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Working Paper

56

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

CONSERVATION PROFILE

F. N. Gichuki

Results of ODI research presented in preliminary form for discussion and critical comment

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CONSERVATION PROFILE

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November 1991

ISBN 0-85003-167-2

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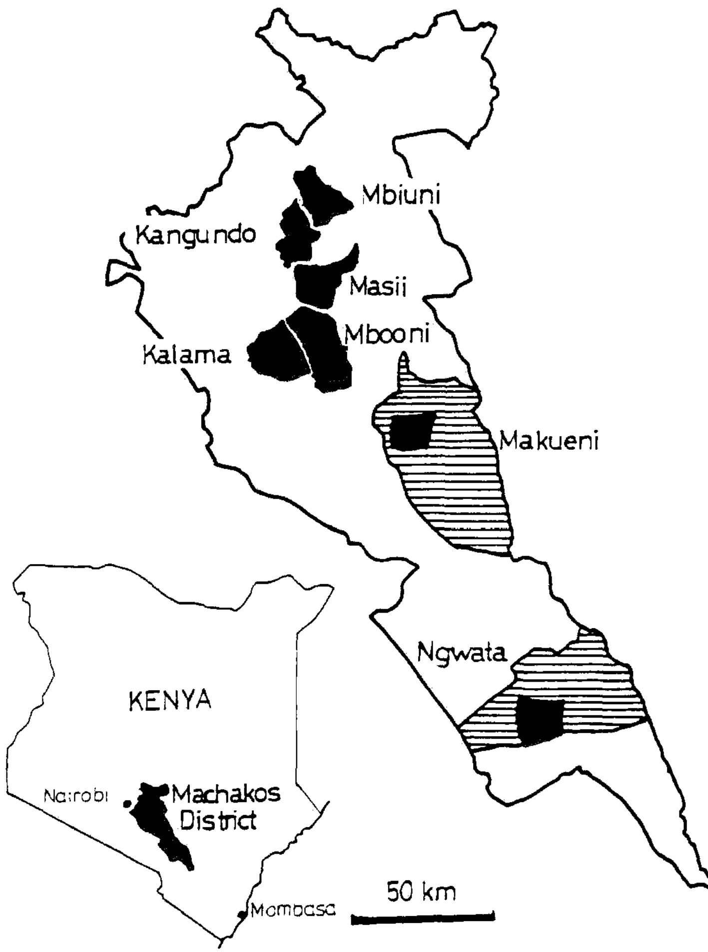
Preface Figure: Machakos District, Kenya, showing study locations
(In Makueni and Ngwata Locations, field studies were mostly within the areas shown black.)



Preface and Acknowledgements

ODI Working Papers present in preliminary form work resulting from research undertaken under the auspices of the Institute.

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. 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 (in which more are planned) are:

Machakos District: Environmental Profile
Machakos District: Production Profile
Machakos District: Technological Change
Machakos District: Land Use Profile
Machakos District: Population Profile
Machakos District: Institutional Profile

Dr F.N. Gichuki is the author of this paper, Conservation Profile. It has been edited, with some additions, by Michael Mortimore. Dr Gichuki is a member of the Department of Agricultural Engineering, University of Nairobi. The author acknowledges the help of Furaha Mutisya, Alex Odour and Eric Unyillo of the University of Nairobi, in carrying out the field work and analysis of the questionnaires. Special thanks go to Professor D.B. Thomas and to Professor M. Mortimore for making valuable comments on the first draft, and to Mr Odour for preparing the sketches.

CONTENTS

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LIST OF ABBREVIATIONS

DAO	District Agricultural Officer
DoA	Department of Agriculture
ICRAF	International Council for Research in Agroforestry
KEFRI	Kenya Forestry Research Institute
PPCSCA	Permanent Presidential Commission for Soil Conservation and Afforestation
MoA	Ministry of Agriculture
MIDP	Machakos Integrated Development Project
MALD	Ministry of Agriculture and Livestock Development
NDRS	National Dryland Research Station
NGO	Non-Governmental Organisation
NPK	Nitrogen, Potassium and Calcium
SIDA	Swedish International Development Agency

1. INTRODUCTION

The problems of natural resources degradation in Machakos District were first reported in the early part of the century and reached an alarming level by 1930 (see Environmental Profile: Soil Erosion). Efforts to control them then began in earnest. The momentum achieved by the late 1950s declined during the 1960s but has been increasing rapidly since 1975, due to a growing recognition of the need for resource conservation, community and individual efforts, and government and donor financial and technical assistance.

This study aims to accomplish the following objectives:

1. to identify how far the degradation described in the 1930s has been checked;
2. to develop a soil and water management profile for the district; and
3. to identify interventions that have been adopted and evaluate their relative effectiveness.

Section 2 provides an historical profile of the spatial spread of soil conservation activities. Section 3 describes the conservation measures used in the District. Section 4 assesses the current effectiveness of the soil and water conservation measures, and the farmer-perceived benefits over time. Farmers' assessments are necessary for an evaluation of trends through time (whether positive or negative), in order to complement results obtained from air surveys (see Land Use Profile). Section 5 presents conclusions and highlights factors that have led to increased population-supporting capacity.

2. HISTORICAL PROFILE OF INTERVENTIONS

In this section, an analytical approach is adopted, in order to consider each type of intervention separately. But it should be borne in mind that there were many lateral linkages between interventions carried out at the same time, and sometimes by the same departments (Agriculture). For a chronological resumé of the early years, see Peberdy (1958) and de Wilde et al. (1967).

2.1 Government Interventions

2.1.1 Soil and water conservation services

The first District Agricultural Officer was posted to Machakos District in 1931. During the early years he worked mainly in Kangundo, Matungulu, Iveti, Kalama and Muputi where Peberdy (1958) reports that significant improvements had been made in conservation farming and ox-cultivation had received widespread adoption. In 1935 there was a renewed interest in combating soil erosion in both European and

African areas of Kenya. The Plant Industry Division of the Department of Agriculture (DoA) produced a bulletin on 'Soil Erosion' emphasising its dangers and describing ways in which erosion occurs, and how it can be controlled. In 1938, a special Soil Conservation Service was instituted within the DoA with the responsibilities of:

1. carrying out advisory work and propaganda in both European and African areas;
2. preparing soil and water conservation schemes; and
3. assisting in their execution.

Mr Colin Maher was appointed Agricultural Officer in charge of the Soil Conservation Service and Mr R.O. Barnes the Soil Engineer. To underscore the gravity of the soil erosion problem in Machakos, the Soil Engineer was placed in technical control of soil conservation work in Machakos District: mainly Kilungu, Mbooni and Machakos areas, with a special area at Matungulu. In Matungulu, 200,000 Ksh were set aside for a scheme of demonstration and experimentation. An additional European was employed in Machakos district to undertake mechanical and hand terracing, contour ploughing and prevention of grazing near gullies and rivers. Staffing reached a peak 1944-1955 (see Production Profile, Table A.2).

From 1956-1975, the staff in the District's soil and water conservation programme was low, compared with after 1975. Renewed awareness between 1975 and 1990 of the need to conserve the natural environment, availability of trained manpower and increased financial support and political will are the main reasons behind such an increase in soil and water conservation activities.

Currently, the soil and water conservation service in the District is very active and adequately staffed. Its efforts are complemented by the activities of the Permanent Presidential Commission of Soil Conservation and Afforestation (PPCSCA), the Ministry of Natural Resources' gazetted forest and rural forestry programmes, the agricultural and livestock extension service, the District environmental officer, and numerous Non-Governmental Organisations (NGOs).

2.1.2 Reconditioning programmes

In 1931, many patches of land were so badly denuded that a massive programme was considered necessary to physically recondition deteriorating pasture land. In Mbooni, an area of 80 ha of steep, badly eroded land was contour-trenched and black Mauritius beans sown along the trench banks. Cattle were kept off the area which was planted with indigenous grass (particularly Cynodon grass noted for its fast spreading and drought resistant habits) and exotic drought resistant forage plants. Gullies were supplied with wash-stops. This reconditioning exercise was intended to serve as a demonstration; the reclamation of larger areas was to be left to the Akamba people. A nursery was set up to supply fodder plants, trees, and wash-stop grasses to the reconditioning schemes and interested land owners. The main species planted in the nurseries included Mexican daisy, spineless cactus, napier, woollyfinger, Bermuda and crested wheat grass, Kudzu vine, black Mauritius bean, drought resistant fodder trees and shrubs (DoA, 1932).

Reconditioning work by the Akambas was started at Kiteta. The area was de-stocked and the government assisted in setting up three trials to assess the economics of reconditioning extensive areas. The trials included destocking alone, with contour trenching and with contour trenching and planting with indigenous grasses (*Cynodon sp.*). The latter treatment proved to be the most successful (DoA, 1934). Following such a demonstration, the Akambas started to fence and make contour trenches in small areas. Persuasion by the administration improved the adoption rate.

In September of 1934, the Local African Council, in order to check and remedy the severe soil erosion, empowered the Headmen of Kiteta and Masii Locations to restrict or prohibit grazing in locations set apart for reconditioning and planting of fodder-producing plants and grasses (DoA, 1934). These efforts were complemented by a regular supply of prisoners' labour for reconditioning work, because no matter how committed the Akamba volunteers were, they were very spasmodic and the type of trenches they dug were not sufficient (mainly due to inefficient tools) (DoA, 1934).

In 1935, a Reconditioning Committee was formed to formulate and plan reconditioning activities in the Akamba Reserve. The committee recommended the use of contour trenching, planting napier grass, water improvements, destocking and planning of stock routes, rotational grazing and demarcation of holdings with sisal boundaries (by improving security of tenure, it was hoped to make the owner feel responsible for reconditioning his own land) - (DoA 1935; Peberdy, 1958). Between 1935 and 1936, the reconditioning campaign closed off approximately 8,000 ha of land, marked out 50 farms near Makaveti for Napier grass planting, and established 7,500 compost pits in Iveti, Kangundo and Matungulu area. By 1937, a large area of grazing land was temporarily closed to stock under organised schemes of rotational grazing, and the restriction had resulted in remarkable regeneration of natural grass and bush (DoA 1937). (See Table 1). Nevertheless, Maher (1937) estimated that at such a rate, 32 years would be needed to close off all the badly eroded areas and that the amount of contour trenching so far achieved was negligible.

According to Peberdy (1958) the Reconditioning Committee died out during the Second World War and had to be resurrected in 1944. The new committee under the Chairmanship of the District Commissioner recommended that for any progress in reversing degradation to be made, the problem had to be tackled on a large scale. In 1946 a total of 24,000 ha were closed to grazing, 1,400 ha of degraded land reseeded, 130 km of terraces and 24 km of cutoff drains laid and constructed. Most of the area that was closed was done by the Chiefs on their own initiative. In Masii, much of the conservation work appears to have been done during the reign of Senior Chief Mutinda (after 1945). Chief Mutinda is reported to have imposed a fine of two bulls for anyone cultivating un-terraced land. In 1955 the Re-conditioning Committee was abolished.

2.1.3 The Land Development Board

Under several names, the Land Development Board and its antecedents constituted the major arm of government intervention in soil and water conservation, as well as in the settlement of new areas (considered below), between 1946 and 1960, when it was absorbed by the Board of Agriculture (for Non-Scheduled Areas) (MoA, 1962; ALUS, 1953; ALDEV, 1954-1960). Machakos District Betterment expenditures increased under the Swynnerton Plan from £53,000 in 1952 to £522,600 in the 18 month period, July 1959-December 1960. The increase was due to the introduction of machinery and an extended scale of operations. The increase reflected a change in priority from new settlement to the betterment of older settled areas.

