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Working Paper

63

ENVIRONMENTAL CHANGE AND DRYLAND MANAGEMENT IN MACHAKOS DISTRICT, KENYA 1930–90

TREE MANAGEMENT

Michael Mortimore

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Preface and Acknowledgements

This Working Paper is part of a study which aims to relate long term environmental change, population growth and technological change, and to identify the policies and institutions which are conducive to sustainable development. The first stage, published in these Working Papers, is to measure and assess as precisely as the evidence allows the changes that have occurred in the study area, the semi-arid Machakos District, Kenya, over a period of six decades. Degradation of its natural resources was evoking justifiable concern in the 1930s and 1940s. By several measures it is now in a more sustainable state, despite a five-fold increase in population. A long-term perspective is essential, since temporary factors, such as a run of poor rainfall years, can confuse analysis of change if only a few years are considered. The study is developing a methodology for incorporating historical, physical, social and economic data in an integrated assessment. The final report will include a synthesis and interpretation of the physical and social development path in Machakos, a consideration as to how far the lessons are relevant to other semi-arid environments, and recommendations on policies for sustainable economic growth.

The project is directed at ODI by Mary Tiffen, in association with Michael Mortimore, research associate, in co-operation with a team of scientists at the University of Nairobi, and with the assistance of the Ministry of Reclamation and Development of Arid, Semi-Arid Areas and Wastelands in Kenya. We are grateful to Professor Philip Mbithi, Vice-Chancellor of the University of Nairobi, for his support and advice. We also thank the Overseas Development Administration, the Rockefeller Foundation and the Environment Department of the World Bank for their financial support. ODI Working Papers present in preliminary form work resulting from research undertaken under the auspices of the Institute. Views expressed are those of the authors and do not necessarily reflect the views of ODI or supporting institutions. Comments are welcome, and should be sent directly to the authors or project leaders.

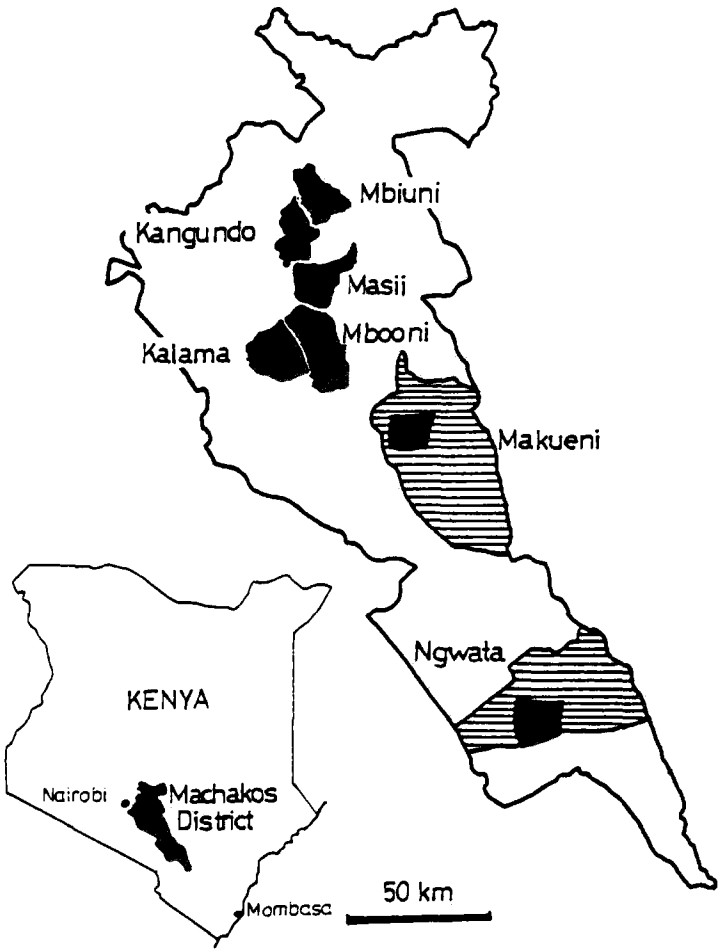
Other titles in this series are:

Machakos District: Environmental Profile
Machakos District: Population Profile
Machakos District: Production Profile
Machakos District: Conservation Profile
Machakos District: Technological Change
Machakos District: Land Use Profile
Machakos District: Farming and Incomes Systems
Machakos District: Institutional Profile

Michael Mortimore is the author of this paper. He is a Research Associate of the Overseas Development Institute.

Colin Trapnell and Gill Shepherd made helpful comments on a draft of this paper.

Preface Figure: **Machakos District, Kenya, showing study locations**
(In Makueni and Ngwata Locations, field studies were mostly within the areas shown black.)



CONTENTS

1. INTRODUCTION

Dryland degradation is usually understood to consist mainly of soil erosion (or degradation), and biomass decline (most obviously visible in deforestation). Other papers in this series have dealt with soil erosion and conservation (see Environmental Profile; Conservation Profile). The purpose of this paper is to review woodland management during the period 1930-1990. The central paradox confronted in such a review is that while, in the 1930s, the Ukamba Reserve was held to be severely degraded, perhaps irreversibly, and that a major aspect of this degradation was the loss of tree cover, now after six decades and a sixfold increase of the population, the position appears to have improved. Encapsulated within this paradox is another: the closely related issue of wood fuel supply and consumption[1]. Evidence is presented in the paper that, while there is and long has been a perceived scarcity of wood fuel in the District, the term 'crisis' is a misnomer, and a sustainable wood fuel equation is within reach. The solutions to both of these paradoxes lie not in the effectiveness of government initiatives in forest reservation and plantation, but in an autonomous development of smallholder tree management, or indigenous agroforestry. This development, while successfully absorbing extension forestry interventions, has often been a step ahead of the agents of intervention, both in conceptual and practical terms.

The first section briefly reviews the history of government interventions in afforestation and extension forestry in the District. The second section analyses the wood fuel equation, using three estimates produced at different times, and asking the question why a wood fuel crisis, confidently predicted, has failed so far to materialise. The third section examines smallholder tree management, which contains the answers to that and other questions. Finally recent agroforestry interventions are reviewed, with attention to the lessons learnt.

2. GOVERNMENT INTERVENTIONS IN AFFORESTATION

2.1 Early Development

Afforestation was identified early on as a major part of the Government's response to the 'Machakos problem' of grazing-induced land degradation. One reason for this perception of priorities was the belief that forests bring about improved rainfall (Bolton, 1953; Leakey, 1955, quoted in Peberdy, 1958:92). They were also thought to improve perennial streamflow, protect the surface from erosion, and break the force of desiccating winds (Nicholson and Walter, nd). In 1920-21, therefore, a plan was begun to plant up the Machakos Hills, using paid labour, and assigning the ownership of the trees to individuals, with 80-120 ha in the Iveti Hills (Peberdy, 1958:7). Nurseries were opened, and seedlings distributed.

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1 In this paper, the term 'wood fuel' includes both firewood (or fuelwood) and charcoal. It excludes crop residues.

A few years later, in 1925, afforestation was considered so far to have failed; but the Government's faith in it had not, and in allocating funds for reconditioning work, 98% of expenditures were earmarked for afforestation and the purchase of fruit trees (ibid.:9). In one year, 340,000 seedlings were supplied, in the two rainy seasons, from the government nurseries. So critical was the afforestation effort believed to be that one District Commissioner tried to remove the control and ownership of nurseries and plantations from the Reserve, and to ban grazing in forest areas. This issue became so contentious that a deputation was sent to the Acting Governor asking for the DC to be removed, and he was replaced in 1927 (ibid.:9). Already, conservation had become a political stumbling block, eleven years before the more famous crisis over compulsory destocking took place.

Afforestation efforts by the Government, from 1930 to 1990, were directed into three areas: (1) the forest reserves, (2) small plantations controlled by the Local Native Council (LNC), later African District Council (ADC) and finally Masaku County Council, and (3) farm tree planting or extension forestry. In addition, the Crown lands outside the Reserve were under natural forest, until opened for settlement.

2.2 Forest Reserves and LNC/ADC Plantations

Under forest reserve legislation[2], gazetted 'native forest reserves' (NFRs) were managed by the Forest Department though the LNC was expected to make financial contributions, and would receive any profit from the sale of forest produce. The sites had first to be set aside by the LNC. Therefore the best land for economic forestry was usually not available. Plans to reafforest the hills focused on the flat tops and steep slopes of the hill masses. The slopes were generally cultivated but the tops were not under permanent cultivation, possibly for lack of water (Bolton, 1953). The Forest Department staff 'would like, ideally, to have both tops and slopes' but this 'is impossible and they have to take what they are given' (Leakey, 1955, quoted in Peberdy, 1958:92). Timber production was more economic on the better top sites. Hence most of the reserves occupied summits.

In 1932-33, a total of 4,224 ha were gazetted as NFRs (see Figure 1). According to Logan (1948), they 'were dedicated to forestry when pressure on the land was far less acute ... the few people cultivating or grazing in the areas were ordered to move out and the Forest Department commenced afforestation operations'. Extensive planting was undertaken, supported by nurseries on or near the sites, so that some 'native forest reserves' became, in effect, government-run plantations of eucalypts, pine, cypress and other exotic species.

The LNC or ADC plantations, which were managed by the Council, were set up on 30-40 small sites with an average size of 10 ha, and a total area in 1937 of 400 ha. Land was dedicated for the purpose by the owners (Logan, 1948). Eucalypts were most common, with some *Grevillea* and cypress. Their large numbers, scattered locations, and small sizes made

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[2] Apart from special regulations granting railway access to adjoining forests (1897), the relevant instruments were the Forestry Regulations of 1902, the Forest Ordinances of 1911, 1915, 1916 and 1941, and the White Paper *A Forest Policy for Kenya of 1957* (Logie and Dyson, 1962).

them incapable of effective professional supervision, so the Forest Department knew little about them, and believed them to be badly managed.

