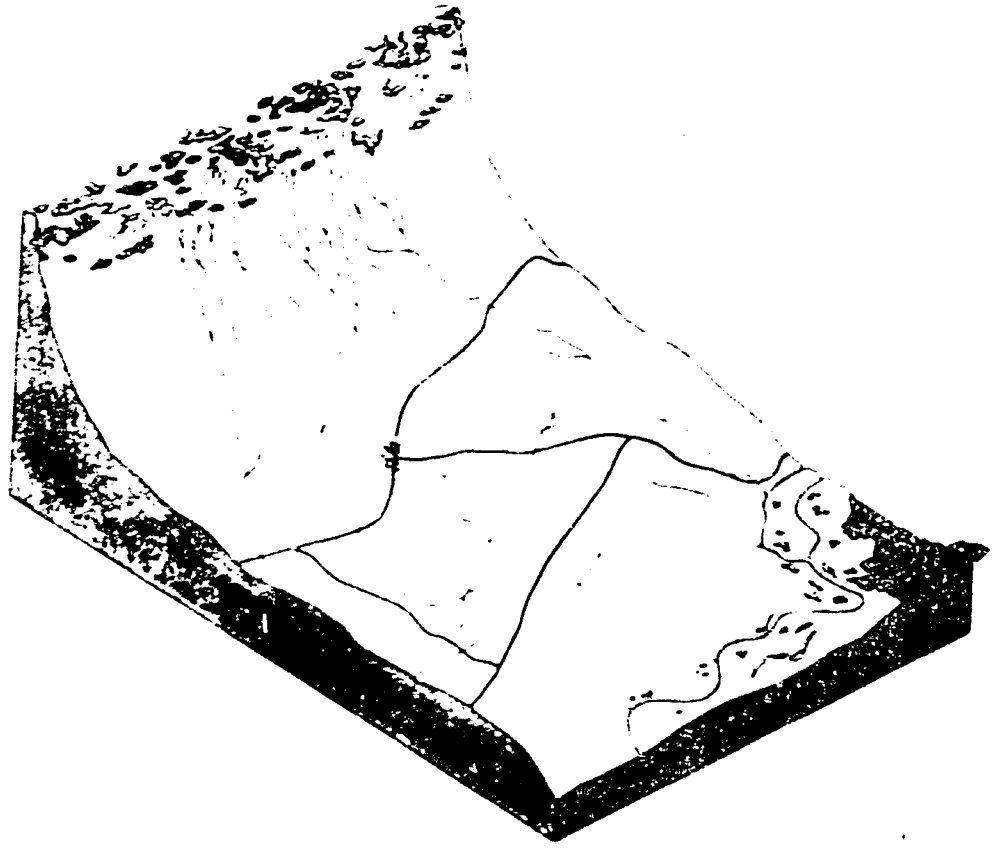
5. Black Cotton Soils, (vertisols):