The mechanical unit began operations in the Kimutwa area in 1952, using D6 tractors for constructing 1,200 acres of terraces. Communal labour, which was summoned by headmen empowered by local byelaws, supplemented the mechanised unit with the construction of narrow base terraces, bench terraces, banana trenches and dams, with manuring, drainage works and silage pits. Compulsory communal labour was already becoming unpopular in 1955, however, and *mwethya* self-help groups, based on the clan system, spread rapidly to most areas by 1957. In the latter year, the Annual Report of ALDEV claimed that 'with the already progressive locations forging ahead, and the laggards...beginning to show signs of awakening', terracing, manuring, cattle sheds, stall-feeding and paddocking were going ahead and fodder crop production was beginning. Streams flowed for longer than for 15 years previously. Impetus, however, slowed in 1959, as political activity 'undermined the self-discipline of the Machakos Wakamba which is so essential to the continued reconditioning and development of the district' (ALDEV, 1960:12).

Table 2 gives data on grazing land conservation from 1955, and Table 3 on conservation structures (see also Figure 5).

2.1.4 Settlement

It was hypothesized that a solution to environmental degradation in the District was opening new lands for settlement. Settlement was intended to reduce population in the Reserve to a level where the people could feed themselves. Maher (1937:258) estimated that 100,000 ha were available in Kikumbulyu Location, which, if cleared of tsetse, could accommodate 25,000 people displaced by closing grazing areas in the Reserve. The search for, and the development of, new lands for settlement absorbed much of the resources of the early land boards (ALUS, 1953; MoA, 1962).

The settlement farms were to be large enough to allow an improved standard of living, and enable the farmer to utilize the services of craftsmen, industrial and farm workers, thereby creating a class that relied on off-farm income (Peberdy, 1958). Thus, as early as 1943, increased off-farm income was considered to be a possible solution to environmental degradation.

The Colonial Government developed the Makueni settlement scheme. The settlement programme cleared the bush and gave new settlers already conserved farms. The general sequence of development and settlement of people was as follows:

1. water development (boreholes and/or dam construction);
2. survey of the area for settlement;
3. cutting roads and demarcating the boundaries of the holdings;
4. demarcation of arable land and selection of applicants;
5. clearing of arable land, followed by ploughing and terracing by tractors; and
6. completion of houses and cattle *bomas*[1] by settlers working communally.

In an effort to ensure a sustainable use of land and water the following settlement orders were made by the District Commissioner (Peberdy, 1958):

1. Not more than one half of the total cultivated area may be planted to maize at any one time.
2. Every registered settler, before he brings his stock, must construct a 9m x 3m cattle *boma* that may subsequently be roofed.
3. Every farm owner shall construct a silage pit each season of dimensions of at least 3m x 1.5m x 1.25m. This pit must be filled with green fodder and the resulting silage fed to the cattle.
4. Stock must be stall fed at periods laid down by the District Commissioner according to conditions.
5. All arable land shall be terraced.
6. All terraces shall be properly maintained by the farm owner and be in a clean sound condition before the commencement of each rain.
7. No crop residue may be burnt, but must be used for feeding and bedding of cattle in *bomas*.
8. Cattle *bomas* must be cleared of all manure at least once a year before the advent of the short rains and the manure obtained applied to the arable land.
9. A farm owner, where bush has been cleared from his land, will be expected to take every reasonable measure to maintain the pasture in good order and prevent regeneration of bush. Should his efforts fail, he must report such regeneration to the section headman.
10. Every settler must plant at least 0.1 ha of cassava.

Despite these harsh conditions some farmers are reported to have fled the forced soil conservation work in Masii area to settle in Makueni (Interview, 1990). In 1956 total expenditure on the Makueni Settlement had accumulated to £280,000 (ALDEV,

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1 *boma* = livestock enclosure.

1956:7), with 1,472 families settled. Prison, communal and family labour were harnessed to the task of clearing the bush. The livestock population was increasing rapidly, even to overstocking (MoA, 1962), but good farming standards were maintained. Population pressures have been somewhat abated by post-independence settlement in former European lands within and outside the District; nevertheless, new settlement spread spontaneously far beyond the area of the original settlement during the 1960s and 1970s.

2.1.5 Research

Early trials in the District concentrated on the rehabilitation of grazing land. The reconditioning experiments proved that destocking alone was very slow in restoring plant cover (5 years), whereas trenching with destocking required 3.5 years, and destocked, trenched and grassed areas required 2 years (DoA, 1934). In 1947, emphasis on grassland experiments shifted from the selection of suitable varieties to a search for suitable management. The main grasses recommended were *Panicum makarikariensis, Cynodon plectostachium* and *Eragrostis curvula* (DoA, 1947).

From 1949 until 1957 the Department of Agriculture carried out experiments at Makaveti that were designed to show that protection and intensive management could restore dead grazing land to a productive condition (Pereira and Beckley, 1952; Pereira et al, 1961). The experiments were successful and the land, which had been borrowed from Wakamba farmers was restored to its owners. Pasture research, which had been forcefully advocated by Pole-Evans (1939) after a tour of Kenya's reserves, was thereafter included in the mandate of the Katumani experimental farm, though activity was on a small scale and seems to have been subsidiary to agricultural research.

Early experimental work at Kampi ya Mawe investigated methods of maintaining and improving soil fertility, and when the Katumani experimental farm was established in 1956, work was started on general crop husbandry, plant breeding and pasture research (DoA, 1956; Thomas, 1956).

In 1961, Katumani experimental station started trials on soil moisture utilization by crops under low rainfall conditions. It was upgraded to a National Dryland Research Station (NDRS). Soil and water conservation research has subsequently addressed the following issues:

1. Evaluation of tillage systems and implements, and modification to make them more suitable under dryland conditions.
2. Determination of draft requirements.
3. Studies of infiltration, run-off and sedimentation under various cropping systems, slopes and soil conditions.
4. Erosion studies and control methods.
5. Reclamation of degraded lands by suitable vegetation and mechanical practices.

6. Climate, soil, crop and water use.
7. Pitting practices for rehabilitation of eroded grazing land.

While most research programmes have been confined to the station, commendable on-farm trials have aimed at testing the techniques under the farmers operating environment both to determine its performance and to promote farmer acceptance.

In view of the importance of understanding soil moisture regimes under various conservationary practices (and especially terracing), it is surprising that little research has been attempted on quantifying the dimensions of these regimes.

2.1.6 Training and extension

As early as 1913, the Akamba people gave a site at Iveti to the Government to built a technical school (Peberdy, 1958). Later, 12 acres (5 ha) were set aside at every Government school for social centres with an agricultural bias. The first schools were started at Mitaboni, Kaani, and Kibwezi. Their objectives were:

1. to promote agricultural education;
2. to demonstrate good methods of crop husbandry;
3. to undertake crop varietal adaptability trials;
4. to bulk and distribute improved seeds; and
5. to promote better animal husbandry (Peberdy, 1958).

The Agricultural Commission of 1929 recommended a conference once a year between the agricultural officers and research officers to review field experiments and extension in Kenya. The early extension work centred on promoting better farming techniques (better use of land, water, labour and capital inputs). Farmers committed to better farming would undertake cultural practices favouring soil and water conservation. Better farming practices were promoted through:

1. demonstration farms;
2. supply of inputs (grain seeds, tree seedlings, etc); and
3. extension messages.

In 1931, the DoA decided to replace the numerous small demonstration plots in the African Reserves with Local Native Council Farms. These farms were envisaged to offer the following advantages:

1. develop a sense of responsibility in the Akamba leaders;
2. serve as demonstration centres for improved crops and methods of planting and harvesting;
3. conduct trials of new crops;

4. improve local crops by selection;
5. maintain a permanent source of uncontaminated seed; and
6. furnish centralized multiplication of seed.

In addition, the propagation of fruit and timber trees and raising of poultry for distribution were also carried out (DoA, 1931). One such farm was set up in Machakos in 1932. The farm was 16 ha and was planted with the following crops and fruit trees: Muratha maize, Kerr's pink potatoes, Canadian wonder, Mung beans, field peas, cow peas, pigeon peas, Washington navel orange and rough lemon. This seed farm was later used for crop trials and selection work (DoA, 1932). In 1933, the Local Native Council established farms in Masii, Matiliku and Kibwezi (DoA, 1933).

The Reconditioning Committee also promoted better farming techniques. In the Kangundo-Matungulu area, they recommended the use of manure, rotational grazing, grazing closures, fodder crops and prohibition of maize growing in some areas (Peberdy, 1958).

In 1953, coffee nurseries were established in Kangundo, Matungulu and Mbooni area. Introduction of coffee in the medium potential areas resulted in improved soil and water conservation through:

1. The requirement that in order to be allowed to grow and sell coffee to the Coffee Marketing Board, it had to be grown on terraced land.
2. Improved returns from the farm encouraged farmers to reinvest part of their earnings in the form of soil and water conservation measures.

With increased donor assistance in soil and water conservation since the 1970s, training became a major input. The following courses are organised by the MoA's Soil and Water Conservation Branch:

- staff retraining seminars;
- catchment planning workshops;
- training of trainers;
- staff induction and training course;
- school approach programme;
- leaders training courses; and
- farmers training courses.

Table 5 presents SIDA assisted training activities in the District.

2.1.7 Presidential soil conservation sites

The commitment of the President Daniel arap Moi to soil and water conservation is demonstrated by the Permanent Presidential Commission on Soil Conservation and Afforestation (PPCSCA), and the Presidential soil conservation sites scattered throughout the country. In Machakos District there are three such sites. Mwanyani site was started in 1982, Uuni in 1984 and Masinga site in 1985. These are demonstration sites of gully control, cut-off drains and terraces, fodder establishment, afforestation and pasture reclamation on badly eroded land.

The PPCSCA organises a National Soil and Water Conservation Competition. In 1985, the competition was won by Mr Abraham Mule Muthike of Mbooni, who was awarded a posho mill and a trip to Zimbabwe and Malawi.

2.2 Donor Support

Farmers appreciate the role of the Swedish International Development Agency (SIDA) and Machakos Integrated Development Project (MIDP) in soil and water conservation. Active NGOs include the Institute of Cultural Affairs, the Green Belt Movement, ActionAid, AMREF, World Neighbours, the National Council of Christians of Kenya, the Catholic Diocese of Machakos, and the Kenya Institute of Organic Farming. Their main activities in natural resource management include the promotion of conservation and organic farming, tree nurseries, gully control and water supply. It is worth noting some of the contributions that SIDA and MIDP have made.

SIDA's support to Soil and Water Conservation Projects in Machakos started in 1974. The overall objective of the project was to contribute to increasing crop production through increases in the arable area and productivity per unit of land, brought about by better soil and water conservation. The specific objectives were (MoA, 1988):

1. to increase arable land by intensifying soil and water conservation practices on steep slopes and in low rainfall areas;
2. to increase crop yields and livestock production through better land and water management;
3. to improve the organisation of soil and water conservation extension
4. to create rural employment by promoting labour intensive soil and water conservation methods; and
5. to promote tree planting, agroforestry and biological conservation.

The project put emphasis on small farming communities in high and medium potential areas with a high risk of environmental degradation. SIDA's method was a 'whole farm' approach using voluntary labour, agreed farm plans, and technical assistance. Its activities have contributed significantly to the control of soil and runoff losses. A typical SIDA annual achievement is shown in Table 6. Other achievements were in the following areas:

1. farmers' and staff training programmes;
2. logistical support;
3. selected catchment rehabilitation;
4. provision of tools;
5. publicising soil and water conservation;
6. technical assistance;
7. tree nursery programmes; and
8. community mobilization (DAO, 1982).