From 1937-38, afforestation effort stagnated (Table 1). This may have reflected a shift in the Government's priorities to physical erosion control measures and grassland rehabilitation, following several major reports on soil erosion and conservation (Barnes, 1937; Maher, 1937; Pole-Evans, 1939). It may also have reflected the strength of Akamba opposition to the dedication of more land to forestry. During the ten years ending in 1947, the area of gazetted forest was reduced effectively to a mere 1,040 ha (Bolton, 1953; Peberdy, 1958:92). The excisions were on account of cultivation and settlement. The most glaring example was the 3,200 ha Momandu Reserve in which only 350 ha were effectively controlled by the Forest Department. The LNC plantations were also reduced, to 325 ha, some of them 'so cut and grazed that they were nearly a write-off' (Bolton, 1953) and others neglected, unthinned, since planting. The lost land had been used for markets, schools and dispensaries or reappropriated by the original owners, with the condonement of the chiefs.

Table 1: Gazetted forest reserves, Machakos District

Year	*Ha*
1920-21	985
1932-33	4,224
1947	1,040
1956	985
1962	6,520
1977	14,502[a]
1989	15,394

Sources: Logan (1948); Bolton (1953); Peberdy (1958); Consortium (1978); DDP (1989-93).

Note: (a) See text.

Following the Logan Report in 1948, there was a change of priority, and afforestation resumed a high profile. A new resident forestry officer began a planting programme in 1950, and funds were allocated from the Betterment Scheme and the Swynnerton Plan. In five years, beginning in 1949, over 2,800 ha were set aside (Machakos Reconditioning Committee, 24 February, 1953). In 1954-55, over 14,000 ha were listed as set aside or awaiting classification (Peberdy, 1958:96).

Most of the new reserves were to be managed by the ADC, under the supervision of the Forest Department, in the expectation that the Akamba were not averse to forests as such, provided they belonged to them. These reserves are shown in Figure 1. The renewed activity reflected Logan's recommendations for environmental 'barrier forests' on the eastern hills (which intercept the dry air flowing into the District from the south-east), and for at least 2,000 ha of fuelwood and timber plantations. The increased tempo of activity is shown in

Peberdy's figures for the mid-1950s (Table 2). The 985 ha of planted forest that dated from 1921 were in process of being extended to 7,894 ha, with a further 8-16,000 ha set aside awaiting demarcation.

Table 2: Forest areas and planting programmes, 1950s

Category		*Ha (sub-total)*	*Ha (total)*
Forest areas, 1956:			
1. Crown forest			5,825
2. Gazetted (effective) NFRs		985	
3. Demarcated, not gazetted		3,427	
4. Part-planted, not demarcated		3,482 (appr.)	
		7,894	7,894
5. Set aside, not demarcated			8-16,000
Swynnerton Plan:			
6. Areas planted,	1954	81	
	1955	474	
	1956	462	
	1957	725	
		2,025	2,025

Source: Peberdy, 1958:101.

Definitions:
1. Natural forest on Crown lands.
2. Native forest reserves, officially gazetted, fenced, guarded, and subject to restricted grazing, burning, cutting and cultivation.
3. Demarcated areas - fenced or marked along the boundaries - not yet gazetted.
4. Partly planted forest areas awaiting demarcation.
5. Areas set aside for afforestation with the agreement of local councils but awaiting demarcation and planting. Such sites might or might not yet be classified in terms of soils, slopes and water.
6. Areas financed under the Swynnerton Plan in settled locations which might include former ADC plantations.

In 1962, according to the Kenya Agricultural Census (1963), forest covered 6,520 ha in the District of which 4,600 were in the Reserve and 1,920 in the Scheduled Areas (the White Highlands) (Table 1). The quickened pace of forest reservation was maintained until the 1970s. By 1977, gazetted areas totalled 14,718 ha, including a large reserve of 5,686 ha in Kibwezi (see Appendix). In addition, more than 1,744 ha were awaiting survey and gazetting. But evidently some of the areas set aside in 1956 had still not been brought under Forest Department management. Only 4,746 ha (32%) had been planted. The rate of planting was

modest - about 200 ha/yr (ibid.). This compares unfavourably with 500 ha/yr achieved on average in the Swynnerton areas. Such planting was based on species trials which, although begun in the 1930s, were not put on to a fully scientific basis until 1970 (Odera, 1981).

In 1989 the area of gazetted reserves remained substantially the same as in 1977 (DDP, 1989-93). The slowdown in the acquisition of land for afforestation reflects an increasing scarcity of land in the District. Some areas set aside must have been relinquished.

There followed some intensification of activity under the MIDP, but 1982 targets for 2000 ha of productive timber plantations, and 600 ha of protective hill plantations, were met only in part - 37% and 62% respectively (Table 3). In Phase II of the MIDP (1984-87), the target achievement rate for protective forestry improved to 75%, but average planting rates were lower than before the MIDP started. Productive forestry was dropped - as an explicit policy objective and as a separate category in the statistics - underlining the modesty of both objectives and achievements. These indicate that serious difficulties stand in the way of large scale, government run afforestation[3]. Between 1984 and 1988, planting continued to fall behind targets, with implementation rates of 60% in plantations and 43% on protective sites; low rainfall was given the blame (DDP, 1989-93).

Quick growing exotics were and still are relied on exclusively, with the aim of supplying the timber market, and with fuelwood production only a subsidiary objective (DDP, 1989-93). Seedling survival rates can be as low as 10% owing to moisture stress and damage from termites (Mwenge Associates, 1988:5.4). Indigenous trees, however, are included in plans for future protective hill planting programmes.

Masaku County Council now controls and manages the small former ADC plantations. They are planted to eucalypts, pines, cypress and wattle, and forest produce is sold. The area of these plantations and reserves was 522 ha in 1977 (Consortium, 1978), so they have less significance in the forest economy[4].

2.3 Extension Forestry

It was observed in Section 2.1 that early efforts in afforestation placed much emphasis on tree planting by farmers. In 1930, another tree planting campaign distributed 415,000 seedlings, and was considered at the time to have been a success (Peberdy, 1958:94). These early campaigns were not without impact. A thin scatter of exotic trees is a significant feature of photographs taken at several locations in the Reserve by Barnes (1937). These appear to have been growing on or near arable land or house sites. There were also some private plantations.

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[3] Ecosystems (1986:2.19) reported a 4%/yr increase in the area of plantation forest from 1981 to 1985. However, the total area in 1985 was reported to be 3,400 ha, which is incompatible with the Forest Department figures quoted above.

[4] Information supplied to J. W. Kaluli by the County Council indicated only 135 ha in 1990.

Table 3: Rates of tree planting under the MIDP, 1978-87

Year	*Rural*	*Protective*	*Productive*	*Total*
1977 and earlier	na	na	na	c200
Phase I				
1978-79	36	30	15	81
1979-80	na	40	135	175
1980-81	266	184	384	834
1981-82	318	118	202	638
% target				
(1978-82)	>62	62	37	48
Phase II				
1984	127.4[a]	101	[c]	228.4
1985	119.1[a]	204	[c]	323.1
1986	168.8[a]	165	[c]	333.8
1987	104.9[a]	88	[c]	192.9
% target				
(1984-87)	52	75[b]		65

Notes: na Not available.
a 'Calculated from MIDP records @ 1600 seedlings/ha' (Mwenge Associates, 1988:49).
b Includes 45 ha of planting in dam catchments for which an annual breakdown is not available (ibid.).
c Productive plantation was not included in the objectives of Phase II (ibid.).

Sources: Phase I, ODI (1982:Chapter 10); Phase II, Mwenge Associates (1988:Section 5).

But, according to Peberdy, these efforts were largely unsuccessful, and in 1958, 'despite the fact that tens of thousands of trees have been distributed to farmers since 1921, the beginning of the Swynnerton period still found Machakos very bare of trees'(1958:91). This was attributed to 'the attitude, antipathy, and in some cases, laziness of the people which prevented the proper care of the seedlings after planting.' Logan (1948:5) thought that 'the principal causes of this are probably lack of advice as to the best species for planting, bad planting, lack of aftercare and unrestricted grazing by goats'. Neither thought to question the suitability of the species offered by the LNC nurseries, yet 'chiefly Gums and Cypress are raised for this purpose. At present sales do not appear to be brisk and there are considerable surpluses of overgrown seedlings left in the nurseries' (Logan, 1948:5). Nor, apparently, was there any attempt to investigate tenurial or other constraints in the farming system that might have affected tree planting. The nurseries themselves were taken over from the LNC by the Forest Department in 1931.

A description of the top of Mbooni Hill (now well wooded) in 1946 described a 'parched and worn out' landscape, with bracken, but no mention of trees (*East African Standard*, quoted in Peberdy, 1958:22).

However, droughts must take a share of the blame. In 1929 a tree planting campaign failed for this cause (ibid.:11). In the drier areas, the seasonal rainfall may be quite inadequate for establishment, and some practitioners believed that planting should only be done in the short rains, which is followed by the shorter dry season when stress on the growing seedlings is less. Heavy weeding was found to be necessary in the government plantations during the early stages of growth, in order to ensure survival (Logan, 1948).

Certainly some trees were planted, but mostly on the hills in AEZ 3. Wattle (*Acacia melasma*) was an early cash earner in the District, and private wattle plantations were so extensive, in some places, that trimmings from these trees undercut the local market for Forest Department produce (Bolton, 1953). Yet wattle is not mentioned among the seedlings supplied by the nurseries. By 1949-52, the Forest Department ran 4-6 nurseries and the ADC about 25, producing only exotic timber species.