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

6. Slopes to the Athi River:

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

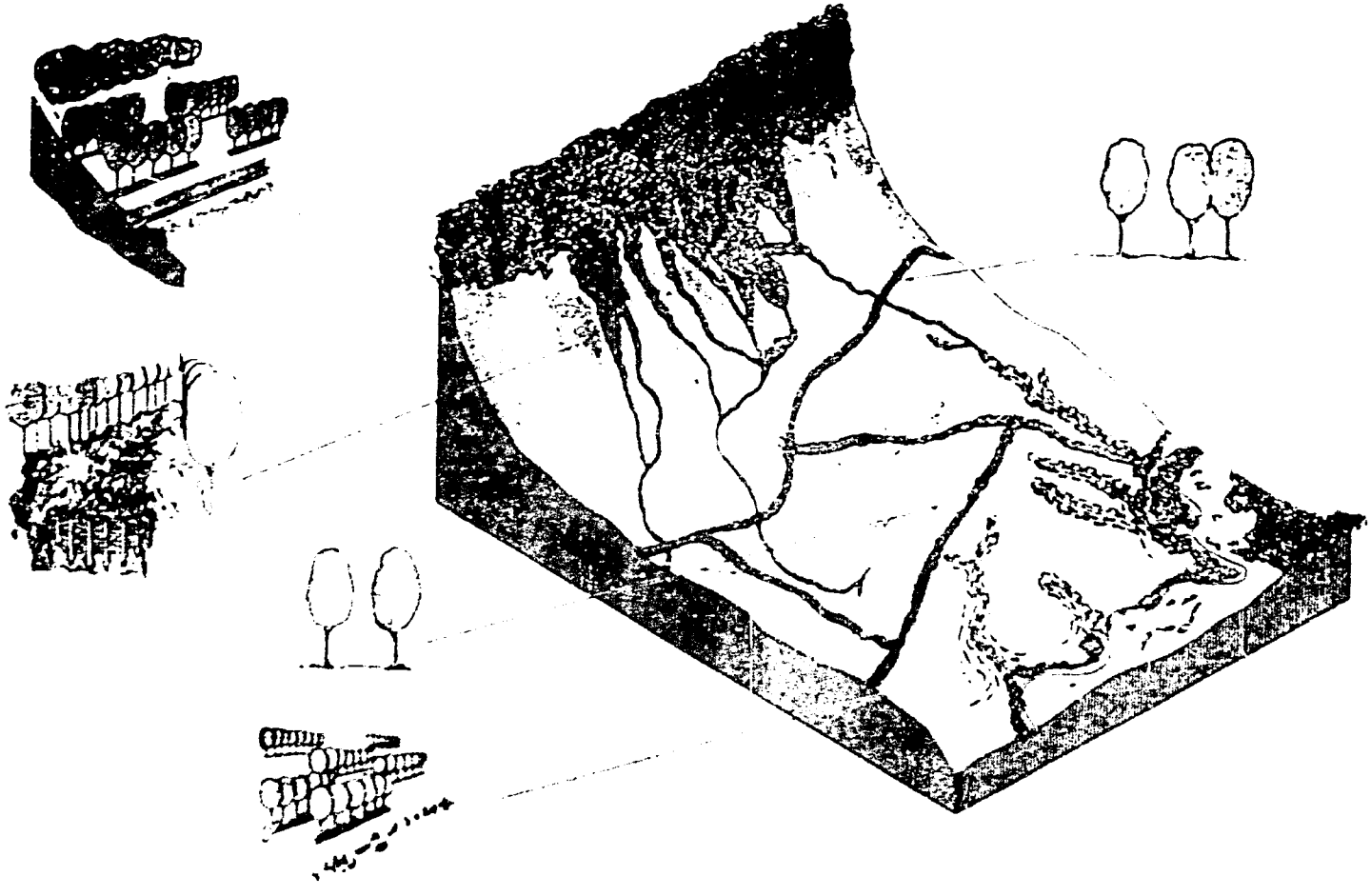
Fig. 32



PRESENT SITUATION

(Hoek, 1983)