The MIDP was started in 1979 (ODI, 1982). Its soil and water conservation programme was very ambitious and concentrated on the following activities:

1. selected catchment rehabilitation;
2. provision of tools;
3. publicising soil and water conservation;
4. technical assistance; and
5. training (DAO, 1984).

The MIDP continued the SIDA 'whole farm' approach whereby unpaid labour was supplied for on-farm work but hired labour was provided for external works such as gully control and drains (ODI, 1982: chapter 9). Credit was provided to participating farmers in 42 catchments which, in 1982, covered 613 km^2. A community development approach - which placed priority on moving people, not merely soil - was considered to be working well in the evaluation of 1982. Resident soil conservation supervisors aimed to motivate change, generate self-help and provide technical demonstrations.

By 1984, MIDP had established catchment protection activities in every sub-location of the district. Their main activities included demonstration of pasture rehabilitation, afforestation, gully control, promotion of roof water harvesting and provision of hand tools. Provision of soil and water conservation tools was considered a vital incentive to sustain the Mwethya group activities in soil and water conservation (see below). All staff were supplied with line levels.

MIDP undertook a massive campaign aimed at publicising soil and water conservation through the use of films and slide shows. The main themes of the film and slide shows were soil erosion, soil conservation, uses of the *Leucaena* tree, gully control, and terracing. In 1979, 60 schools and adult education classes were selected and shown slides and films on soil erosion and soil conservation methods. Some of the farmers interviewed vividly recall the impact that the films had on their perception of soil erosion and soil conservation. Others credited the programme for having enlightened their children on the losses associated with soil erosion and the benefits of soil and water conservation.

MIDP provided a number of soil conservation specialists and supported a baseline survey to determine the state of land use, soil loss and soil conservation activities (Ecosystems, 1982). MIDP also employed 40 supervisors to assist in laying out soil conservation structures and to monitor and supervise activities.

MIDP supported skill-upgrading training courses for local staff. In 1979 alone, 60 technical assistants were trained and equipped. Other Government officers also received training (mainly chiefs, assistant chiefs, teachers, leaders, and community workers). Farmers also received on-farm training or training at the Farmers Training Centre.

2.3 Community Efforts

In the late 1940s the Akamba were in a state of great unrest and distrust. The situation had arisen because of the reaction of the returning soldiers from World War II and the failure of the Government to provide additional land. The European farmers made the matter worse by claiming that the only solutions to the denudation problem were compulsory destocking and movement of large numbers of people to the European farms as labourers. This made the Akamba very apprehensive of any Government rehabilitation programme in the Reserve, as it was seen to be a move towards annexation of their land to the European farms (Interview, 1990).

There was a considerable amount of coercion for soil and water conservation activities. An administrative officer visiting the Kaumoni area on February 18 1942 reported that Chief Nzalu admitted that very little reconditioning work had been going on for the past few months, and the excuse was that the farmers had been busy scaring birds. He ordered the Chief to ensure that anybody who did not attend communal work should be taken to the tribunal. The following day, he found a large number of men and women at work, and concluded that the people of Kaumoni would turn up regularly if the Chief had more drive. McCreath (1947) reported that soldiers returning from World War II were adopting what they saw in India. He concluded this when he observed that two farmers had, on their own initiative, constructed a series of small earth dams in Kalama area and were planting rice below the dam sites.

After this hurdle was overcome, the Akamba created very strong communal working groups that are credited for most of the conservation work at the time. In many areas, most of the work was achieved by women, since 60% of the able-bodied males were employed outside the District (DoA, 1953). After 1954, there was a general decrease in the communal labour available for soil conservation, owing to increasing demand elsewhere as a result of the Mau Mau Emergency and struggle for independence (DoA, 1954; Interview 1990).

Mwethya groups started replacing communal labour in soil conservation in 1956. An elderly lady narrated how they had rehabilitated their land. When they settled in Kalama Location around 1954, the trees had been cut indiscriminately and the ground vegetative cover destroyed by overgrazing and termites. They closed the land from grazing, and were assisted by Mwethya groups to plant star grass and establish some terraces. The land that was once bare and capped has been transformed into a productive piece of land.

By 1959 most of the conservation work in the District was being undertaken by Mwethya groups (DoA, 1959). In 1960, however, there was a general lack of interest owing to increased political activities. The use of Government officers in registering voters made it very difficult for the necessary pressure to be maintained (DoA, 1960). This problem persisted until 1964. De Wilde (1967) reports that construction of new terraces fell off sharply in 1960 and that towards the end of 1961 the area protected by effective terracing had dropped to less than a quarter of the cultivated area.

While the Mwethya groups of the 1950s were composed of both men and women and were clan-based, they are now predominantly women's groups. They are organised as Mwilaso, Utuii and clan groups (see Institutional Profile). Table 7 illustrates the role of the Mwethya group in soil and water conservation programmes. Table 4 shows soil conservation tools issued to groups.

3. CONSERVATION MEASURES

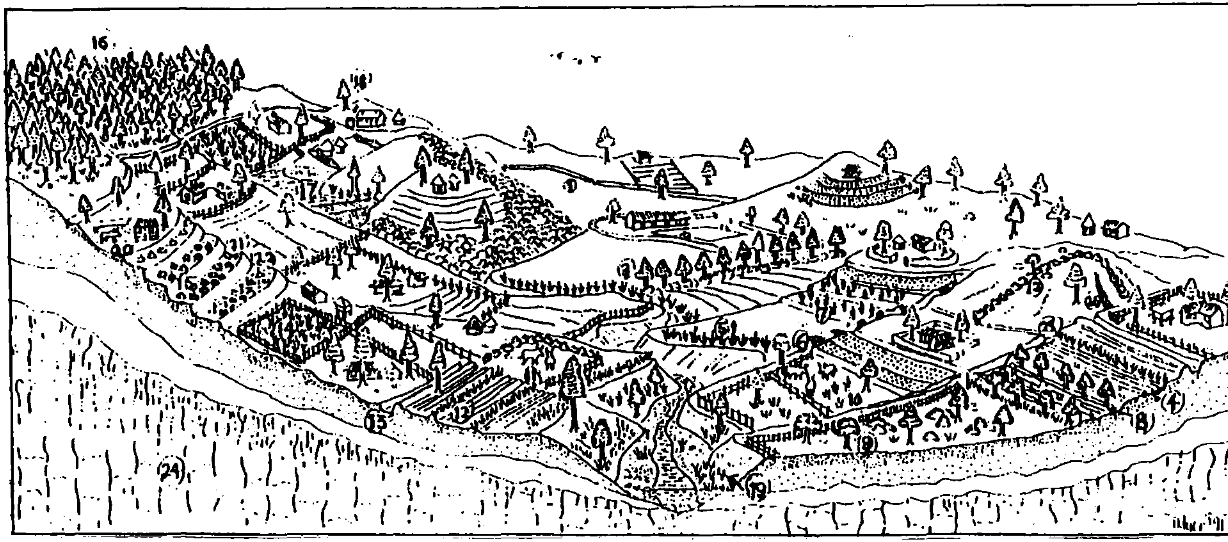
Soil and water conservation measures aim to control soil erosion and runoff by:

1. improving ground cover, thereby reducing the rate of detachment and transport of soil particles;
2. improving soil structure, thereby increasing the infiltration rate and resistance to erosion; and
3. controlling water flow and/or wind, thereby reducing the amount of erosive kinetic energy available for transporting soil particles.

The major measures used in Machakos District (see Figure 1) include:

- Cropland practices
  - contour farming and trenching
  - mulch farming and use of manure
  - multiple cropping and rotation
  - grass strips and agroforestry
  - cutoff drains
  - narrow base terraces
  - bench terraces
  - runoff harvesting
- Grazing land
  - contour trench and reseeding
  - range pitting
  - destocking and stock limitation by-laws
  - stall feeding
  - controlled grazing and planning of stock routes
  - demarcation of holdings
  - closing off denuded grazing land

Figure 1: **Soil and water conservation activities in Machakos District**



1. Weather road
2. Protection of denuded land
3. Windbreak and live fence
4. Ridge and furrow tillage
5. Sisal hedgerow
6. Gully checkdams
7. Intercropping
8. Agroforestry
9. Woodlot
10. Paddocking
11. Improved pasture
12. Forward sloping benches
13. Cut off drain
14. Pasture establishment
15. Excavated level bench terraces
16. Gazetted forest
17. Earth dam
18. Roof water catchment
19. River bank protection
20. Stall feeding
21. Coffee plantation
22. Crop residue management
23. Waterway
24. Soil profile
25. River or stream
26. Gully erosion

Other lands

- gully control
- river bank protection.

3.1 Cropland

Control of runoff and soil erosion in cropland has presented the greatest challenge, mainly due to the slopes, the small amount of soil loosening required, and low crop cover during periods of highest erosion potential. Strategies for erosion prevention and control are based on crop, soil, slope and runoff management.

3.1.1 Crop management

The basis of the crop management approach is an effective spatial and temporal vegetative cover. A good vegetation cover reduces erosion and runoff losses in the following ways:

1. interception of rain drops; thereby reducing its dispersion of the soil and the amount of water contributing to surface runoff;
2. decrease in runoff velocities by increasing flow resistance and preventing concentration of flow;
3. knitting and binding effects of rooting systems on the soil particles thereby increasing soil resistance to erosion;
4. improving the environment for biological activities ameliorating soil structure, aeration and permeability; and
5. delaying, through transpiration, onset of soil moisture saturation and runoff (Fahlen, 1988).

Since approximately 70% of the erosive storms normally fall within 30 days of the start of the rainy season, early planting and fast crop establishment are needed to reduce runoff and erosion (Fisher, 1978; Moore et al., 1979). Farmers may achieve effective ground cover through early planting of good quality seeds at recommended spacing, multiple cropping, strip cropping and a bit of agroforestry.

3.1.1.1 Cropping systems

Crop selection influences soil fertility and physical properties. Soil-building crops add nutrients to the soil. Legumes are notable for adding nitrogen. When a crop is mainly grown for seed and most of its biomass is retained in the field, the crop can be considered to be a soil maintaining crop. Soil depleting crops are those which remove a great quantity of nutrients from the soil, and most of the crop residue is removed. Maize and vegetables are considered to fall into this category especially where the stover is used as livestock feed. In most farms there is a mixture of soil building and soil depleting crops.

Multiple cropping has the following advantages:

- increased land use intensity;
- reduced risk by diversification;
- improved vegetative cover through space and time; and
- increased water and nutrient use efficiency (Fahlen, 1988).

The following types of multiple cropping are practised in Machakos District in varying degrees:

- sequential cropping;
- intercropping; and
- relay cropping.

In sequential cropping systems, the farmers plant two crops per year in sequence on the same area. This is facilitated by the bimodal rainfall pattern.

In intercropping systems, two or more crops are grown simultaneously on the same area. Intercropping of maize and pulses is widely practised in the District. Beans intercropped with maize will establish a 50% cover earlier than a maize monoculture.

Relay cropping is planting a succeeding crop before the first crop has been harvested. In most parts of Machakos District, maize planted in November may not be ready for harvest at the start of the March-April rainy season. Therefore, farmers prepare the land and plant the March-April crop before harvesting the November crop, thereby increasing ground cover at the start of the March-April rainy season.

Rotation is the management of the order and composition in which crops are grown. It influences soil fertility, soil erosion and runoff. Rotation is not practised extensively in Machakos District. Some farmers rotate maize and pulses with cotton. Cotton has deeper and more vigorous roots which improve the soil physical properties.