In 1971, impelled by an expected wood-fuel crisis, a need to protect existing forests from over-exploitation, and the receptivity of the rural population to tree planting on farmlands, the Forestry Department of Kenya changed its policy priority from plantations to extension forestry. The Rural Afforestation Extension Programme (RAES) opened offices in every District, location chiefs were ordered to open nurseries, and the number of seedlings produced for rural planting in all nurseries reached 75 million in 1983 (Kenya Forest Department, 1984).[5]

Under the MIDP, a further eight nurseries were added to the six operated by the Forest Department, and rural afforestation became - in Phase II - the foremost objective of the programme. Its achievements are suggested by Table 3. But it should be emphasised that the planted area, which is estimated by applying a planting rate of 1,600 seedlings/ha, may not be a good guide to the effectiveness of trees that are mostly planted individually or in lines along boundaries, and nor is there any evidence on the rates of establishment or survival. By 1977, the RAES ran four nurseries in Machakos, and there were two permanent plantation nurseries, each group having a potential output of 4-500,000 seedlings. Target achievement was not high - only 52% in Phase II - and the targets themselves were very modest. But the MIDP nurseries themselves only achieved 46% of target seedling production in Phase II, and they had to supply protective plantations, as well as the farmers, which suggests that the Government's failure to deliver seedlings in adequate quantities may have been a major contributor to under-achievement in farm tree planting.

Fruit tree seedlings are first mentioned by Peberdy (1958:9) in 1925. Their production was mainly undertaken by the Agricultural Department (see Mortimore and Wellard, 1991). Large scale distribution to, and planting by, farmers appears to have taken off in some AEZ 4 locations as recently as the 1980s, but significant beginnings were made 30 years earlier

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5 This total included RAES nurseries, and those run by location chiefs, schools, NGOs, and the Forest Department plantations - over 1,000 nurseries.

(Hayes, 1986). By the 1980s, government nurseries were considered to be ineffective in meeting the growing demand for seedlings, and private nurseries were filling the gap (ADEC, 1986:5.7). This component of afforestation, therefore, is difficult to document - being earlier beyond the purview of the Forest Department and later, of the Agricultural Department as well. There is no doubt that today, fruit trees are the most important component of farm tree planting and major contributors to the observed increase in the densities of trees.

2.4 Policy Choices

The benefits of forest reservation and plantation were articulated in official statements concerned to justify the large gap between departmental revenues and expenditures. These benefits were believed to be: (1) climatic amelioration, (2) erosion prevention, (3) the conservation of soil moisture and permanent springs, (4) employment, in the cutting, carting, marketing and processing of timber products, and (5) the provision of fuel and timber. The revenue from selling forest produce (fuel, poles, timber and charcoal) was set against expenditures and profits were to be paid to the LNC.

However, the gazetted reserves always ran at a loss (Logan, 1948; Bolton, 1953; Leakey, quoted in Peberdy, 1958:91-2). Forest royalties (or selling prices) were not increased from 1920 to 1953. Increased royalties were resisted by the Department on the ground that they would encourage the cutting of indigenous trees - the very outcome the Department wanted to prevent. In other words, the high costs of forest reservation (which, in Machakos, included extensive planting, maintenance and protection work) were justified in social and environmental, not commercial terms.

However the Akamba did not like handing over land for gazetted reserves; they settled and cultivated inside the reserves illegally (which resulted in large 'excisions' having to be made from the gazetted areas), insisted on grazing forest areas wherever possible, lobbied for de-gazetting some reserved areas, and regarded the reserves as belonging to the Government, and not to them. The last point was especially significant, as land alienation was the most sensitive issue of all in the history of the Ukamba Reserve. Forest guards, therefore, were major costs in the Department's budget.

The Department had to plant up the reserves without delay. Bolton (1953) rejected spontaneous regeneration as a lower cost alternative to planting. Unless a reserve was planted, the Akamba 'will believe it is not being put to the use originally stated, and will abuse the land, either by grazing, or, if the area is not continually patrolled, will *return* [our emphasis] and commence cultivating'. Gazetting extinguished all individual rights. 'Legally, therefore, eviction is clearly in order but in practice it presents very considerable difficulties' (Logan, 1948:4). There were two reasons for Akamba disillusionment: 'the people feel that the land and the forests thereon are no longer theirs; they enjoy no rights, privileges or any share on the control thereof and look upon the land as alienated. Secondly, 'they have as yet had no revenue from any of these forests' (ibid.).

The LNC/ADC plantations, which were owned and controlled by local communities, were not popular with some foresters because of their small size, scattered locations and inefficient management - 'in the more outlying areas often grossly mismanaged, if at all' (Peberdy,

1958:92). Nevertheless, in the expansion of afforestation activity that followed the Logan Report in 1948, it was recommended that Machakos LNC, under Forest Department supervision, should dedicate and preserve the 'barrier forests', and establish and manage the plantations; and also undertake gully and streambank planting. Communal, as opposed to Crown ownership of forests, 'is a system that has ... been proved to work excellently in many countries and has a special appeal to rural people in that such forests are *their* forests and do not belong to the Government, which is always regarded as something remote and seems to be suspected' (Conservator of Forests, B.R. Waterer, to District Commissioner, Machakos, J.W. Howard, 8 May, 1951).

Fear of alienation weakened after Independence, and afforestation policy was driven more by technical and economic considerations. Nevertheless, a recent evaluation of MIDP forestry programmes (Mwenge Associates, 1988:51) found fault with the Tulimani plantation, where 'there is hardly any participation of the local communities in tree planting and all work is done through casual labour'. Another plantation, Utunene, where 162 ha were set aside in 1954, required a permanent forest guard and patrol man to defend it. The lessons of the past were, it seems, difficult to apply.

The high costs of running plantations included nursery maintenance, weeding and cleaning work and roads. Three-quarters of the money spent on forestry 'went on cleaning and removing weeds from existing forests' (Machakos Reconditioning Committee, 24 February, 1953). New planting competed with extension forestry for what was left. Thus in 1953, small (community-accessible) nurseries were closed down to save money for the plantations (Bolton, 1953). The costs of maintaining the plantation forestry sector thus created a powerful inertia against extension, social or farm forestry.

An evaluation carried out in 1977 identified a formidable list of difficulties facing plantation forestry (Consortium, 1978):

1. Land was not available on the scale necessary to ensure economic operations;
2. Drought caused losses and complicated the choice of exotic species;
3. Seed was scarce;
4. Termites threatened new plantings;
5. Deep cultivation, fertilization and weeding were necessary to secure optimal growth;
6. Nutrient and water demands of fast-growing exotics were high;
7. Planting was delayed for financial reasons;
8. Staffing was inadequate;
9. Nurseries were inadequate.

Farm tree planting campaigns, on the other hand, are much cheaper than plantations, raise none of the questions regarding procurement of land, ownership and control of trees, transfer most of the costs to the farmer, and offer potential marketable and consumable products directly to the household. The very high failure rate of the seedlings planted (or merely distributed) in the early years may account for the lower profile given extension forestry in

policy after 1937. By the 1970s, however, a shift in policy towards extension forestry was inevitable in view of the problems being encountered in the plantations, though when it came, it was justified mainly for energy and timber production on farm holdings (Kenya Forest Department, 1984). Such a shift called for a significant reorientation away from punitive regulation of the forest resource to new forms of cooperation with local communities (Odera, 1981).

In view of the negative assessments offered, as late as 1958, of the farmers' propensity to plant and protect trees (reported above), the change that has occurred subsequently is very remarkable. A comparison of arable landscapes as they appear in 1990 with Barnes' photographs taken in 1937 shows, at every site, a substantial increase in both the density and the average size of farm trees. This change is so significant in its implications for biomass and management that the term revolution is not inappropriate.[6]

However, the Forest Department cannot claim all the credit for this change.

Fast-growing exotics were propagated through the Forest Department's nurseries with a view to meeting an assumed demand for timber and fuelwood. Eucalypts and other exotics may be seen on arable lands today, indicating some degree of acceptance. Eucalypts provide useful timber, but they are poorly suited for fuelwood. It is significant that wattle, which does not appear to have been supplied from the Forestry Department's nurseries, was more popular until the 1950s. Wattle bark was a cash crop.[7] More recently, it is known that women farmers' tree planting has favoured fruit trees. These anomalies suggest that the choice of species offered may have contributed to the early failure of extension forestry. Fruit trees have been promoted by the Agricultural Department since the 1930s, but no record of the promotion of wattle has been found (see Peberdy, 1958:288-289). Fruit trees on arable land increased between 1981 and 1985, according to Ecosystems (1986:2.15).[8]

3. WOOD FUEL

The production, management and consumption of wood fuel have central significance not only in explaining the trends of deforestation and reafforestation, but also to rural development and welfare (Leach and Mearns, 1988; Bradley, 1991). Woodcutting was believed to have accounted for some of the deforestation observed in the first half of the century. By 1984, according to an official estimate (Kenya Forest Department, 1984), wood fuel was being

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6 Ecosystems (1986, Vol.4:2.19) reported a decrease in farm trees and woodlots between 1981 and 1985. This finding conflicts with almost all the other evidence.

7 Wattle bark exports from the District commenced in 1936 and peaked at 2,130 tons in 1954 (Peberdy, 1958:153, 288-289).

8 District-wide data on fruit trees estimated by Ecosystems (1986, Vol.4:2.9,2.15) work out at 1.2/ha of cultivated land in 1981, rising to 1.7/ha in 1985. Fruit trees are rare in the very large proportion of the District that is AEZ 5 and 6, although they are certainly grown in AEZ 5.

consumed at four times the national rate of natural regeneration. Studies in Machakos have also related consumption levels to population growth, projected an accelerating scarcity into the future, and prescribed extensive fuelwood plantations, by the Government, as the solution. The evident paradox that the District has become more, not less wooded, as its population grew fivefold, has not been addressed. This conclusion is based on (a) the observable increase in trees and woody vegetation on arable land, in hedgerows and around houses, (b) the improved management of private grazing land, (c) the diminished area of degraded common-access grazing land, and (d) the increase in forest reserves.

Three estimates of wood fuel and supply in Machakos District have been recovered. A comparison of them shows a rapid escalation in the estimates, both of consumption per person and of the amount of planting necessary to meet future demand.