Fig. 33: Landscape Design Sketch



MASTER PLAN

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

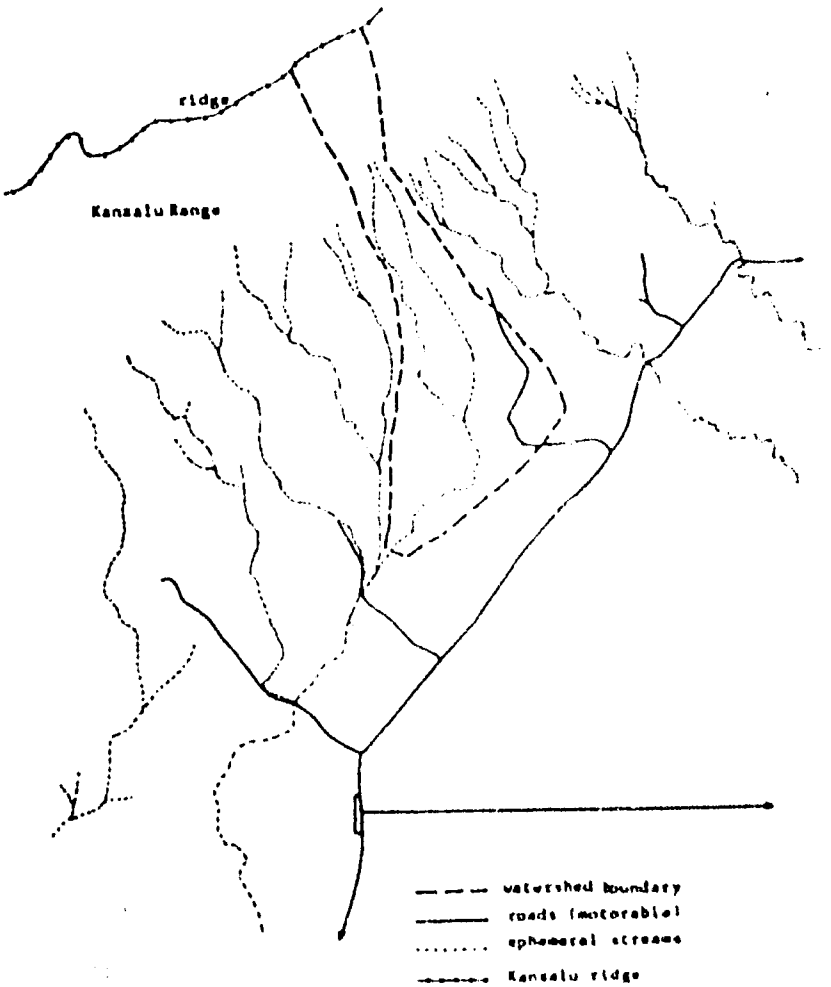


FIG. 35: LAND USE IN THE WATERSHED

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

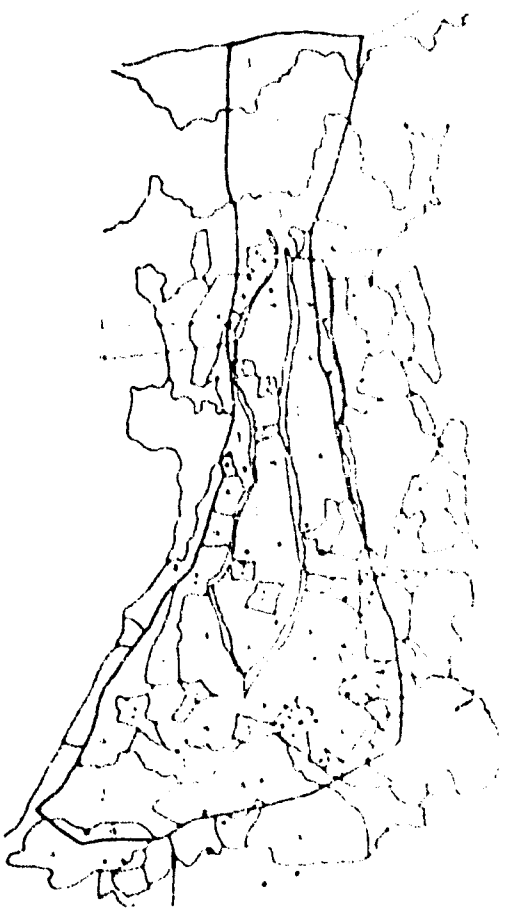


Table 6: Land use in the Watershed Aggregated by Category

	Wooded Ravines	Grazed Woodland	Sustainable Pastures	Degraded Grazingland	Cropland	Public Lands	Total
ha	5.6	17.3	18.0	11.6	52.5	1.0	106.5ha
% of total	5%	16%	17%	11%	50%	1%	100%