3.1.1.2 Agroforestry

The direct uses of trees in cropland are: (1) increased availability of soil cover material by pruning and litter; (2) partially permeable hedgerow barriers that reduce runoff losses and facilitate progressive development of terraces through soil accumulation; and (3) increased erosion resistance. Supplementary uses include the stabilization of earthen conservation structures and making productive use of land occupied by conservation works (Young, 1989).

Traditional agroforestry, mainly in the form of incomplete bush clearing on crop and grazing land, has been practised by Akamba people since the beginning of cultivation.

Agroforestry was promoted through the reconditioning exercise of the late 1930s (Peberdy, 1958).

Agroforestry took new dimensions with the establishment of the International Council for Research in Agroforestry (ICRAF) based in Kenya. In 1983, ICRAF conducted a study to determine the potential role of agroforestry in Machakos District. Following this study, on-farm and on-station research on dryland agro-forestry was initiated to address the problems of soil erosion and loss of soil fertility. Alley cropping emerged with potential for conserving soil moisture, reducing soil loss, enhancing soil fertility and improving the supply of fuelwood. Studies indicated that alley cropping has a high initial investment and reduces yield in the early years. These are compensated for after a few years by lower inputs and higher yields (Young, 1989).

In 1984, MIDP and the Ministry of Agriculture and Livestock Development (MALD) were involved in a joint agroforestry project with ICRAF and the NDRS, Katumani, with on-farm trials at Kakuyuni catchment. ICRAF and the Kenya Forestry Research Institute (KEFRI) continue research in dryland agroforestry in their stations based near Katumani supplemented by on-farm trials. KEFRI established on-farm grazing-land rehabilitation plots using various agroforestry techniques. The project provided seedlings and technical inputs while the local community groups provided the labour input. The dramatic results of site recovery during the trials convinced several farmers to adopt the technique for rehabilitating their degraded grazing land (Rocheleau et al. 1988).

3.1.2 Soil management

Soil management is here used to mean all soil modification techniques used to improve the soils ability to support sustainable crop production. The main soil properties that influence erosion are the infiltration rate of the soil and the resistance of soil to dispersion and erosion.

3.1.2.1 Soil fertility

Decline in soil fertility was identified as the main technical problem confronting the DoA in 1932. The Department embarked on a campaign to demonstrate, by its model small holding, the advantages derived from mixed farming and by propaganda, the importance of farm yard manure, rotation, use of compost and planting of old farms with grass rather than allowing reversion through the cycle of weeds to a poor quality bush (DoA, 1932). To increase the supply of manure, night enclosure of livestock was advocated (DoA, 1940). In 1946, the agricultural officer reported that there was widespread use of *boma* manure in northern locations and in almost every field in Kangundo and Matungulu location (DoA, 1946). In 1956, it was estimated that over 70% of the farmers in high potential areas were using manure, though only 2% in semi-arid areas (DoA, 1956).

3.1.2.2 Appropriate land use

By the 1930s, efforts to encourage appropriate land use had been started. By 1938, farmers were encouraged to cultivate the relatively flat parts of their land, and contour lines of live wash stops were made at 3 feet (1 m) vertical interval. Owners of uneconomic small parcels of land were persuaded to sell out to their neighbours and apply for holdings in the Makueni area. Cultivation of valley bottoms, where storm water discharges, was prevented and such areas were demarcated and planted with Star grass. Cultivation was prohibited within 10 yards (approximately 9 m) of the banks of the rivers and gullies (DoA, 1938).

A farm survey and planning team organised 12 holdings in 1958 (DoA, 1958), and also operated in the District in the early 1970s. By the early 1980s a rough land capability map and a set of recommendations for the use and conservation of different kinds of land had been developed for Machakos District, and provides a simple guide for conservation farming (Wenner, 1981; Jaetzold and Schmidt, 1983). Currently, this service is provided by the Farm Management Officers in conjunction with the Soil and Water Conservation Officers.

3.1.2.3 Crop residue management

Use of plant residue or other material to provide a protective soil cover against splash erosion and improve infiltration and water holding characteristics and fertility status of the soil has been practised for a long time. Under shifting cultivation the crop residue was left to decompose in the field. Even today one still sees a fair amount of stubble left in the field. Plant residue increases the organic matter of the soil thereby improving soil aggregate stability, water holding capacity and microbial activities. Mulching was introduced and practised mainly in the coffee farms. It continues to be used for high value crops (coffee and horticulture).

The Government started to encourage the Akamba to lay all waste from their farms in contour lines in the 1940s. While the response was good, grazing and termite destruction reduced the effectiveness of crop residues in controlling soil and water loss. The farmers interviewed reported that this technique is losing prominence due to:

1. shortages of residue as it is mainly used as dry season livestock feed;
2. problems of pests and diseases (especially stalk borer); and
3. lack of implements which can cultivate and plant through the crop residue.

3.1.2.4 Contour farming and buffer strips

Contour farming implies performing most of the cultural practices (ploughing, weeding, planting, etc) along the contour. The resulting micro-relief is one that creates improved detention storage and impedes runoff. Contour farming was introduced as part of the better farming technique in the 1940s and has been used in some parts of the District with oxen and has resulted in improved yields. Most of the farmers visited reported that they have been practising contour farming since the 1960s. This practice is difficult to implement when the farmer is using the hoe on steep slopes.

Vegetation wash stops (trash lines, grass strips on cropped land and sisal and bush hedges along farm boundaries) have been effectively used to control soil and water loss. This is accomplished by slowing down runoff (increasing detention storage, infiltration and distributing flow). Slowing of the runoff results in the deposition of sediments, leading to gradual build up of the ridge. No evidence of such practices was seen by Maher in 1937. The use of trash lines has decreased recently due to the increased use of crop residues for feeding livestock, and increased risk of stalk borer when maize stalks are used. We were impressed by Mr Kimongo's efforts to control soil loss. A trash line may reduce the width of the terrace by dividing it into two. Trash lines (sorghum stems) laid out during the rains of November 1989 had trapped about 20cm on the upper side by August 1990 and were approximately 60cm wide. Grass was already establishing on them.

Zero-grazing encourages the use of grass strips in crop land for the joint purpose of controlling soil and water loss and producing fodder. Grass strips have also been effectively used to start the formation of terraces.

Sisal and bush hedges are in widespread use in the district. Fencing of individually owned land was encouraged in the 1930s so that controlled grazing could be facilitated (DoA, 1939). Free sisal suckers were issued. The subsequent growth of the sisal industry provided additional impetus for widespread adoption of sisal hedges.

3.1.2.5 Conservation tillage

Traditional and conservation tillage are practised in Machakos District. Conservation tillage encompasses a large number of tillage techniques used to reduce soil and water loss and energy input and to increase timeliness of operation and the effectiveness of weed control (Marimi, 1977; Muchiri and Gichuki, 1982).

Most farmers use oxen for ploughing, planting and weeding of maize and beans. The operations are done along the contour as much as possible. During ploughing, which is carried out either after harvest or at the onset of the rains, furrows and ridges are formed and seeds planted in the furrows. During weeding ridges are formed in between crop rows. This ridge and furrow system collects rain water and increases infiltration time, thereby minimizing runoff and increasing the available water. On well ridged crop land, runoff does not occur (Muchiri and Gichuki, 1982). In places where ridges are likely to be overtopped by runoff, tied ridges have been employed to reduce the risk of erosion. Tied ridging is however not popular, partly due to its high labour requirement.

3.1.3 Conservation structures

3.1.3.1 Cutoff drains and infiltration ditches

Cutoff drains have always been considered as an integral part of soil and water conservation. They are used to divert excess runoff and either convey it to a waterway for safe disposal or encourage infiltration through increased detention time (infiltration ditches). The size of the channel depends on the quantity of water to be discharged. The soil is thrown downhill to increase the size of the channel thereby minimizing overtopping damage. The channel should be vegetated (possibly with Star or Kikuyu grass) and the embankment can be planted with fodder grass and/or trees. Cut off drains were observed on farms in Mbooni in 1937 (Maher, 1937:18).

The farmers give the following reasons for poor adoption of cutoff drains in the early days:

1. high labour requirements;
2. taking land out of production; and
3. high maintenance cost of de-silting.

Initially, cutoff drains were seen as runoff control structures. However, planting bananas in pits in such drains was started by some farmers in Masii about 1948 (Kenya National Archives: DC/MKS/8/5) and was encouraged by government soil conservation teams (see ALUS, 1953). With diminishing cultivated land per capita, farmers made more use of the cutoff drain for banana production and other tree crops. With time they realized that the benefits far outweigh the costs. The communal approach and government assistance in construction of cutoff drains provided additional impetus for widespread adoption.

3.1.3.2 Terraces

A terrace is an embankment or ridge of earth constructed across a slope to control runoff and minimize soil erosion by modifying slope length and degree. Terraces can only be justified on crop land where other less expensive conservation measures are insufficient, and should always be used in combination with appropriate soil and crop management practices.

The two major types of terraces used in the District are narrow based terraces, mainly used to remove or contain water, and bench terraces, which reduce the land slope.

Narrow based terraces have a base width of 1-2.5m and can be further classified as channel and ridge type (Figure 2). The channel type is constructed by digging a trench and throwing the soil downslope to form a ridge. There is no modification of ground slope and the channel can either be graded (to convey runoff at safe velocity to the outlet) or level for water retention in the field. Graded channel terraces are recommended where controlled removal of water is of importance. A graded channel terrace is very similar in function and construction to the cutoff drains. However, it carries less water than a cutoff drain and is therefore much smaller. Level channels are used where the soil has a high permeability and where there is no outlet. The ridge type is recommended where the primary objective is to intercept and retain the runoff. The ridge is therefore the most important feature and is formed using soil from both sides. The main drawback of narrow base terraces is that the ridge cannot be cultivated and the channel is prone to siltation. It is therefore unpopular with many farmers.

Bench terrace systems consist of a series of embankments that convert steeply sloping ground to a mild forward or backward sloping or level area (See Figure 3). Bench terraces are used where the soil has a sufficient depth to allow earth movement during the construction.

Forward sloping bench terraces are formed by providing a bank of sufficient height to reduce the slope of the cultivated land. The popular *fanya juu* method, throwing the soil uphill, gradually leads to the formation of a forward sloping bench terrace. Forward sloping terraces are only a partial solution since erosion in between the embankments is likely to occur. A terrace lip is required to pond the water thereby increasing the water retained, reducing the amount of water that would pass over the edge and erode the bank. The forward sloping terrace may have a channel on the lower side of the embarkment to contain any runoff that may over-top the terrace lip.

Runoff from a backward sloping terraces accumulates at the rear of the bench, thereby eliminating runoff from the terraced area completely. It is recommended in areas with deep soil with a high permeability and where moisture conservation rather than water removal is of primary importance. The backward slopes formed are very gentle to reduce any inter-terrace soil movement.

Level bench terraces have an almost level cultivated area. A terrace lip is required to contain any ponded water.

Terrace embankments are generally protected with grass. The common grass is *panicum maximum* in the low rainfall area, *makarikariensis* in medium areas and Napier grasses in the hill masses. Grass planted on the terrace ridge serves the following purposes:

1. the roots act as a soil stabilizing network to protect the embankment from being demolished;
2. the stalk and leaves build up a dense protective cover on the surface which filters transported sediments and decreases overland flow velocity; and
3. it acts as a source of fodder.

Napier grass (*Pennisetum purpureum*) is well suited to humid and sub-humid areas and has high yield potential and good fodder quality as well as being an effective soil barrier. This was clearly demonstrated when, in 1934, small farms in Kiteta location were measured out in a number of villages for planting Napier grasses and 1500 bundles of grass was supplied to the farmers (DoA, 1934).