Table 4: Logan's estimates of wood consumption and supply in 1948 and projected to 1958

Wood consumption (m^3/person/yr)	firewood (excl. deadfall)	0.085
	timber	0.028
Estimated population in 1948		240,000[a]
Total consumption (m^3/yr)	firewood	20,400
	timber	6,788
	total	27,188
Projected demand in 1958 (m^3/yr)[b]	firewood	22,656
	timber	7,080
	total	29,737
Percentage	collected	75
	produced	25
Production required in 1958 (m^3/yr)	firewood	16,992
	timber	5,381
	total	22,373
Assumed MAI in plantations (m^3/ha/yr)		11
Plantations required in 1958 (ha)	existing in 1948	1,215
	additional	810
	total	2,025

Notes: (a) The census of 1948 gives a population of 366,000, suggesting total consumption of 31,110 m^3 of firewood, 10,284 m^3 of timber, and a total consumption of 41,358 m^3/yr.
(b) At 10%/yr.
MAI: mean annual increment.

Source: Logan, 1948.

3.1 Logan's Estimates

Logan's estimates (and projections for 1958) are shown in Table 4. The rate of wood consumption assumed per person is very low (cf. Table 6) and (even though it excludes

'deadfall') is unrealistic. In addition, the population estimate used was low. If the Census total for 1948 is used instead, rather higher consumption figures are obtained (41,358 m^2).

Logan's low assumptions led to the conclusion, which seems complacent in the light of later estimations, that wood requirements could be met by an additional planting of 810 ha during the following 10 years - hardly a disaster scenario.

3.2 Peberdy's Estimates

Peberdy (1958) produced a projection (but without a baseline estimate) of wood consumption and supply in 1980, which must be assumed to have originated in the Forest Department. This set of estimates is reproduced in Table 5. Using a more realistic consumption rate for firewood, and a larger population, and expecting that 65% would have to be met from plantations, this projection called for about 20,000 ha of plantation production. Again, the population was underestimated, and if we use the actual District population for 1979 (substantially higher wood requirements result. It may be observed that the expected mean annual increments from plantations are relatively optimistic, even for exotic trees, in such a dry environment. Given sub-optimal management, a larger area of plantation would be required to produce the same amount of wood. These requirements may be compared with actual and target areas of plantation in the 1950s, shown in Table 2.

Table 5: Peberdy's estimates of wood consumption and supply in 1980

Wood consumption (m^3/person/yr)	firewood	0.85
	timber	0.085
Estimated population in 1980		706,000[a]
Projected demand in 1980 (m^3/yr)	firewood	301,742
	timber	31,025
	total[b]	332,767
Percentage of firewood	collected	35
	produced	65
Production required in 1980 (m^3/yr)	firewood	191,990[c]
	timber	31,025
	total	223,015
Assumed MAI in plantations (m^3/ha/yr)	firewood	13
	timber	12
Plantations required in 1980 (ha)	firewood	14,294
	timber	5,240
	total	19,534

Notes: (a) Excludes non-Africans.
(b) The Census of 1979 gives a total population of 1,022,522, suggesting a total consumption of 434,571 m^3 of firewood, 43,457 m^3 of timber, and a total of 478,0288 m^3/yr.
(c) Assumes that 15,000 Africans living in the White Highlands 'produce their own'.
MAI: mean annual increment

Source: Peberdy, 1958:97.

3.3 Mung'ala and Openshaw's Estimates

Mung'ala and Openshaw's estimates for 1977 and their projection for the year 2000 are shown in Table 6. This work took separate account of charcoal and fuelwood, household and non-household, rural and urban consumption. The consumption estimates were based on 100 surveyed households. The supply estimates were based on forest inventories. The conclusion of the exercise was that consumption in 1977 was already running at four times the rate of natural growth (MAI) and that 'If estimates of consumption and growing stock are anything near correct, the trees will be depleted by about 1986; even if the volume estimates were doubled or tripled, the stock would still be exhausted by 1991 or 2005 respectively. Thus an acute shortage of woodfuel is imminent' (p.117). Planting programmes in hand by the Government, including those financed by the MIDP, promised to deliver only 15% of the anticipated demand (330,000 m^3/yr).

The authors took no account of plantation output in estimating the offtake in 1977, but this is likely to have been small. A more significant aspect of the projection is that the authors assumed no wood fuel would be collected in 2000. The household survey showed that in 1977, 91% collected some of their wood fuel and 74% collected all of it. The sources of collected wood are not stated, but the authors probably mean the savanna. They imply that savanna woodland will be eliminated as a significant source by the year 2000. They take no explicit account of wood fuel collected from cultivated land, roadsides, etc.

3.4 Why the Projections were Wrong

The three estimates of wood fuel supply and consumption reviewed above show an escalating pessimism in official and expert views, which is characteristic of the wood fuel literature in dryland Africa. But it is now clear to the observer that Mung'ala and Openshaw's prognosis that 'at the present consumption rate [1977] all the stock could be depleted as early as 1986' was not what occurred. Both woodland and bushland (on the one hand) and farm trees (on the other) are visible in all parts of the District. The air photographic evidence of 1948, 1960-61, and 1978 (reviewed in Rostom and Mortimore, 1991) provides no evidence of woodland degradation in the longer term - though much woodland was converted to cultivation. Surface photography taken in 1937 (Barnes, 1937), and repeated in 1990, does not indicate any significant reduction in the timber volume of woody vegetation communities. There is some evidence of bush encroachment on grazing lands (see Farah, 1991). Although there has been a large scale transfer of land from woodland and bush to cultivation, this has gone along with a noticeable increase in the density and size of farm trees.

If a doomsday scenario for the energy equation - with all that means for environmental conservation - seems inappropriate, how can this be explained?

Two possibilities can be dismissed immediately - increased use of alternative energy sources, and imports. Kerosene, although used for lighting by 96% of the rural households surveyed in 1977, was used for cooking by only 7%, and by only 50% of urban households. The use of gas and electricity was not reported outside urban areas at all, except by a few non-household users (Mung'ala and Openshaw, 1984). Since 1977, price relativities have not attracted new users in large numbers to non-wood cooking fuels. The second possibility is

Table 6: Mung'ala and Openshaw's estimates of wood consumption and supply in 1977 and 2000 (wood fuel only)

	household	non-household	total
Wood consumption (m^3/person/yr)			
firewood	0.96	0.09	1.05
charcoal	0.34	0.11	0.45
wood fuel	1.30	0.20	1.50[a]
Estimated population (1977)			903,000
Total consumption (1977) (m^3/yr)			
fuelwood			949,700
charcoal			411,800
wood fuel[b]			1,361,500
Percentage collected			74-91[c]
Supply (m^3/yr MAI)			
forest (including plantations)			12,000[d]
savanna woodland			226,000[e]
total			238,000
Excess of consumption over supply (m^3/yr)			1,123,500
Projected consumption in 2000 (m^3/yr)			2,264,000[f]
Percentage collected in 2000			0[g]
Assumed MAI in plantations (m^3/ha/yr)			10
Plantations required in 2000 (ha)			226,000

Notes: (a) Assumes 12 m^3/tonne of charcoal produced by traditional methods. If a lower figure (6 m^3/tonne) is used, as preferred by some other authors, charcoal consumption is halved and a total consumption rate of 1.30 m^3/person/yr results.

(b) If the Census of 1979 is projected back to 1977 at a rate of growth of 3.76% per year (the average for 1969-79), a total of 949,500 is obtained, suggesting a total consumption of 996,975 m^3 of fuelwood, 427,275 m^3 of charcoal, and 1,424,250 m^3 of wood fuel.

(c) Households only, by frequency. Collected means 'not purchased'. Some households both collect and purchase wood fuel, hence a range is given. Non-household wood fuel is all purchased.

(d) The estimated MAI is 3.4% of a standing stock of 350,000 m^3 on 20,000 ha.

(e) The estimated MAI is 2.0% of a standing stock of 11,300,000 m^3 on 1,130,000 ha.

(f) At 2.2% a year.

(g) Not stated by the authors but implicit in their argument.

MAI: mean annual increment.

Source: Mung'ala and Openshaw, 1984.

that the District imports wood fuel on a massive scale. There is no evidence of this. The market is different for fuelwood and charcoal. For fuelwood, buying and selling are localised and no significant trade between locations has been observed or reported. Charcoal is used in urban areas, where markets are found, and is produced for these markets in the rural areas of the District. The evidence therefore points to a continuing dependence on local wood fuel resources for cooking and heating purposes in nearly all rural households and in the majority of urban ones.

There are four ways of accounting for the discrepancy between Mung'ala and Openshaw's projection and the relatively stable condition of woody vegetation:

1. The estimated rate of consumption per person in 1977 was too high. Studies in other parts of dryland Africa have produced lower estimates, less than 1 m^3/person/year, but there is much variation. This estimate was based on a survey of 100 households. The assumption of a more efficient conversion ratio for charcoal (see Note a under Table 6) would, however, reduce total estimated consumption to 1.174 million m^3 (on the authors' population estimate) or 1.297 million m^3 (on the revised population estimate).

2 The rates of mean annual increment used by the authors are too low. From the figures they provide, rates of MAI can be computed as follows: for forest, 0.6 m^3/ha/yr; and for savanna, 0.2 m^3/ha/yr (see notes d and e under Table 6). Accurate data on the rates of MAI in natural vegetation formations is extremely scarce in Africa. To double these rates, however, would not exceed the bounds of possibility (1.2 m^3/ha/yr for forest and 0.4 m^3/ha/yr for savanna). This would have the effect of increasing the estimated supply from 238,000 to 476,000 m^3/yr, and extending the lifetime of the standing stock accordingly.

3 Wood fuel is harvested from farmland (farm tree trimmings and dead wood, hedgerows (e.g. *Euphorbia terucalli*), roadsides and other public land (e.g. *Lantana camara*). These sources appear to have been ignored by Mung'ala and Openshaw. Their use is widespread, as evidenced on any journey through the District. In a study of agroforestry practice in Mbiuni Location, it was estimated that 50% of wood fuel needs could be met from appropriately planted and managed linear features in farmland (field boundaries, paths, roads, and river banks: Rocheleau and van den Hoek, 1984; Rocheleau, 1985). According to Ecosystems (1986:2.10, 2.19), natural and planted hedgerows increased at 2%/yr from 1981 to 1985, when they covered 16,500 ha, 6% of the cultivated area and over 1% of the District.