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

	Roads and Paths		Gullies and Channels		Property and Internal Boundaries		Total
	Major	Minor	Major	Minor	Existing	Bench Risers or Rows	
Length m	2,600	1,400	4,200	3,200	6,340	15,000[3]	35,740 m
Width m	2	1	3	2	1	1	
Area m^2	5,200	2,400	12,600	6,400	6,340	15,000	49,940 (5.0ha)
Potential fuel production $\times 6\ yr^{-1}$	10,400	4,800	25,200	12,800	16,680	30,000	84,880 (8.4 Gj) - 100,000 kg (100t)
% of total watershed	7%	3%	17%	9%	11%	20%	67%
Potential fodder production trees kg yr^{-1}	10,400	4,800	25,200	12,800	16,680	15,000	84,880 kg yr
grass kg yr^{-1}	4,576	2,112	12,600	6,400	6,458	6,000 (riser only)	38,746 kg yr
Combined kg yr^{-1}	13,420	5,856[4]	16,632[2]	8,448[2]	20,943[4]	19,356	84,655 kg yr
% of total fodder	6%	5%	6%	4%	9%	9%	39%

1. Estimated assuming 1 lopped tree per m^2 producing 2kg DM leaf and 2kg DM wood $tree^{-1}$ and 2.5kg m^{-2} yr^{-1} grass (1.5kg m^{-2} measured) and 1kg m^{-2} of Napier grass in gullies (based on rapid appraisal and data from Otzelo and Tarito, 1981; Maggio, 1982).