Figure 2: **Narrow based terraces**

(Upper = ridge type Lower = channel type)

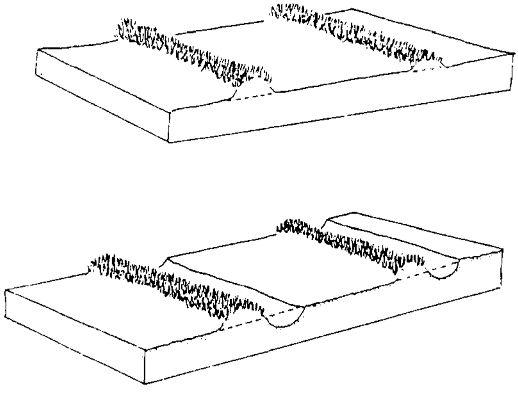
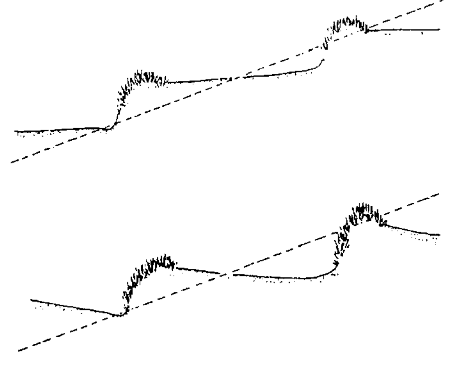


Figure 3: **Bench terraces**

(Upper = forward sloping Middle = level Lower = backward sloping)



Historical development. In 1937, Barnes and Maher saw preliminary pegging out of terrace lines in Muisuni and Iveti (Barnes, 1937:41; Maher, 1937:17), both supervised by Mr Hobbs, the Agricultural Officer. Barnes also photographed trash lines near the Mission at Muisuni and observed that they had not been contoured correctly so would not provide a starting point for terraces. The origin of the *fanya juu* technique is of some interest:

> *The first series of 'fanya juu' were made in 1937 in a Machakos area but owing to the bank or burm not being kept up or maintained at the top of the step, they have not progressed into becoming true benches and in fact to some extent simply continue to erode on the slope and are very little flatter than when made twenty three years ago. In the revival of this system in the Central Province the maintenance of the bank has been rightly insisted on and has been very successful. It is emphasised that heavy manuring must be given on the back section of the benches to bring up fertility as cultivation moves the soil forward* (Barnes, 1960:63).

This was confirmed by J. Mwilu of Tala (personal communication). According to a local witness (Mr Mutunga) the first site was bare. The terraces were constructed between widely spaced cutoff drains, of which no signs remained in 1990. The terraces have since developed into level benches with embankments 1.2 - 1.5m high and a small lip at the top, planted with grass.

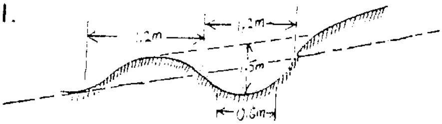
Narrow based terraces were introduced in Kenya following Maher's visit to the USA in 1940. Maher (1940), the senior soil conservation engineer, recommended the use of shallow narrow based terraces in the African Reserves due to the shortage of tools and the high labour requirements of the other types of terraces. This policy prevailed for fifteen years. The types of terraces that were being used on arable land in 1948 were as shown in Figure 4. Type 1 (shallow narrow-based) was recommended for African farms while types 2 (narrow-based) and 3 (broad-based) were for European farms. Type 4 (bench) was to be used for growing high-value crops such as tea, coffee and vegetables on steep slopes, because of its high labour requirement.

According to data published by Throup (1987:80), the miles of narrow based terraces constructed increased from 587 in 1945 to 1,995 in 1947, protecting (in the latter year) over 4,000 ha. By 1955, approximately 4,000 ha per year were protected by narrow based terraces constructed by communal labour and 1,200 ha by mechanised units. By 1956, there was a reduction in the amount of narrow based terracing done and a compensating increase in the amount of bench terracing. In 1958 the construction of narrow based terraces fell sharply, with the number falling into disrepair exceeding new construction. A considerable part of this retrogression was caused by lack of proper maintenance (de Wilde 1967).

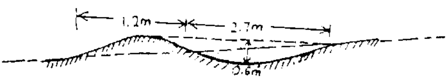
The shift from narrow based (*fanya chini*) to bench (*fanya juu*) terrace construction reflected a long-standing controversy in the Department of Agriculture between Maher, the initiator of narrow based terracing schemes, and the proponents of alternative methods (Throup, 1987:142-3). Narrow based terracing schemes were

Figure 4: **Types of terraces used in the 1940s**

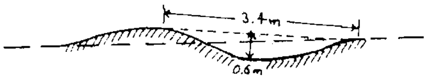
1.



2.



3.



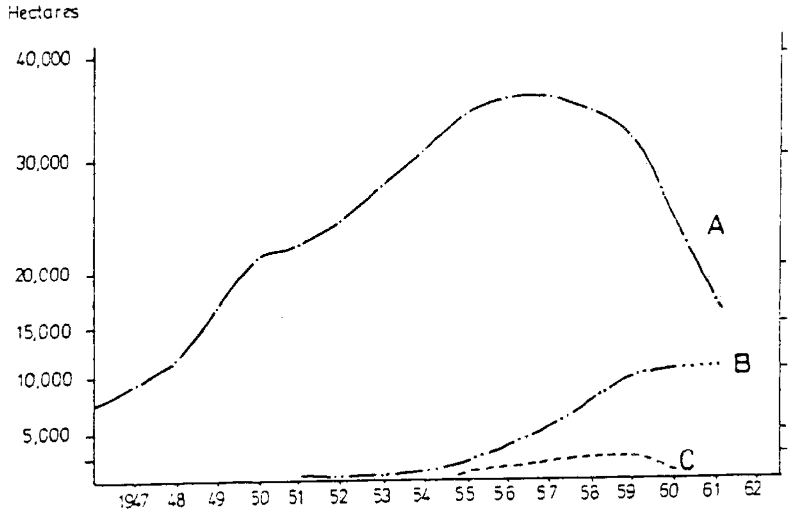
4.

	Cross-section (m^2)	Slope (°)
1.	0.3 - 0.4	16
2.	0.7 - 0.8	8 - 12
3.	0.9 - 1.1	0 - 8
4.	variable	up to 25

Source: Kenya National Archives (DC/MKS/8/5 Reconditioning).

imposed on a number of smallholdings irrespective of their owners' wishes, removing a significant percentage of the land from cultivation and using compulsory communal labour which was unpopular. Data presented by Peberdy (1961) show that the transition from narrow based terraces to bench terraces occurred between 1956 and 1960 (Figure 5). The cumulative total is arrived at after deducting those that had fallen into disrepair.

Figure 5: **Terrace construction, 1946-62 (after Peberdy, 1961)**



A: Shambas adequately conserved by narrow based terraces
B: Shambas bench terraced
C: Benching effort

After 1959, all terracing effort went into a decline during the run up to independence as *mwethya* labour could not be mobilised. By 1961, the total area conserved by both types of terrace was 27,000ha, compared with a peak of 42,000ha in 1958, out of a cultivated area of about 110,000ha. In the short rains of 1961, much damage was done by abnormally heavy rainfall. In the revival of terrace construction that subsequently occurred, the scale of operation was the individual farm (even when *mwethya* labour was used), in contrast to the schemes imposed on a whole ridge or group of farms under Maher's direction.

By the mid-1960s most farmers had appreciated the need for soil conservation and it was easy to convince them to change to bench terraces because the *fanya chini* method had problems of silting and breakage (especially after heavy rains) and was seen to be accelerating erosion, by throwing the soil downslope. Also, *fanya juu* facilitates the utilization of terrace risers and embankments for production of fodder and trees. The danger of using the *fanya juu* method is that ridges constructed using loose soil fail easily, if heavy runoff takes place before grass planting and consolidation has occurred. By 1977, *fanya juu* had become the most popular method of developing bench terraces despite its high labour requirement. Other methods used for developing forward sloping bench terraces include leaving unploughed strips of land, grass strips, trash lines and stone lines.

3.1.3.3 Water harvesting

Water harvesting for crop production aims at providing supplemental water by intercepting surface runoff (runoff harvesting) or by diverting seasonal flood water onto low-lying arable land (water spreading). Runoff harvesting systems include a runoff area (mainly non-cropped upland) and a runoff collecting area where crops are grown. The main forms of runoff harvesting techniques practised in Machakos District are bench terraces, contour bunds, micro basins, pasture furrows and range pitting.

3.1.3.4 Waterways

Waterways are constructed to drain away excess runoff safely to the natural waterway. In most, excess water is discharged into natural depressions such as footpaths, cattle tracks or along the farm boundaries. The resulting waterways, therefore, do not have an adequate conveyance capacity and are not well maintained. Some such waterways have led to the formation of deep gullies.

3.2 Grazing Land

The main problem on grazing land is inadequate vegetative cover. This is particularly true during the July-October dry season and following seasons of below average rainfall. Attempts to control erosion on grazing land aim at improving grass cover throughout the year and the productivity of the grass.

Most of the work of the Reconditioning Committees (see above) was aimed at rehabilitating denuded grazing land. Beginning in 1935-36, 'stagger trenching' and closure to grazing were the main methods used. Recovery could take more than five years on badly denuded land (Barnes, 1937; Maher,1937).

Controlled grazing, the adoption of rotational systems of pasture with crops, with the protection of cultivated land were considered the prerequisites of sustainable development in 1938 (DoA, 1938). Wholesale destocking of the Reserve was advocated by Maher (1937) and Barnes (1937) and attempted unsuccessfully in 1938, creating a breakdown in confidence in the Government.

Since some of the land was individually owned, fencing the outer boundaries and giving the individual responsibility for controlled grazing on his own holding, was a workable first step. To facilitate fencing, free sisal suckers were issued. Communal grazing areas were put under the control of headmen, and a system of rotational grazing together with stock limitation introduced.

From 1949 until 1957 the Department of Agriculture carried out experiments on grassland rehabilitation at Makaveti. This land (150 acres) was loaned to the Department by its owners, in a condition described as badly overgrazed and eroded (Pereira and Beckley, 1952). It was fenced and protected, and 32 one-acre plots were sown or planted with *Chloris gayana* (Rhodes grass) *Cenchrus ciliaris* (African Foxtail grass), *Cynodon dactylon* (star grass) and *Panicum coloratum* var. *Makarikariensis* under ploughing, ridging , and manuring treatments. Notwithstanding two drought years (1949 and 1950), by the short rains of 1950 grazing could be recommenced and effective grass cover had been achieved. This work demonstrated that irrevocable loss of soil fertility had not occurred, and that temporary closure and intensive management could restore a grassland visibly more productive than that outside the project fence.

After 10 years, *Cenchrus* had established itself as the most productive and drought-resistant grass, and the local grasses growing on protected land were second to it. It was concluded that the natural grasses, without cultivation, seeding or fertilizing, could support one 550 lb beast on 4 acres (1.6 ha/TLU) throughout the year provided that half the area was closed for haymaking for two months.

Using the intensive methods, one beast could be supported on two acres (0.8 ha/TLU), according to the Land Development Board (ALDEV, 1958:13). At a high stocking rate, using local cattle, the weight gain per acre obtained under ranch conditions could be doubled, though at only half the rate of weight gain per animal.

In fact, four acres/beast was approximately the density of cattle in the Reserve as a whole (Pereira and Beckley, 1952). But goats and sheep were an extra burden on the grazing, and 20% of the land was estimated to be unproductive steep slopes, rocks or gullies. On the other hand, Wakamba owners also fed crop residues to their animals. Neither the fertility nor the structure of the soil benefitted significantly from the ten-year grass ley, however.