4. Substantial quantities of non-woody vegetation - crop residues, foliage, weeds - are also burnt. Given the generally perceived scarcity of fuel, this is a strong possibility and Mung'ala and Openshaw note that pigeon pea stalks are burnt after harvest. However, a prior use of non-woody crop residues is for feeding livestock.

New survey data are necessary in order to assess the first and second possibilities. With regard to the third and fourth, it is necessary now to set wood fuel use in the wider context of smallholder tree management.

4. SMALLHOLDER TREE MANAGEMENT

4.1 Trees and Shrubs on Grazing Land

Grazing land is now almost all subject to individual tenure, and in the older settled areas of the former Reserve, nearly all is enclosed. Natural woodland is managed for grazing, woodcutting, beekeeping and the collection of wild produce. The proscription of firing, throughout our period of study, gave the competitive advantage to woody species at the expense of grasses under heavy grazing by cattle. Examples of the species composition of grazed communities in AEZ 4 and 5 are provided in Farah (1991). The sites in AEZ 5 (in the south of the District) are dominated by *Acacia tortilis* and *A. mellifera* (trees) and *Acalypha fruiticosa, Boscia coriacea, Combretum exalatum* and *Commiphora schimperii* (shrubs). The sites in AEZ 4 (in Masii Location) are dominated by *A. tortilis* (trees), *Terminalia* spp. (shrubs) and *Lantana camara* (an invader).

The indigenous species that grow on grazing land have a variety of uses, exemplified in a list compiled from a study of four sublocations in Yatta (Table 7). It is noteworthy that several species (*Acacia* spp. and *Terminalia brownii*) that have high use ratings appear at the top of the frequency list, indicating that a large proportion of households consider them important and maintain them for this reason. (Actual numbers, however, are not available from this source.) *Terminalia brownii* gives termite-resistant timber for the construction of houses, stores, oxen yokes, farm and household tools. The systematic and knowledgeable use of trees and shrubs grazing land is widely attested (Fliervoet, 1982; Gielen, 1982; Neunhauser et al., 1984; Rocheleau and van den Hoek, 1984).

Management of grazing land includes the clearing of unwanted vegetation (especially the invader, *Lantana camara*), occasional lopping of trees to improve timber growth, and the use of goats to control bush encroachment, as well as the planting of creeping grasses (Gielen, 1982:53-54). Tree planting is not usually attempted on grazing land; the farmer's task is seen as the selective control of spontaneous regeneration.

4.2 Trees on Cultivated Farmland

When land is cleared for cultivation, the dominant acacias (except for *A. tortilis*) are removed and volunteers controlled, because of their thorny habit and reputation for harbouring crop pests. *Terminalia brownii* and *Combretum*, on the other hand, are preserved. The composition of indigenous woody vegetation on farmland shows the extent to which the natural conditions have been modified by management, which incudes selective control, protection, and planting.

A survey of 56 households in three sublocations of Mbiuni, carried out in 1980-81 (Gielen, 1982:32) showed that only six households grew no trees on their cultivated land, and most of these were in the smallest size class (Table 8). The data showed that 86% had at least one fruit tree growing, and 54% at least one indigenous tree. But the fruit trees were the more numerous.

Table 7: Common indigenous trees grown on grazing land in Yatta

Species	*Per cent of households (N=61)*	*Uses: Edible fruit*	*Browse*	*Fencing*	*Construction*	*Fuel*
Acacia tortilis	59	-	+	-	++	+
Terminalia brownii	64	-	++	++	++	++
Acacia mellifera	46	-	++	++	+	++
A. etbaica	25	-	+	+	+	+
Commiphora africana	21	-	-	+	-	-
Acacia brevispica	20	-	+	+	+	+
Balanites aegyptiaca	20	+	+	+	-	-
Premna oligotricha	20	-	+	-	-	+
Rhus tenvinervis	18	+	+	+	+	++
Croton megalocarpus	16	-	-	-	+	a+
Lannea schweinfurthii	16	-	-	-	+	+
Lonchocarpus eriocalyx	16	-	+	-	-	+
Clerodendrum spp.	13	-	-	-	-	+
Acacia nilotica	12	-	+	+	+	+
Combretum zeyheri	12	-	+	-	+	++
Lannea rivae	12	-	+	-	-	+
Acacia senegal	8	-	+	+	-	-
Albizzia anthelminthica	8	-	+	-	-	+
Combretum apiculatum	8	-	-	-	+	+
Pappea capensis	8	+	+	-	-	+

Notes: - No important use
+ Important
++ Very important use
(a) Gielen reports a higher rating for fuel

Source: Neunhauser et al., 1983:51-53.

Table 8: Trees growing on cultivated farmland in Mbiuni Location, 1980-81

	Farm size class					*Per cent*
	I	*II*	*III*	*IV*	*Total*	*overall*
Indigenous trees & fruit trees	4	5	11	8	28	50
Fruit trees only	3	9	3	5	20	35
Indigenous trees only	0	2	0	0	2	4
No trees	4	2	0	0	6	11
TOTAL	11	18	14	13	56	100

Source: Gielen, 1982:32.

Table 9 shows how the species composition of indigenous trees was found to have changed on the cultivated lands in the Yatta survey (cf. Table 7). *Terminalia brownii* and *Acacia tortilis* still head the list, but many other species common on the grazing lands (e.g. *Acacia mellifera, A. etbaica, A. brevispica, Balanites aegyptiaca, Commiphora africana*) appear much lower in the household frequency listing, while *Euphorbia terucalli*, the favourite hedging plant, assumes third place. The differences between Mbiuni and Yatta are ecological (AEZ 3/4 and 5 respectively). *E. terucalli* appears to have been ignored in the Mbiuni survey.

Table 9: Indigenous trees growing on cultivated land (per cent)

Species	*Yatta: Households (N=61)*	*Mbiuni: Households (N=56)*	*Mbiuni: Individuals (N=117)*
Terminalia brownii	41	72	38
Combretum zeyheri	2	28	8
Kigelia aethiopicum	5	24	8
Grewia plagiophylla	-	14	12
Balanites aegyptiaca	5	10	3
Vanguiera spp.	-	10	3
Combretum collinum	-	7	8
Cassia singueana	-	7	3
Combretum apiculatum	2	7	3
Acacia polyacantha	-	7	2
Boscia augustifolia	2	7	2
Croton megalocarpus	2	7	2
Lonchocarpus eriocalyx	12	7	2
Ormocarpum kirkii	-	7	2
Erythrina abyssinica	-	3	3
Acacia robusta	3	3	2
Lannea schweinfurthii	15	3	2
Acacia tortilis	25	-	-
A. mellifera	16	-	-
Rhus tenvinervis	10	-	-
Clerodendron spp.	8	-	-
Albizzia anthelminthica	6	-	-
Lannea rivae	5	-	-
Acacia nilotica	5	-	-
A. etbaica	3	-	-
Commiphora africana	3	-	-
Acacia brevispica	3	-	-
A. senegal	3	-	-
Thespesia danis	3	-	-

Sources: Gielen, 1982:45; Neunhauser et al., 1983:51.

More significant, however, in its impact on the farmland ecosystem, is the planting of exotics, and especially of fruit trees. Surveys conducted during the early 1980s showed a high level

of planting activity, whether measured in terms of the incidence of planting households, the diversity of species planted (often five or more per household), or the numbers of individuals planted per household (Table 10). Hayes found that 93% of a sample of 87 Masii families planted trees.

Table 10: Tree planting by households (most frequent species, per cent)

Species	*Households:* *Mbiuni (N=56) AEZ 3/4*	*Masii (N=87) AEZ 4*	*Yatta (N=61) AEZ 5*[a]	*Households growing <10 individuals >10 (Masii)*	
Fruit trees planted:					
lemon	32	70	15 (10)	84	16
orange	18	59	8 (13)	57	43
mango	61	57	41 (16)	72	28
pawpaw	50	55	51 (3)	73	27
banana	68	53	31 (3)	35	65
guava	32	26	11 (8)	78	22
Other trees planted:					
Eucalyptus	13	31	6 (18)	44	56
Croton megalocarpus	23	0	2 (13)	+	+
Jacaranda	7	13	3 (8)	82	18
Cassia siamea	5	9	0 (2)	75	25
Grevillea	4	7	5 (3)	+	+
Leucaena	0	6	0 (0)	+	+
Cypress	1	3	0 (0)	+	+
Azadirachta indica	+	+	na (2)	+	+
Melia azadirach	+	+	na (2)	+	+
Euphorbia terucalli	R	+	R	+	+

Notes: (a) Figures in brackets are the percentages of Yatta households planting in the year prior to the survey.
+ Not reported, or numbers too small to have meaning.
R: reported, no numbers.

Sources: Mbiuni - Gielen, 1982:33, 68;
Masii - Hayes, 1986:212-35;
Yatta - Neunhauser et al., 1983:51, 55.

Among the fruit trees planted in Mbiuni and Masii, lemon is the most common, but banana, followed by orange, is reported in the largest numbers per household. In drier Yatta, citrus and banana growing households are less frequent, but mango and pawpaw maintain their popularity. Among the other trees planted, Eucalyptus is the most common; more than half the planting households in Masii have more than 10 individuals, in which respect it compares only with banana among the fruit trees. Reported in Mbiuni and Yatta, but not in Masii, is

the planting of *Croton megalocarpus*, the only indigenous species listed in Table 10. It is valued as fuel (especially) and construction timber. Gielen also reported the planting of hedgerow trees. Almost all farms have planted rows of *Euphorbia terucalli* (finger euphorbia), and *Commiphora* spp. is also common, especially for fencing cattle bomas. But indigenous multipurpose trees are slow in growth performance, as a general rule (Jama et al., 1989).

It is important, if possible, to quantify this landscape transformation. Using Gielen's data, Table 11 shows the average densities of fruit trees per hectare of cultivated land, by size class, and of indigenous trees, on all classes.