2. ½ area in grass strips with ½ area in fodder trees

3. Assume 300m per farm (50 farms)

4. Grass yields have reduced by ½ to account for working near trees.

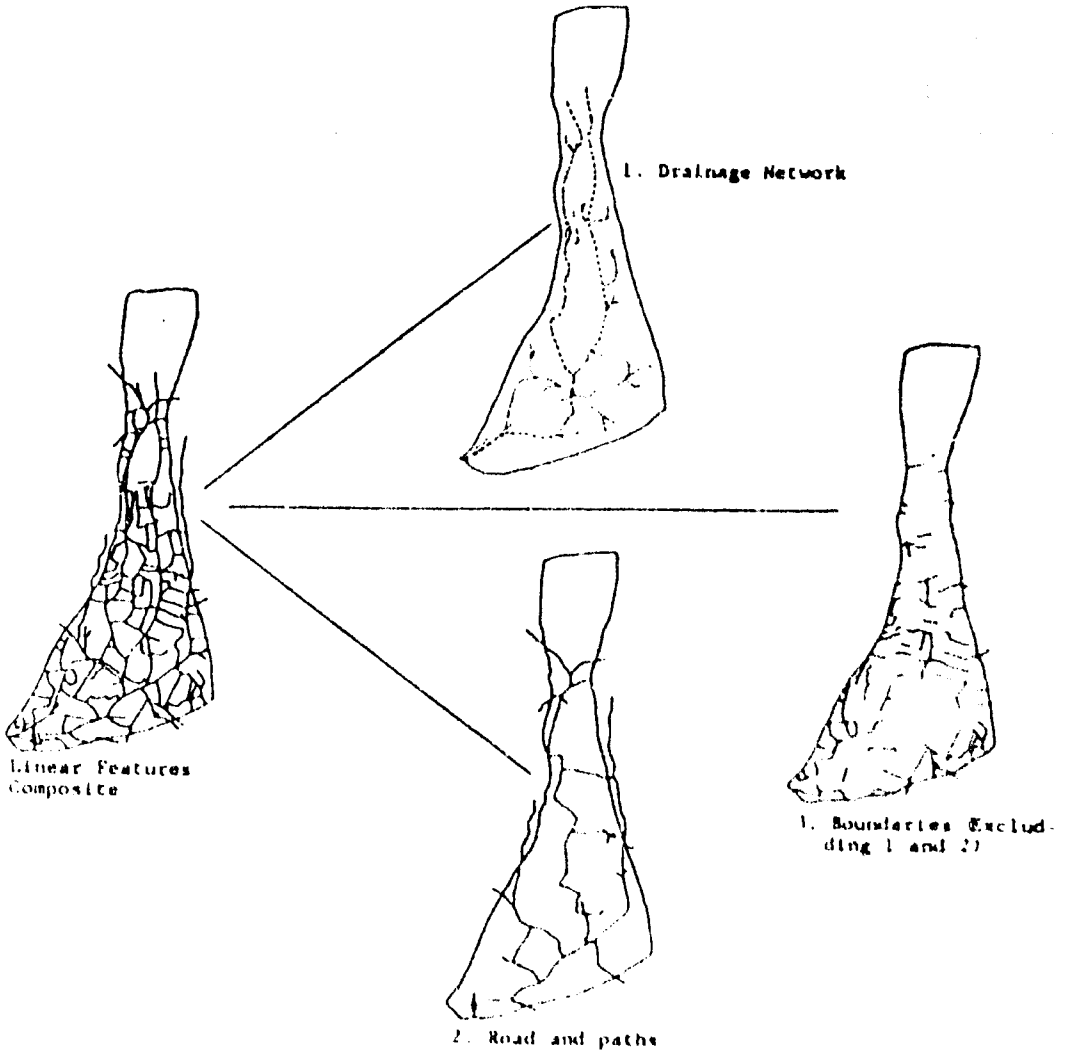


FIG. 36: LINEAR ELEMENTS OF LANDSCAPE WITHIN THE WATERSHED

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

Gully repair with related land treatment

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

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

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

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

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

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

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

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

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

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

The specific objectives of the pilot project were:

1. to develop AF methods suitable for implementation, monitoring and evaluation of larger-than-farm scale group projects;

2. build rapport with the groups and assess their organizational and technical capabilities and potential;

3. modify AF designs/implementation plan to fit (2)

4. to integrate proven or promising AF technologies (for feed, timber, fodder and food production) into existing and planned soil and water conservation works on and off farm within the study area (in coordination with MIDP soil and water conservation efforts);

5. to assess the time, personnel and materials required for (4), and to modify AF designs/ implementation plan accordingly;

6. to identify both indigenous and exotic multi-purpose trees for future inclusion in landscape designs for soil and water conservation under similar conditions;

7. to test and/or monitor promising species and AF technologies and to promote proven species on private farm lands through liaison with existing groups.