It is not known how much of an impact these experiments made on local grazing management. They were not costed, but the returns per acre from animal production on the restored grassland were less than half those of crop production (Pereira et al, 1961). They may not have been an economic management option for smallholders. Until recently, little land management effort has been directed at grazing land, whereas conservation investments have spread to almost all cropland in the District.

In 1953, stall feeding was actively encouraged by the African Development Council. Ninety-two new cattle sheds were built and the manure from these sheds was highly appreciated by a large number of farmers in Kangundo area (DoA, 1953). In 1960, about 52 farmers in the district planted silage crops in anticipation of obtaining Sahiwal and grade cattle in 1961 (DoA, 1960). However, grade cattle were not successful till the 1980s (see Production Profile). With diminishing land available for new settlement, some farmers have resorted to pasture improvement, tethering, stall feeding, reduction of livestock numbers and rearing improved breeds (especially cattle). Conservation structures may be seen in abandoned cropland now under grazing and some structures (cutoffs, pits, terraces, ridges) have been constructed to improve the soil surface storage of rainfall.

3.3 Other Lands

3.3.1 Gully control

Barnes (1937) described gullies in Matungulu, and prescribed methods of controlling them by revegetation (masonry being considered too costly except where unavoidable). But there is no record of any practical attempts to control gullies before then.

Early efforts to control gully erosion were by cutoff drains and sisal hedges to prevent further eating back and widening. Today one sees a wide array of gully control activities. The head of the gully is protected by brushwood, stones or gabions. The floor of the gully is protected by wide and shallow checks facilitated by vegetation strips and/or stones or narrow and steep check dams (wooden, stone or gabions). The sides of the gullies, especially around bends, are protected by vegetation, wooden materials and gabions.

3.3.2 Riverbank protection

Cultivation along the banks of rivers, streams and gullies was discouraged in the 1930s (DoA, 1937). Cultivation of valley bottoms, where storm water discharged, was prevented and such areas were demarcated and planted with star grass. Cultivation was prohibited within 10 yards (9 metres) of the banks of the rivers and gullies (DoA, 1938).

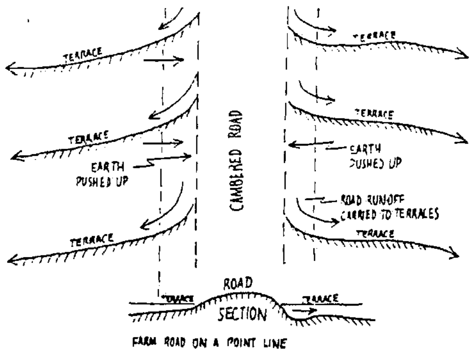
After independence, there was encroachment of farming along the river banks. In mid-1980, the Government instituted river bank pegging to demarcate areas prohibited for cultivation. In 1989, the Government established posts for River Scouts to advise farmers on river bank utilization. The farmers are allowed to grow perennials such as arrowroot (for leaf not tuber production), Napier grass, wild castor, and bananas.

The booming construction business, in the District and in Nairobi, has a major influence on river water resources and soil erosion. Many tons of sand are harvested from the river banks and transported to building sites. The increase in County Council fees per truckload of sand, and a restriction on the amount of sand that can be harvested from a given river reach, have ameliorated the situation.

3.3.3 Road side drainage

To reduce erosion damage caused by roadside drainage, Barnes (1956) proposed roadside drainage water disposal (Figure 6) for farm roads and main and community roads. Today, this system is used to harvest roadside runoff in the drier area. This runoff is in some cases directed into infiltration ditches. Disposal of roadside runoff remains a major problem owing to the unavailability of convenient waterways and the poor construction and maintenance of road drains.

Figure 6: **Terraces and roads interaction**



Source: Barnes (1956).

3.3.4 Forest land

Agro-forestry and afforestation practices aimed at controlling soil and water loss in the District were initiated in the 1930s. In 1934, a fodder tree arboretum was established at the Veterinary Quarantine Station, Machakos (DoA, 1935). In 1981 over 116,000 forest trees and over 5,000 fodder trees were planted in the 37 catchments throughout the District as part of the MIDP catchment rehabilitation programme (DAO, 1981). Currently, the Ministry of Environment and Natural Resources has established a rural forestry branch whose main responsibility is to promote tree growing at the farm level. This effort is complemented by other organisations.

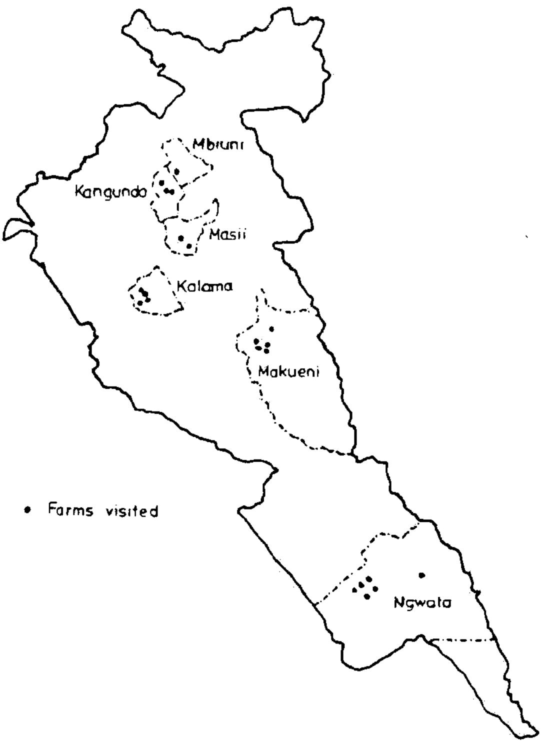
4. CURRENT ASSESSMENT

4.1 Methodology

A quick survey was undertaken between August and December of 1990 to improve our understanding of the different physical, biological and socio-economic components of the farming and soil and water conservation systems, the interactions between then, the changes which have been induced by man and climate and to obtain some idea of how rapidly changes are taking place.

Road traverses and footpath traverses were made in order to assess degradation and conservation practices. The routes were planned so as to give a balanced picture. Approximate locations of the area visited are shown in Figure 7.

Figure 7: **Locations of farms visited**



Interviews were undertaken at two levels:

1. *Key informants' interviews*
   Key informants were chosen from a list of persons with a wealth of information on agriculture in general and soil conservation in particular. They included retired agricultural extension staff and administrators.

2. *General farmers' interviews*
   Selection was done at random but based on the diversity of factors. For each study site, attempts were made to obtain information from a wide cross-section of informants falling into the categories, young and old, resource rich and resource poor, farming well and poorly, male and female, poorly and well educated, and those

cultivating steep and flat lands. Selection of the footpath transects was done after consultation with the staff of the Divisional Agricultural Office so as to arrive at the most optimal route which would expose us to varying terrain and at the same time enable us to interview farmers in the above categories.

A semi-structured interviewing approach was used to fill questionnaires. In order to encourage a free exchange of information and ideas, questions were not put exactly as written, or in the order they appear in the questionnaires, but were selected as necessary based on the discussion. Some cross-questioning and counter checking was made to ensure that the data collected was consistent and reliable.

After interviewing farmers, we requested permission to evaluate on-farm conservation efforts. Clinometers, tape measures, soil augers, lists of trees, shrubs and grasses with local and botanical names were used to collect evaluation data. The adequacy of terraces was assessed on the following criteria:

1. Design flaws such as appropriateness of the structure chosen, spacing, embankment height and slope;
2. Construction flaws such as layout, stability of embankment, height of the lip, breakages, bank stabilizing measures;
3. Maintenance condition of the lip and embankment.

4.2 Current Status

To understand soil and water conservation it is necessary to relate it to the farming system. Figure 8 shows the calendar of activities in a soil and water conservation system. The period of peak erosion coincides with the highest labour demand. At this time it is not feasible for the farmer to divert any of his labour into conservation; hence the need for agronomic measures. The discussion that follows highlights current status of soil and water conservation.

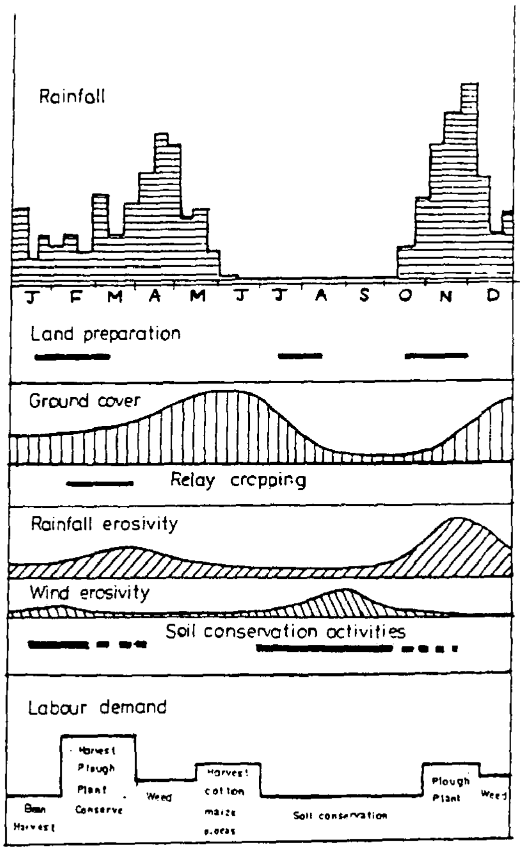
4.2.1 Cropland

Soil and water conservation in cropland is fairly satisfactory in most areas. Where terraces are well constructed and maintained there is some soil movement within the terraces but not from one terrace to the other. Agronomic measures and tillage techniques have reduced the amount of soil movement within the terraces.

4.2.1.1 Cultivation of steep slopes

A study conducted by Thomas (Mbithi et al., 1977) around Wamunyu, Masii, Kalama, Kilungu and Mukaa reported that in the hilly areas over 1600m, 35% and 43% of the farms had slopes of 16-34% and >34% respectively. We observed an increase of cultivation on steep slopes in Kalama, Kangundo and Masii areas in 1990. This is attributable to the fact that climate is more favourable in high areas leading to a higher population density. Despite the fact that the present legal limit for

Figure 8: **Calendar of activities**



cultivation is a 35% slope, the number of farmers cultivating land steeper than the legal limit has increased, thereby posing the following questions.

1. Should such cultivation be legalised?
2. Are conservation practices, developed for slopes less than 34%, appropriate for steeper land?

Observations from the top of Kalama Hill and along the roads we followed indicated that most of the cultivated steep land was terraced. Some abandoned terraced land was being used for grazing.

4.2.1.2 Crop management

There is considerable interest in improving crop production especially among those with a substantial off-farm income. Most of the investment in improved crop management is in high value horticulture (pawpaw, mangoes, oranges, tomatoes, kale and cabbages). Coffee is also being introduced in some marginal areas. The main crops and crop mixes have not changed much over the years. Maize, beans, cowpeas and pigeon peas are still dominant. Other crops include sweet potatoes, Irish potatoes, coffee and sugar cane at higher attitudes and cassava, sorghum, cotton and sunflower at lower attitudes.

The farmers interviewed reported an increase in the area occupied by perennial crops, mainly fruit trees, fodder in both medium and low potential areas, coffee in medium potential areas and cassava in low potential areas. Since most of the area is planted to two crops per year, the land is generally bare and exposed to erosive rainfall during the critical rainy months of April and November before annual crops have grown sufficiently to produce effective cover. Perennial and long season crops (pigeon peas), and to some extent relay cropping and early planting, have ameliorated the situation. Crop residue has been effectively used to reduce splash erosion and encourage the formation of terraces on some farms, where competition for animal feed and firewood, and termite damage, are small. The residue is scattered around the farm or collected and piled in a trash line. In situ moisture conservation in the semi-arid areas is facilitated by loosening the soil before the rains, mulching, contour farming, ridging and conservation tillage.