Table 11: Tree densities per hectare in Mbiuni Location

	I	*II*	*III*	*IV*	*All*
Farm size class (ha)	<0.5	0.51 - 1.0	1.01 - 1.5	1.51<	
Average cultivated area (ha)	0.44	0.78	1.32	2.52	1.23
Tree densities/ha:					
banana clumps	45.5	30.8	17.4	13.1	20.3
mango	6.8	3.8	3.0	1.6	3.3
pawpaw	4.5	2.6	4.5	2.0	3.3
lemon	0	6.8	5.1	3.6	4.8
guava	2.3	0	3.0	0.4	1.1
Total fruit trees	59.1	44.0	33.0	20.7	32.8
Indigenous trees	-	-	-	-	1.7[a]
All trees[b]	60.8	45.7	34.7	22.4	34.5
All trees (excl. bananas)	15.3	14.9	17.3	9.3	14.2

Notes: (a) Computed from a total of 117 trees at 2.1/household.
(b) Data are not given on indigenous trees by farm size class; so the average density has been added to each total for fruit trees.

Source: Gielen, 1982:17, 33-45.

The overall densities are impressively high (the locations are in AEZ 3/4), even if bananas are excluded. Nevertheless, the figures understate the total because some less common fruit trees, and all planted exotics, are omitted, together with hedgerows, which add significantly to the standing volume of timber.

An equally remarkable feature of Table 11 is the gradient in the density of fruit trees from 59/ha on the smallest cultivated holdings to 21/ha on the largest. This provides strong support for an hypothesis relating intensification to land scarcity; it does not support the hypothesis that the land-poor cannot invest in trees.

This review of trees on cultivated land leads, therefore, to the following conclusions:

1. A managed ecosystem combining crop production with fruit and other trees of economic value is well established on cultivated land in the District.

2. The species composition of the woody component of this system, owing to protection, control, and planting, represents a major transformation of the woody vegetation, as found under natural conditions, and as still managed on grazing lands.

3. Planting by smallholders favours fruit trees over other trees.

4. Amongst the other trees, planting favours exotic over indigenous species, with one major exception (*Croton megalocarpus*).

5. Diversity is characteristic of the tree population on individual smallholdings.

6. There are marked differences amongst holdings and between areas which, together with the shortage of data, make generalisation difficult.

7. Tree planting on cultivated land, and especially fruit tree planting, may reach very high densities; there is evidence that this is a form of intensification correlating inversely with the size of cultivated holding.

4.3 Tree Planting and Control

Smallholders do not plant trees in response to a generalised rationale of conservation, still less to theories about the influence of trees on rainfall, but for reasons that are specific to the species in question (Table 7). Trees are investments of capital and labour and have implications for the management of the smallholding. The early failures of extension forestry suggest that this principle was not adequately grasped.

The decision to plant a tree reflects a gender division of responsibility and rights of access on the farm. Men plant trees for timber: e.g., building poles (*Eucalyptus* spp.); fuel (e.g. *Croton megalocarpus*); windbreaks and hedgerows (e.g. *Euphorbia terucalli*); and for ornamental, shade or amenity purposes (e.g. *Jacaranda* spp., *Grevillea* spp.); according to Gielen (1982:69). Women, however, plant fruit trees (Hayes, 1986; Rocheleau, 1991). This is because of their need for both household food supplies and an independent source of cash, needs that are accentuated by frequent absences of the men. Furthermore, fruit tree planting requires little start-up capital or special education, and competes minimally with the production of crops, representing an attainable form of intensification (ibid., 215), as Table 11 shows. Mens' involvement in planting is only necessary for bananas, which are usually put into deep mulched or fertilized pits.

Fruit tree seedlings are either bought - from local nurseries or markets, or by family members on their travels - or raised from seed in farm nurseries (Hayes, 1986:215-29). Oranges are grafted onto rough lemon stock in private nurseries. Mango seeds are planted directly where they grow. Little management is given to fruit trees, but some women fertilize or water

orange trees, or construct micro-catchments and terraces around them. Oranges and bananas are the most important in market terms, though all fruit are marketable. Table 10 shows that some households specialise in these to a greater extent than in other fruits. The least important market fruit is guava. Rights to produce are exercised exclusively or jointly by the women in the great majority of households, even including bananas. In Masii the oldest fruit trees (up to 30 years old) were mango. Planting of fruit trees continued through the 1960s and 1970s but, with the exception of mango, accelerated sharply in the 1980s, and of citrus and banana especially.

Other tree planting, according to Hayes' informants, is dependent on seedlings supplied by nurseries, and there is a high failure rate. This, as noted earlier, has always been characteristic of farm forestry in Machakos. Rights to the produce of these trees are ill-defined, according to Hayes (ibid.,230-5). But it can probably be assumed that men normally exercise rights to the timber, while women collect the trimmings and dead wood for fuel. A small proportion of Masii households specialise in Eucalypts. Table 10 shows 56% with more than 10 trees.

Tree planting and management, therefore, must be understood in relation to both the specific uses of each species, and the gender division of household responsibilities and rights of access to produce. Early forestry extension programmes failed to 'target' those who today do most of the planting and management of trees (women), and in stressing conservation objectives - to be achieved through quick growing exotics - they may have under-rated the specific needs of the household for special quality timbers, fodder, food or medicines.

4.4 Woodfuel Management

The most popular trees for firewood and charcoal making in the Yatta area are *Acacia mellifera*, *A. tortilis*, *A. etbaica* and *Terminalia brownii* (Neunhauser et al., 1983:56; see also Table 7). According to Lubega (1987:37), the first two are preferred charcoal burners, for their hardness, but scarcity forces other woods to be used. Even Eucalypts may be used. Women collect firewood, but men usually make charcoal. The first is a regular harvesting activity, making use of a range of woody resources in the locality. The second is an intermittent industrial operation requiring a substantial bulk of wood, if not entire trees, at the site. The first is directed to the consumption needs of the household; the second (in large part) to the market, a form of income diversification. Mention should also be made of brick making (Gielen, 1982; Lubega, 1987), which is on the increase because burnt bricks are preferred to wood construction as they are not affected by termites. There are no quantitative estimates.

Women's collection sites for firewood include: (1) the household's cultivated land (hedgerows, trimming or pollarding of farm trees); (2) grazing land (dead wood, loppings and - rarely - coppicing of trees and shrubs; (3) roadsides, pathways and river banks; (4) other common access woodland, if any; (5) government forests, if within reach; and (6) the lands of other households, by consent of the owners or, if absent, their wives (Gielen, 1982:72; Hayes, 1986; Rocheleau and van den Hoek, 1984).

Household sufficiency in firewood is critically important. Of Gielen's 56 households in Mbiuni, 47% supplied themselves from their own lands, but only 37% reported no problems with their supply (1982:73). Labour constraints (distance and time) were cited most commonly, and lack of enough wood came third. Lubega (1987:37) found that 50% of a sample of women interviewed ranked firewood collection among the five most time-consuming activities in their work load, though few recognised a present scarcity. Hayes' study classified 87 women householders on a scale of self-sufficiency (Table 12).

Table 12: Women's access to firewood in Masii Location

Class		*Per cent of households (N=87)*	*Perception of scarcity (%)*
1.	Lenders	26	9
2.	Self-sufficient	30	42
3.	Borrowers	20	94
4.	Dependent	9	100
5.	Buyers	6	100
6.	Complex	9	38
Total		100	46

Source: Hayes, 1986:170-88, 193 (the terms used in Col.2 are ours).

In the table, the term 'lenders' (1) means those who are self-sufficient in firewood and allow women from other households to harvest their surplus stock. Help with farm work or in carrying water is sometimes given in informal 'payment'. Self-sufficient women (2) do not 'lend' rights of collection, though some claimed to have done so in the past. Borrowers (3) are not self-sufficient and must 'borrow' rights from others. Few admitted to making payment. Dependent women (4) have no trees on their husbands' lands; again, payment for 'borrowing' is reported to be unusual and, where it occurs, is informal. Buyers (5), however, depend on the market for wood. To reduce costs, they also burn crop residues. Finally, 'complex' users (6) both borrow and lend.

Less than half (46%) of the sample perceived a scarcity of wood in their households, and the distribution (shown in the last column of the table) is predictably related to self-sufficiency. In time perspective, for some 13% of the sample, wood had become more scarce, but for a few, an improvement had occurred. The adjudication of individual land holdings was the major factor that initiated 'lending' and 'borrowing', according to 46% of the sample. Not only the tree biomass influenced perceptions of scarcity, but also the size (cooking needs) of the household.

Women who 'borrow' collecting rights are subject to various forms of restriction, the most common being: against collecting green wood, fence material, cut wood or trees; and being limited to places shown, or to wood already on the ground. The costs of such rights of access

are various forms of informal payment, such as farm labour and water carrying, which increase their already heavy work load (ibid., 195-6). Such 'borrowing', though not articulated in a formal market, incurs a form of social indebtedness (Rocheleau and van den Hoek, 1984:30), which emphases inter-household inequalities. Only 12% of Hayes' households sold firewood, and 5% whole trees (contingency sales) at the time of the survey; these figures had not changed significantly since 'the past', and men were more often than not the agents (Hayes, 1986:279-80). Such figures do not make a strong case for the existence of a developed firewood market, especially when the inter-household differentiation, considered above, is taken into account. Rather, inequality in resource endowment is dealt with by the women's negotiation of collecting access rights in a framework of reciprocal obligations.

The position is different with charcoal, which being made intermittently in bulk, is normally bought and sold even in rural areas.[9] Of Gielen's sample households, 30% sold charcoal while 45% made it and 29% purchased it. If these figures are at all representative as a guide to production, then urban consumption within the District (which is 6% urbanized) may comprise only a small proportion of the market. However only 6% of Hayes' households sold charcoal (Hayes, 1986:279-80). Charcoal making for the market is more common in newly settled areas where woodlands are still abundant. Exports from the District are unknown.

This review of field evidence, if these few locations are representative of the District, has shown that wood fuel use is gender specific, with firewood collecting and consumption in the hands of women and charcoal production and marketing largely in the hands of men. Firewood collection is undertaken from a variety of sites, and inter-household differentiation (in access to resources and in cooking requirements) is corrected by a system of reciprocal obligations among the women. Access to wood fuel resources is complex and highly specific to location, household, and gender.