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

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

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

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

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

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

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

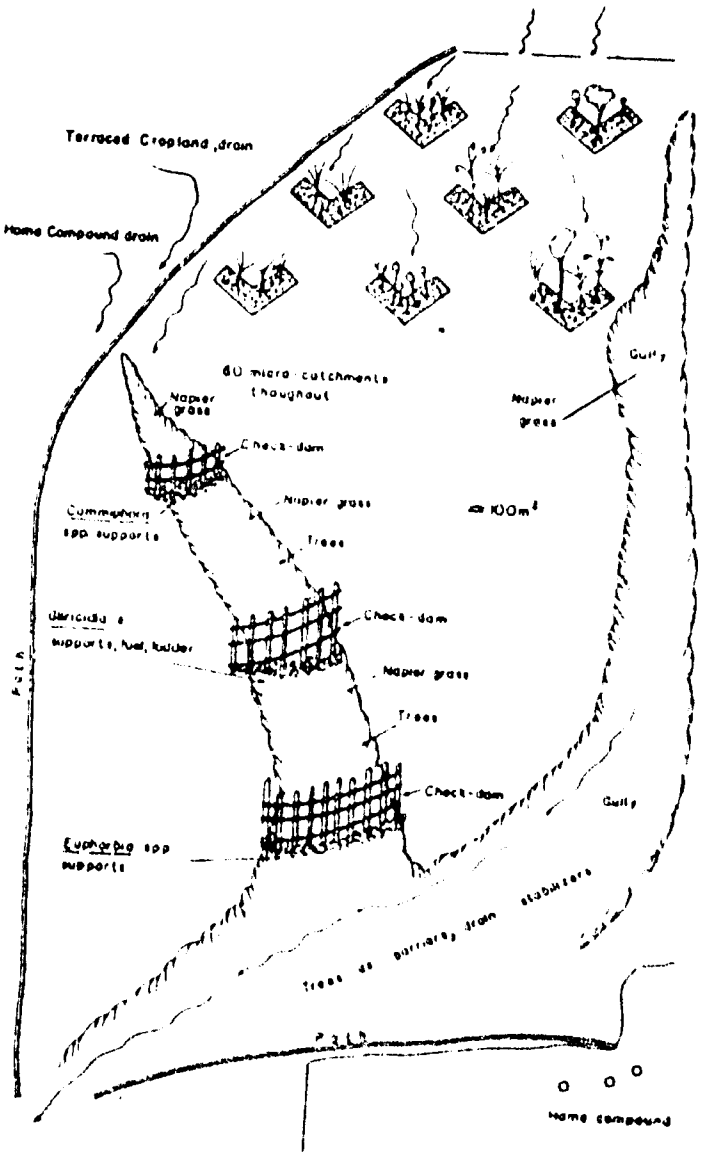

FIG. 37: DETAILED DESIGN FOR GROUP WORK SITE NO. 1

2. Gully

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

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

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

1. Grazing land plot (micro catchments)
   - Acacia holosericae*
   - Azadirachta indica*
   - Cassia siamea
   - Melia azidirach*
   - Napier grass

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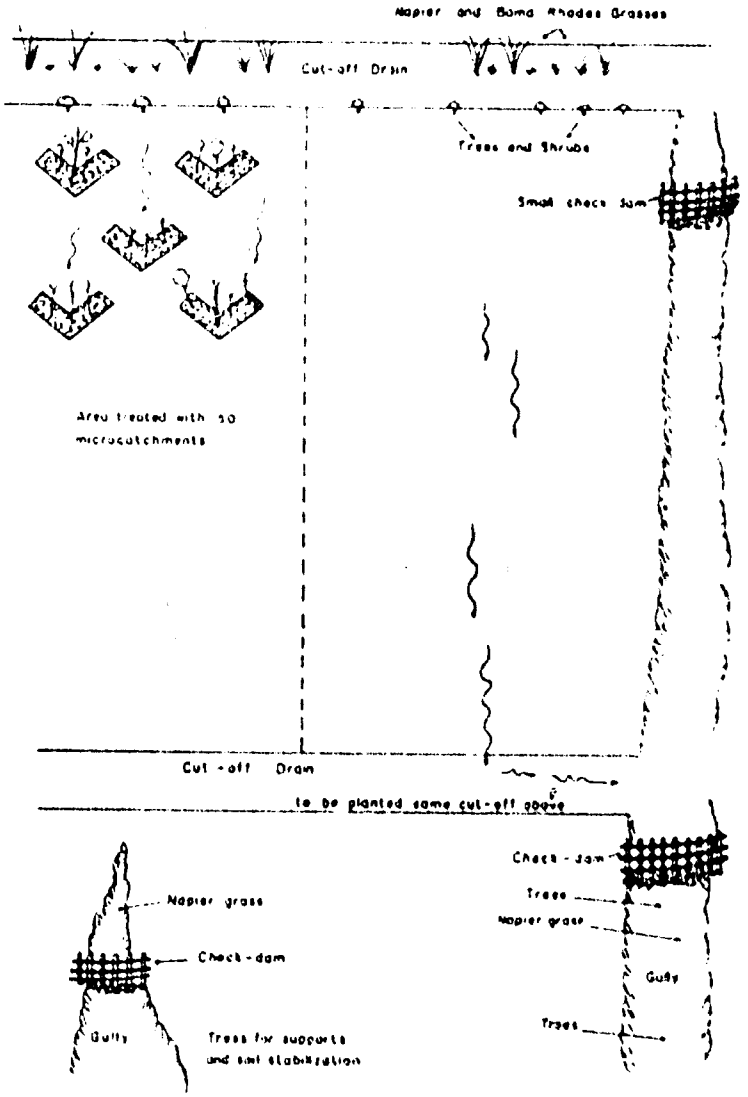
* unproven species to be planted and monitored as experimental introduction to this area.

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

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



2. Gullies and Drains

same as for gully at first site, plus Acacia albida

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(2) with Washington navel orange.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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