4.2.1.3 Terraces

There are many different types of terraces in the district. Based on this limited survey of 60 terraces, and the work done by Muya (1990), the main types are presented in Table 8. Most of the narrow based channel terraces were found on shallow soils with slopes of 5 - 20%. These terraces showed signs of silting and in some cases signs of overtopping. Some embankments were protected using sown grass, but most of them by sparsely populated self sown grasses and weeds. The farmers using these terraces expressed their interest to change to *fanya juu.*

There exist many variations of the *fanya juu* structure and the utilization of land around it. The options include grassed or non-grassed embankment, channel on lower side, banana and other fruit tree pits on lower side. The trench on the lower side is to trap excess runoff if there is a break in the embankment.

Embankment protection is identified by farmers as the main maintenance requirement. The common practice is to build up the embankment to ensure that there is sufficient runoff storage to reduce the risk of overtopping. The condition of terrace embankments varies, but most of them are in fair condition.

Mr Karoi, a farmer near Kambu, is a strong advocate of terracing. He has well constructed and maintained terraces. Bank heights are 0.5-1.0m, bank width about 1m and lip, 10-15 cm. The embankments are stabilized using Makarikari grass.

Mr Musyoki, a farmer near Muthuwani Primary School in Mbiuni, has constructed and maintained impressive terraces. The terrace banks were stabilized by beating them when wet to compact the soil. They have become very hard like sun-dried bricks and are very stable. The bank height is about 1.2m and the bank angle is about 75°. There is a sufficient lip to prevent overtopping.

The effectiveness of terraces in controlling soil and runoff loss is dependent on the design, construction and maintenance. Most are effective for controlling soil movement and runoff into the lower terrace. The area around the terraces is used productively to grow fodder, fruit trees and fuelwood.

In a few areas the results are disappointing. For example a survey of the effectiveness of soil conservation measures in Machakos District revealed that some forward sloping terraces were poorly constructed and inadequately maintained (Thomas, 1978; Mbote, 1978). Inspection of an area near Mavindini, which showed signs of rilling on the 1978 aerial photos, revealed that most of those rills are still conspicuous.

Maintenance of conservation structures still remains a major problem, as aerial photos and ground observations show rills in terraced land, particularly the lower benches. Only well-off farmers using hired labour have an effective maintenance programme, coupled with high value cropping (mangoes, citrus, pawpaws, vegetables, etc).

4.2.1.4 Cutoff drains and infiltration ditches

In a study conducted in Machakos District on the manual terracing programme, it was reported that 58% of the cut-off drains assessed were inadequate due to: poor alignment (17%), bank too low (7%), channel silted up (43%) and channel overgrown with bush and weeds (10%) (Thomas, 1977). Approximately 48% of the cut-off drains discharged into a grassed area, 31% into bare ground and 14% into stock tracks or foot paths. Field observation in 1990, revealed that in 1990 some of the cutoff drains are inadequate to handle large storms. The farmers also reported that they sometimes overflow. Poor design, construction and maintenance are blamed. Poorly laid and/or maintained cutoff drains lead to gully erosion as a result of poor outlet conditions, low spots within the drain and blockage.

Channel silting was observed in some cutoff drains. Cropping in the trenches, although beneficial, seems to reduce the design conveyance and storage capacity of the terrace, thereby leaving it highly susceptible to overflowing through the low and weak spots.

4.2.1.5 Soil fertility

The farmers report that for the last 10 years there has been an increase in the use of farmyard manure. This was promoted by the increased understanding of the role of manure in increasing crop production and reducing soil loss, the high cost of fertilizer, an increase in the availability of manure as a result of zero-grazing and stall feeding and night enclosure of livestock.

4.2.2 Grazing land

Conservation in grazing land was observed to be poorer than on crop land. The reasons given for the low level of conservation of grazing land are:

1. **Drought**: The farmers reported that during the dry season the grass dries and becomes loose so that the animals uproot it. Frequent drought combined with overgrazing results in a decrease in perennial grasses and an increase in unpalatable species, thereby reducing the productivity of the grazing land.
2. **Decreasing grazing land**: While it is true that the number of livestock has decreased on many holdings, grazing land has also decreased as more land is put into crop production. This has tended to increase the grazing pressure.
3. **Termite activities** during the dry season can be very devastating. Farmers reported that termites devour most of the dry fallen vegetation, thereby reducing dry season grazing for livestock.
4. **Overgrazing** around water points. In some cases these spots were completely denuded.

Some of the grazing land has some *fanya chini* terraces and pits installed to trap runoff and encourage revegetation. Use of *fanya chini* terraces alone is a step in the right direction, but does not lead to a quick restoration of cover between terraces.

Most farmers interviewed reported that the numbers of livestock they keep have reduced. This has been brought about by restricted grazing, increased demand for cash (leading to sale of some livestock) and a change of priority from quantity to quality. In the absence of communal grazing land, and decreasing farm sizes (as a result of subdivision), most farmers have restricted livestock numbers to what their land can support. Tethering is widely practised. Farm boundaries are respected and there is no significant grazing encroachment from the neighbours.

4.2.3 Other lands

There is evidence that most of the old gullies are relatively stable. Some of the gullies around Kyangala are about 12m deep with steep side slopes and have claimed the lives of several people who fell into them. Minor wearing away of the gully head scarps was also noticed. Farmers are utilizing the gully bottoms for the production of trees and fodder crops. Others have planted sisal and trees to prevent further lateral spread. The following general observations can be made:

1. Gully reclamation efforts have slowed the rate of gully development. Some gullies have vegetation growing on the sides and on the floor.
2. Gabion structures placed in gullies have not been very successful due to overturning, bypassing and/or undercutting.

3. Roadside drainage still continues to be a major problem. Some farmers utilize this water by diverting it into retention ditches and banana pits in their farms.

4.3 Economics of Conservation

An economic analysis of soil and water conservation projects is complicated by our inability to adequately quantify the costs and benefits involved. But according to Lindgren (1988), soil and water conservation activities can be justified at both project and farm level, and a 59% internal rate of return is reported on SIDA-funded conservation investments.

4.3.1 Project level

Major direct and indirect inputs into the Machakos District soil and water conservation programmes can be classified as facilitating and implementing inputs. Activities are facilitated by Government and NGOs. Their costs are mainly in the form of salaries, travel and subsistence allowances and administrative expenses.

Implementing and maintaining inputs fall into two main categories:

1. communal and individual labour inputs; and
2. individually purchased, and donor- or government-purchased tools.

At the project level, the benefits can be categorised as follows:

4.3.1.1 Increased and sustained crop yields

In Kangundo and Matungulu, farmers with bench terraces report that they generally obtain higher yields than those without. This is particularly true during the dry years because of the moisture retention capacity of bench terraces. Increased crop yield is attributed to an increase in productivity per unit of land, and increased cultivated land as a result of improved land and water management. According to Lindgren (1988), terracing of land increases yield by 400 kg/ha and 77 kg/ha for maize and beans respectively.

Terrace banks, which were at one time thought of as wasted land, are the main production areas for fodder, fruits, fuelwood and timber. Farm boundaries are the main sources of sisal fibre and poles and to a limited extent, a source of firewood.

4.3.1.2 Improved water resources

1. the quality of water has increased;
2. there is reduced siltation of reservoirs;
3. there is a reduced peak flow and increased base flow in, quantity and duration; and
4. the density and yield of springs has increased.

We noted several springs which the farmers claim have emerged recently in the Kalama and Makueni areas. This phenomena may be attributed to improved rains in recent years, improved soil and water conservation and changes in land use.

4.3.1.3 Increased value of land

Farmers report that the value of well conserved land has appreciated. This is attributed to:-

1. prevention of further top soil loss making the soil available for future generations;
2. reduced degradation thereby minimizing future inputs in crop production; and
3. better crop and fodder yields.

4.3.1.4 Increased employment opportunities

Soil and water conservation activities have increased employment opportunities, directly in the employment of people to implement soil and water conservation activities, and indirectly in increased agricultural activities on well conserved land and its influence on the rural economy. As a consequence, the rural area supports a larger population today than was once thought possible.

4.3.2 Farm level

The decisions to invest in soil and water conservation activities at the farm level and the level of investment, are influenced by the perceived benefits and by the following factors, in particular:

1. **Type of land use**: Soil conservation activities are higher in areas under high value crops (coffee and horticulture) and lowest on grazing land.
2. **Off-farm income**: Farmers with a substantial off-farm income use hired labour to complement their own labour in constructing and maintaining conservation structures.
3. **Land productivity**: Farmers in AEZ 3 have in general invested more in conservation than those in AEZ 5.
4. **Period of settlement**: New settlers with a conservation tradition, and financial resources to make the land productive, adopted conservation farming in their new environment. Original settlers of the area are generally slower in adopting conservation farming.
5. **Level of degradation**: Donor rehabilitation assistance has mainly been channelled to areas in dire need for rehabilitation as evidenced by the reconditioning works in the 1930s to 1950s, and SIDA and MIDP assistance in the 1970s and 1980s.
6. **Conservation method**: Excavated bench terraces have the highest initial cost, while wash stop methods (grass strips, trash lines) have the least initial cost.

7. **Land tenure**: Improved land tenure is credited for having increased farmers' commitment to conservation and in some cases access to development credit.

4.4 Constraints

The major constraints to soil and water conservation activities are:

1. Increased subdivision, making it difficult to undertake optimal soil and water conservation layouts, enforce proper land use or obtain convenient waterways.
2. High labour requirements for construction and maintenance of terraces.
3. High levels of risk associated with crop production in a semi-arid area make it difficult for most farmers to realize the full benefits of conservation.
4. Poor availability of appropriate tools (Muchiri, 1977).
5. Competition for crop residue, labour and other inputs.
6. Design and construction problems, such as: improper spacing; terraces not laid out on the contour; and construction done during the dry season when the soil is hard, making it very laborious and resulting in a weak embankment (due to poor compaction of the soil), highly susceptible to breakage if a heavy rainstorm occurs before the establishment of a grass cover.
7. Terrace degradation, due to: insufficient cover, forward slope, steep embankment with no stabilizing material, inadequate lip causing frequent overtopping, and poor maintenance.
8. Neglect. In Masii, farmers believe that the conservation works are not taken as seriously as they were during Chief Mutinda's era, despite the high level of awareness of the benefits and incentives provided by various donor and MoA programmes. Similar views were expressed by farmers in Kalama and Makueni.

4.5 New Approaches

Hitherto, conservation efforts were aimed at the farm or community levels. A catchment approach to soil and water conservation was launched in 1987, in order to facilitate:

1. Conservation problem identification at the level of the catchment.
2. Logical planning and design of conservation measures.
3. Concentration of staff effort for greater and faster work achievement.
4. Encouragement of community involvement and participation by other ministries, departments, NGOs, etc.
5. More efficient staff deployment and productivity, through clear duty assignment, thus making them more accountable and more easy to supervise.
6. Ease in the incorporation of soil and water conservation messages into the on-going National Extension Programme (MoA, 1988).

New thinking emphasizes:

1. prevention rather than cure;
2. the loss of land and water productivity rather than the physical loss of soil and water;
3. conservation farming rather than soil and water conservation; and
4. long term support to resource conservation programmes.