The critical question concerns scarcity. If, as earlier analyses argued, the wood resources of the District have been and are being over-exploited (i.e., the average annual offtake exceeds the mean annual increment to the standing stock), then degradation of the woody vegetation is a necessary consequence. A reduction of the standing volume means in turn that wood fuel requirements, even if held constant, can only be met by mining the stock at an exponential rate.

Such an argument fails to square unequivocally with the evidence.

1. No objective photographic or quantitative evidence has been recovered that suggests a general degradation - in terms of timber volume or tree density - in areas of natural woodland (now nearly all privately owned, and managed as grazing, woodcutting, beekeeping and produce collecting lands). This observation does not support an apparent consensus that such degradation is taking place.

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9 Charcoal burning and transporting are illegal, but since it is outside local government control, occasional arrests of charcoal lorries have little effect on activity.

2. Given a normal distribution of land holdings and household sizes, the number falling below the average in firewood production per person equals those above it. We may redefine these classes as self-sufficient and insufficient. The two household level studies reviewed above - in Mbiuni and Masii Locations - found that about half the households were self-sufficient or in surplus (47% in Gielen's and 56% in Hayes'). There is no evidence as to whether the ratio is changing.

3. The amount of time taken in collecting firewood (though it may be undesirable) is not excessive, given the nature of the work. Mung'ala and Openshaw's survey found that household woodfuel collection in 1977 took 59 man-days per year (1982: Table 5) - or one day in six for one woman per household. Hayes (1986:174,177,180) gives modal values of one collection per week for various classes of collectors (though twice a week was commonly cited; the length of time was not). Neunhauser et al. (1983:56) report that in Yatta, in 47% of households, firewood collection took from 1 to 6 hours per week, and in 36%, from 7 to 12 hours, irrespective of the size of the household. There is no evidence as to whether average collecting times are changing.

4. The firewood market is not strongly developed in the District. It does not account for a large proportion of consumption, it is not growing rapidly, and does not appear to be spatially extensive. Of Mung'ala and Openshaw's households, 74% relied entirely on collected firewood and only 9% depended exclusively on the market. Of Hayes' households, only 6% depended exclusively on the market (Table 12). The District was only 6% urbanized in 1979. The frequency of selling firewood did not seem to be increasing significantly among Hayes' sample households (1986:279-80). There is little evidence of inter-locational movements of firewood, nor of movements into or out of the District.

5. People do not plant trees, on the whole, in order to produce fuel, even though common access woodland is scarce and most wood fuel is now obtained from private land. Mbithi and Kayongo-Male (1978, quoted in Hayes, 1986:214) reported that only 7% of their respondents gave firewood supply as a reason for planting trees. Hayes' male householders thought construction timber is a more important reason for planting trees. Only 10% mentioned fuel as a use of Eucalyptus trees (1986:231) - though this wood is not liked, being slow burning and smoky. And the women do not plant fuelwood trees even though it is they who do the collecting. They prefer to plant fruit trees (1986:214,236).

That wood fuel, and firewood in particular, are widely perceived to be scarce is not in doubt (80% of Mung'ala and Openshaw's respondents said that fuelwood was 'scarce' or 'very scarce' in 1977; 88% of Neunhauser et al.'s women respondents thought it was scarce in 1988). Resources are carefully husbanded at the household level and fuel-efficient stoves are believed to be in widespread use. What evidence there is, however, suggests that this scarcity falls well short of a crisis. This is the opposite of intuitive expectation in a densely populated semi-arid area.

5. AGROFORESTRY INTERVENTIONS

During the 1980s, the International Council for Research in Agroforestry (ICRAF), in collaboration with Kenyan institutions (the Kenya Forest Research Institute, the National Dryland Farming Research Station, Katumani, and the Machakos Integrated Rural Development Programme), used Machakos District for a number of agroforestry initiatives. These differed, in several major respects, from the technological interventions in other sectors, whose impact is reviewed by Gichuki (1991) and Mortimore and Wellard (1991).

1. 'Agroforestry is a land use system, not a commodity' (Rocheleau, 1987), and candidate technologies were researched and evaluated in terms of their impact on the productivity of the whole system (Hoekstra et al.,1984).

2. Agroforestry is not new to Machakos, except in the sense of certain formal designs such as alley-cropping. Smallholders have been managing natural woodland (grazing land), and planting, protecting, controlling and harvesting woody species on cultivated areas, for several decades.

3. A radical departure from earlier diagnostic assumptions characterised these initiatives, at least in intent. A 'Diagnosis and Design' methodology was implemented by a multidisciplinary team of scientists, beginning with 'rapid rural appraisal' of land management constraints and agroforestry potentials, going on to the design of appropriate technologies, and to a combination of farm and station research, to test these technologies. Iterative stock-taking of project experience incorporated the knowledge, preferences and participation of the farmers into the modified research plan (Hoekstra et al., 1984; Rocheleau, 1985).

The sites selected for the ICRAF interventions were the Kakayuni catchment in Kinyatta Location (AEZ 5) and Kathama in Mbiuni Location. An early focus on landscape ecology identified the linear and boundary features (rivers, roads, paths, and field boundaries) as priority areas for productivity-enhancing management. The Kathama study has been documented well, and from the many lessons learnt, three main themes may be distilled that have relevance for the present study.

The first arises from technical trials conducted on the study site in conjunction with farmers and self-help groups. Trials of trees and other technologies were conducted at the farm level, and of conservation strategies for the eroded grazing lands, at the group level. The insight that emerged from this work was a conception of farmers (men or women) as 'choosing, mixing and matching' from a selection of possible practices (Rocheleau and Malaret, 1987:16; Rocheleau et al., 1989). Ethno-science, or ethno-ecology, were put to effect in two specific investigations at Kathama, using cycles of interviews with knowledgeable groups. The first of these was the identification of useful indigenous tree species worthy of research and development. The second was an investigation into the extent and nature of termite activity (Rocheleau and Malaret, 1987). Technical innovations proposed by the scientists were filtered through farmers' perceptions of rationality: for example, the planting of fruit and fodder trees as part of a communal gully control project on degraded land was rejected, in favour of individual plantings at home.

The second theme concerns the need for intervention agents to ensure local participation, not merely in the form of labour inputs to agroforestry projects, but in terms of responsibility and choice, for example by women's self-help groups. Labour, given perhaps reluctantly, is not participation in this sense, as witnessed by the early difficulties of soil conservation schemes in the District (see Gichuki, 1991).

The third theme is the need to recognise adequately the differentials that exist in rights to use resources, and in the ensuing benefits, among members of the community, whether women or men, individuals or groups. Technology designs should include incentives built in to take account of these differences. Gender is a particularly significant, but not the only, issue. Formal adjudication of landholdings had changed traditional rules of access. As the study progressed,

> *In effect, the community peeled back the survey map to reveal another map of potential use and users, derived from traditional rules of reciprocity and mutual aid. Yet the power to determine exactly who could use exactly which resources, and where, had shifted from the community and large kin groups to the individuals who controlled the legal boundaries. Thus a third map emerged which combined traditional norms with new loci of power, at both community and household level. The fact that men actually owned most of the private plots and formally controlled the public lands, set the stage for a gendered struggle for access to resources no less serious for its finesse and skilful manipulation by individual women and self-help groups* (Rocheleau, 1991).

Gender complementarity and conflict is discernible in five areas : (1) in rights of access to the land and other resources; (2) in their actual use; (3) in technical knowledge (ethno-science or ethno-ecology); (4) in work, or labour inputs to resource exploitation; and (5) in the division of rewards (Rocheleau, 1990). When these are superimposed on patterns of socio-economic differentiation among the multiple resource users - households, self-help groups and individuals - a very complex system of productive relations is revealed at the village level.

Such agroforestry interventions, by the very nature of their interactive and iterative methodology, are difficult to evaluate in terms of their impact on farming systems, on incomes or welfare, or on environmental sustainability. Indeed the boundary of the intervention cannot and should not be defined, since it occurs within the framework of an existing agroforestry system. The most important result of these localised experiments in farmer-scientist collaboration is the insights they yield on the relations of production at the micro-scale, where real households are engaged in managing the natural resources of defined territories.

6. SUMMARY AND CONCLUSION

6.1 Government Interventions in Afforestation

The history of the Government's afforestation efforts, acted out against the backcloth of the Ukamba Reserve's special conservation problem, shows a tension between centralised (forest reservation and plantation) and decentralised (extension forestry) approaches. The commitment of a large proportion of expenditures to running and extending the Government's forest estate left little over for extension forestry, whose early programmes had discouragingly little impact. Still less effort was available for tailoring the services provided to the real needs of the smallholders and addressing the constraints under which the farming systems operated - in particular, tenure, which recent studies of farm forestry have shown to be significant. Policy priorities were corrected with the commencement of the RAES in 1971. But the end of our period of study still finds government nurseries and advice inadequate, species provision often inappropriate, and planting failure rates high. Private nurseries, and farmers themselves, fill this gap. Rather than presiding over the reafforestation of the farmlands, or driving a revolution in the management of the grazing lands, the Forest Department is still heavily committed to running the forest estate - an economic enclave as far as the bulk of the Akamba are concerned.

With respect to the long term conservation objectives of government afforestation policy, three comments are in order.

1. There is no evidence to show any ameliorative impact of plantation forestry on rainfall, whose record (see Mutiso et al., 1991) shows no secular trend that is capable of correlation either with deforestation in the longer term or with the limited progress made since 1947 in protective afforestation.[10]

2. The area of gazetted forest is just over 1% of the District, and has been achieved at considerable cost over a period of about 70 years. A substantial extension of this area seems impracticable within the foreseeable future. This area should be compared with that occupied by 'field dividers' (including woody hedgerows), which was estimated to be 1.7% in 1985 (Ecosystems, 1986:2.9). These cost the government nothing and yield many valuable products, including fuel.

3. Afforestation of hillsides and dam catchments is, or may in future (when new plantations become established) be beneficial, in terms of reducing erosion and conserving soil moisture locally. However this benefit has been achieved by removing land from arable or grazing use. As a general strategy, therefore, its scope is increasingly limited by the scarcity of land for farming. There remain many steep and eroded sites, mostly on private land, where afforestation would be beneficial. But on

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10 'Occult precipitation' that occurs on forested hilltops is due primarily to altitude.

such sites, establishment costs are higher and expected income lower than on the better sites.[11]

In Phase I of the MIDP, the greater part (64%) of the afforestation budget was allocated to 'productive forest plantation', only 26% to 'rural afforestation' and a mere 11% to 'protective forest plantation'. A proposed forest research station was to cost more than all three combined (ODI, 1982:10.2). In Phase II, productive plantations were dropped, and rural afforestation was accorded priority, though budget data are not available. This highly significant reversal of priorities was maintained in the ensuing District Development Plan for 1989-1993. Such a shift is strongly supported by the evidence and arguments presented in this paper. It stands to reason that, with almost 99% of the District outside Forest Department management, and most of it in the hands of smallholders, the farmers themselves must continue to be the main agents of afforestation.

6.2 Wood Fuel

A review of the estimates that have been made of woodfuel supply and consumption exposes a contradiction between the expected outcome of projected consumption levels and the observable state of wood fuel resources today. The prognosis that, at the consumption rate of 1977, all the stock could be depleted as early as 1986 (Mung'ala and Openshaw, 1984) has not been justified by events. It is suggested that there are four possible reasons for this: (1) the estimated rates of consumption used in the projection were too high, (2) the estimated rates of mean annual increment were too low, (3) wood fuel is gathered from cultivated land to a larger extent than was assumed, and (4) non-wood fuels are used to a greater extent than expected. The first and second possibilities cannot be assessed without new data.

6.3 Smallholder Tree Management

Smallholder tree management has effected a transformation of the natural woodland. Shepherd's account of farm forestry in Embu, though describing a different (and on the whole, wetter) area, adequately sums up the experience of Machakos:

> *... what has gone on is a process of improvement upon what nature gave in the first place. A tract of bush is turned into a farm with trees on it, through careful processes of selection and enrichment. While the diversity of good hardwood species is gradually lost, the gain in fruit trees, in appropriately placed trees of all kinds and in species which are really wanted, is enormous* (Shepherd, 1989:27),

and,

> *the survey made us realise how committed farmers already are to trees and tree planting and how the project [the ODA/Government of Kenya Embu-*

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11 At least one farmer interviewed planted eucalyptus (for revenue) on his steep land.

> *Meru-Isiolo Forestry Project] must improve its own performance ... Farmers need trees and planting advice, not motivation sessions* (ibid.,28).

Tree planting in Machakos is a form of intensification on cultivated land, in which fruit trees are gaining over other trees, and useful exotics over indigenous species, though the last still have a role to play. Tree planting, management and control are inseparable from the gender division of labour and farm responsibilities.

In the woodfuel system, women collect firewood, and men make and sell charcoal (with some exceptions). Firewood collecting rights are redistributed amongst unequally endowed households by means of reciprocal networks of women's obligations. The market is localised and rather underdeveloped. Charcoal is marketed to a greater extent. The evidence that can be gathered together on wood fuel scarcity does not support the notion of a crisis. Rather, the logic of the situation suggests that scarcity will help to drive an intensification of farm forestry.

6.4 Agroforestry Interventions

Experiments in farm- and community-based agroforestry research and design have generated further insights into the complexity of rights of access to natural resources and the benefits of their exploitation, and in particular the complementarity and conflict of gender roles. These insights are not only relevant to the development of agroforestry technologies but, because they concern the operation of whole land use systems, they inform our understanding of environmental management.

At the village scale, households operate closely regulated access rights on defined territories. In this area, the securing of individual title has had a profound impact. On the one hand it weakened shared interests in common access resources, which declined in importance and in extent, while on the other it strengthened incentives for individuals to manage, under a sustainable regime, the lands to which they enjoy secure and heritable title. However, individual title does nothing to generate the capital and labour required to institute such regimes. Consequently, the cadastral mosaic of access rights is itself reflected in an uneven quality of management. Population growth and the subdivision of holdings provide incentives for the conversion of more grazing land to arable and more tree planting on this arable. Agroforestry technologies that can improve the efficiency of nutrient cycling on such diminishing holdings are a priority.

6.5 Conclusion

The revolution in tree management on farmlands shows that smallholders respond rationally to economic opportunities and constraints where trees are concerned. The evidence suggests that sustainable production of wood fuel may be attainable as an outcome of continuing agroforestry intensification, driven by its scarcity. This is an appropriate objective for interventions and wholly consistent with sustainable dryland management.

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APPENDIX

GAZETTED FOREST RESERVES

Figure number	*Name*	*Ha (appr.)* [a]	*Figure number*	*Name*	*Ha (appr.)* [a]
1	Iveti	341	23	Nzaui	967
2	Kiteta	22	24	Kalimani	179
3	North Mbooni	40	25	Kithendu	218
4	South Mbooni	208	26	Ikilisa	79
5	Momandu	139	27	Mutula	567
6	Kilungu	149	29	Kyai	106
			29	Nthangu	844
9	Kanzalu	NS	30	Kyungwami	30[b]
10	Uuni	93	31	Nduluni-Kalani	60[b]
11	Tulimani	326		Kioo (1)	35[b]
12	Kibauni	1,619[c]		Kioo (2)	?[b]
13	Kalima Nzalu	NS	32	Kyemundu	141
14	Kitoo	37	33	Ngunguu	83
15	Utunene	170	34	Utangwa	55
16	Katende	949	35	Kenze	188
17	Kitondo	1,085	36	Waiya	263
18	Makongo	166	37	Mataa	43
19	Kilala	151	38	Kibwezi	5,686
20	Makuli-Nguuta	1,653	39	Masue	NS
21	Kitumbuni	76	40	Ithumba	NS
22	Ndatai	14	41	Mavindini	NS
	TOTAL (excluding Nos 9, 12, 13, 31) gazetted (1977)				14,718

Sources: Logan (1948), Bolton (1953), Peberdy (1958), Consortium (1978).

Notes: NS Not surveyed or gazetted in 1978. In addition, 6 unlocated reserves awaited survey and gazetting.

(a) Areas according to Consortium (1978). In some reserves shown on the 1:50,000 topographical maps (usually revised in 1974-76) these areas appear to be under-stated.

(b) Not included in 1978 listing but shown in earlier lists and on 1:50,000 topographical maps.

(c) Not gazetted in 1978.

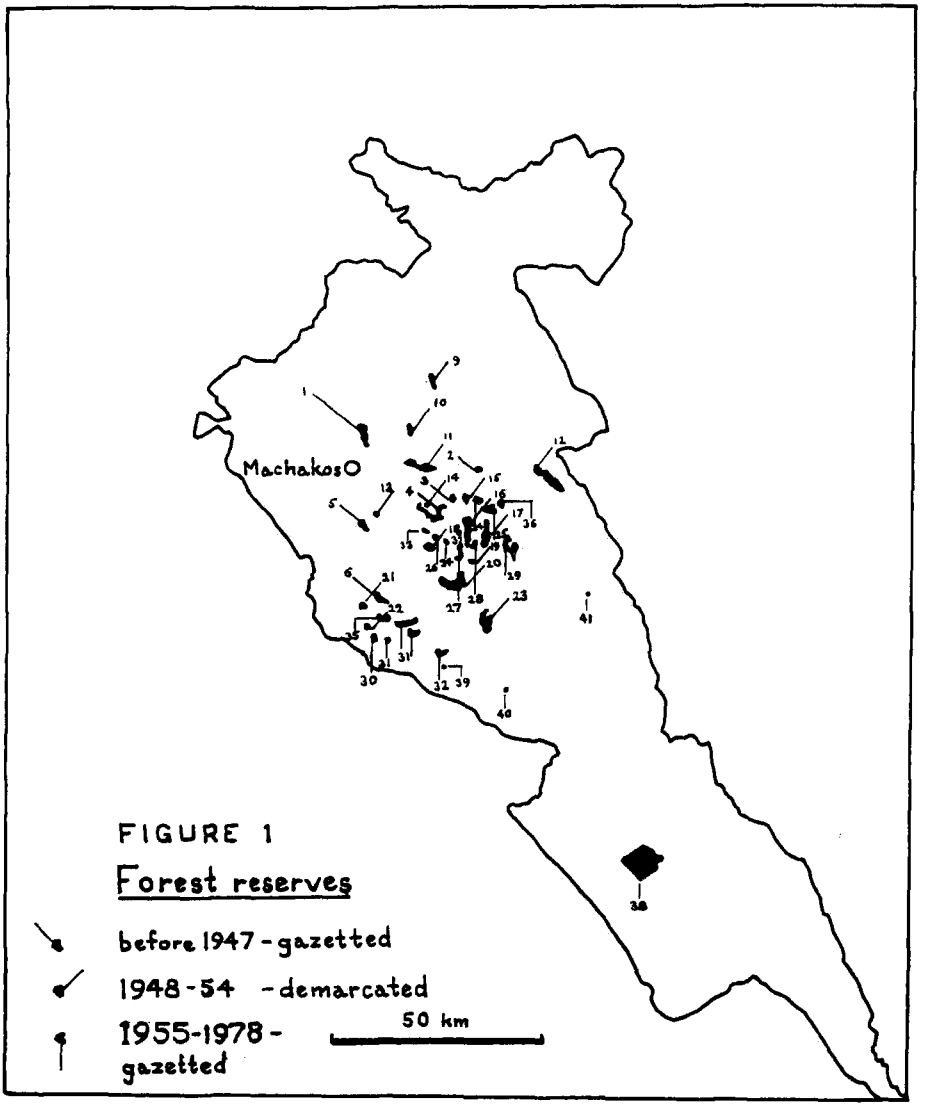

FIGURE 1

Forest reserves

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