5. CONCLUSIONS

5.1 Interventions

The degradation problem feared in the 1930s has been reversed. The long history of conservation interventions in the District has created a favourable environment for attaining sustainable agriculture. There has been a long term political, social, economic and technical commitment to soil and water resources conservation. The results of this commitment include an impressive increase in both the percentage of farmland terraced in some form, and the total area of terraced land (see Land Use Profile). This has resulted in an increased population supporting capacity in the District, as illustrated in Figure 9. Improved capacity of the technical staff and the community mobilization staff has provided additional impetus to the soil and water conservation activities. The society has also responded favourably to government and donor interventions.

5.2 Conservation Measures

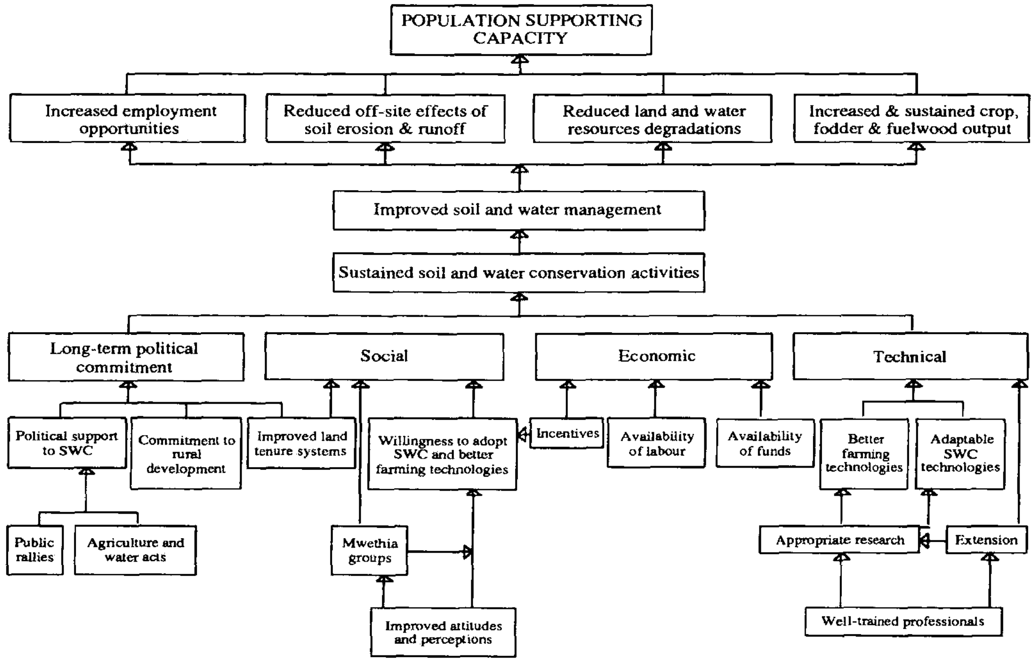
Soil and water conservation measures on crop land have been carried out more vigorously than on grazing land. Much of the grazing land is in very poor condition, especially during the dry season. Efforts to improve vegetative cover and productivity of the grazing land is still inadequate. The situation is improving slightly as a result of the reduction in livestock numbers, stall feeding and tethering.

The main conservation structures in Machakos District are *fanya juu* terraces and cutoff drains. Their widespread adoption was facilitated by food-for-work, tools-for-work, Mwethya group efforts and increased awareness of the need for soil and water conservation. Today, hired labour is extremely important.

Well designed, constructed and maintained terraces can control runoff and soil loss, but if they are poorly constructed and maintained, runoff passes from one to the next, and embankment breakage and rilling damage increase downslope.

Structural measures of soil and water conservation will continue to play an important role in controlling erosion and runoff, especially where cultivation on slopes over the legal limits is practised. Erosion and runoff control using non-structural measures is severely limited by environmental and economic factors.

Figure 9: **Factors leading to improved population supporting capacity**



5.3 Soil Moisture

Soil moisture conditions under conservationary management are under-researched. It is likely that improved soil moisture, especially during growing seasons with rainfall below average, is mainly responsible for yield superiority commonly observed on well terraced fields (see Figueiredo, 1986; Lindgren, 1988).

Farmers' perceptions of soil moisture do not seem to have been thoroughly investigated. An hypothesis worth empirical testing is that conservation measures, designed and promoted to save the soil, have succeeded in gaining acceptance because they save soil water.

5.4 Labour

Owing to the high labour requirements in constructing terraces and cutoff drains, casual hired labour and communal labour are the only ways in which soil and water conservation works can be achieved. There are very few individuals who have effectively conserved their farms using only family labour. Resource-poor farmers are more dependent on communal groups for soil and water conservation; the better off on hired labour.

5.5 Land Tenure

Improvements of land tenure status (issues of title deeds and respect for farm boundaries) has resulted in marked improvements in farmers' commitments to soil and water conservation on their land, and also to reduced grazing pressure previously experienced under communal grazing management.

5.6 Constraints

The major constraints to soil and water conservation are land subdivision; and shortage, disputes and litigation; geomorphology (site limitations); availability of tools, labour, and cash; and droughts followed by heavy rains.

5.7 Development Options

The inhabitants of high potential areas of Machakos District have three ways of coping with the population pressure, namely:

- out-migration to urban areas;
- out-migration to low potential areas; and
- sustainable development in situ.

They have had, and will continue to have, the following impact on soil and water conservation.

Out-migration to urban areas:

1. Reduced population pressure, limiting the amount of marginal land put under unsustainable cultivation and grazing.

2. Increased off-farm income, as urban migrants provide financial support to their relatives or invest in intensive agriculture in their home areas. This increases the amount of capital available for conservation farming.

3. Interaction with rural inhabitants from other parts of the country is a pragmatic mode of transfer of ideas and technology. (For example, soldiers returning from World War II).

4. Improved communication between rural and urban areas stimulating the demand for cash crops, which may avail funds for conservation.

The main disadvantage of out-migration is reduced labour availability, particularly during the peak demand season. This may slow the adoption rate of soil and water conservation technologies.

Out-migration to lower potential areas:

1. Reduced population pressure in the high potential area.

2. Transfer of conservation technology and tradition to lower potential areas.

3. Increased investment in conservation farming in low potential areas, as resource-rich farmers move in.

4. Improved communication between high and low potential areas thereby improving the transfer of ideas, technology, financial and labour resources and agricultural inputs and outputs.

The positive impact would not be realised if resource-poor farmers with no conservation tradition or willingness to adapt to the new environment were to be the main immigrants.

Sustained development in situ:

1. Continued refinement of conservation and other supporting technologies.

2. Long term commitment to sustainable agricultural development, as the farmers are convinced that they do not have anywhere else to go.

3. Adoption of more intensive agriculture which requires a higher level of resource conservation input.

4. Increased employment opportunities and increased economic activities in the area.

REFERENCES

ALDEV

ALUS, 1953; 'African Land Utilisation and Settlement Annual Report for 1952.' Mimeo with photographs from African Land Utilisation and Settlement Board.

ALDEV, 1956; *Annual Report July 1954 - June 1955.* Nairobi: African Land Development Board.

ALDEV, 1957; *Annual Report July 1955 - June 1956.* Nairobi: African Land Development Board.

ALDEV, 1958; *Report of the Land Development Board (Non-Scheduled Areas) for the financial year 1st July, 1957 to 30th June, 1958.* Nairobi: African Land Development Board.

ALDEV, 1959; *Report of the Land Development Board (Non-Scheduled Areas) for the financial year 1st July, 1958 to 30th June, 1959.* Nairobi: African Land Development Board.

ALDEV, 1960; *Report of the Land Development Board (Non-Scheduled Areas) for the financial year 1st July, 1959 to 31st December, 1960.* Nairobi: African Land Development Board.

Barnes, R.O., 1937; 'Soil erosion, Ukamba Reserve.' Memorandum, July. Kenya National Archives, Nairobi: DC/MKS/10A/29/1.

Barnes, R.O., 1956; *Field visit report.* Nairobi: Ministry of Agriculture.

Barnes, R.O., 1960; 1. Soil conservation: Lecture notes used over a period of years up to 1960. 2. Soil & water conservation: Notes for agricultural department 1960 (map, diagrams, rainfall graph). Rhodes House Library, Oxford: (Mss Brit.Emp.T1.)

DAO, 1981; 'Annual report of Machakos District Agriculture and Livestock Development Office, Animal Production Division for 1981.' Machakos: District Agricultural Office.

DAO, 1982; 'Annual report of Machakos District Agriculture and Livestock Development Office, Animal Production Division for 1982.' Nairobi: District Agricultural Office.

DAO, 1984; *Annual report of Machakos District Agriculture and Livestock Development Office, Animal Production Division for 1983.* Machakos: District Agricultural Office.

De Wilde, J.C. et al., 1967; *Experiences with agricultural development in tropical Africa*, Vol 2: *The case studies.* Baltimore, MD, USA: Johns Hopkins Press [International Bank for Reconstruction and Development].

DoA, various dates, 1927-61; *Annual report.* Nairobi: Department of Agriculture.

Ecosystems, 1981-2; *Survey of agriculture and land use - February 1981.* 4 Vols. Nairobi: Ecosystems Ltd.

Fahlen, A., 1988; 'A concise manual in soil conservation techniques and soil erosion processes in the Tropics.' Lecture notes from Uppsala, Sweden.

Figueiredo, P., 1986; *The yield of food crops on terraced and non-terraced land - a field survey of Kenya: Report from a minor research task.* Working Paper No.35. Uppsala: Swedish University of Agricultural Sciences.

Fisher, N.M., 1978; 'Cropping systems for soil conservation in Kenya.' In: *Soil and water conservation in Kenya.* Occasional paper No.27. Nairobi: Institute for Development Studies, University of Nairobi.

Jaetzold, R. and Schmidt, H., 1983; *Farm management handbook of Kenya.* Vol.2: *Natural conditions and farm management information.* Part C: *East Kenya. (Eastern and Coast Province).* Nairobi: Ministry of Agriculture.

Lindgren, B.M., 1988; *Machakos Report 1988: Economic evaluation of a soil conservation project in Machakos District, Kenya.* Nairobi: Ministry of Agriculture.

Maher, C., 1937; 'Soil erosion and land utilisation in the Ukamba Reserve (Machakos).' Report to the Department of Agriculture. Rhodes House Library, Oxford: (Mss. Afr. S.755).

Maher, C., 1940; *A visit to the USA to study soil conservation.* Nairobi: Ministry of Agriculture.

Marimi, A.P.M., 1977; 'The effects of certain tillage methods and cropping systems for conserving rainfall in a semi-arid area of Kenya.' In: Westley, S. B. (ed) *Soil and water conservation in Kenya: Report of a workshop held at University of Nairobi, 21-23 Sept 1977.* IDS occasional paper no.27. Institute for Development Studies and Faculty of Agriculture, University of Nairobi.

Mbithi, P., Muchiri, G., Kayonga-Male, D. and Thomas, D.B., 1977; 'An evaluation study of the Machakos Manual Terracing Programme by Mwethya groups: Technical supplements: 1. Soil conservation methods; 2. Soil Conservation tools and equipment.' Unpublished typescript, Departments of Sociology and Agricultural Engineering, University of Nairobi.

Mbote, F.W., 1978; 'Comparison and evaluation of Fanya Juu channel terraces in Kyangulumi sub-location.' Report for Post Graduate Diploma in Soil and Water Management, Department of Agricultural Engineering, University of Nairobi.

McCreath, D.C., 1947; *Kalama field trip report, August, 1947.* Nairobi: Ministry of Agriculture.

MoA, 1962; *African land development in Kenya, 1946-62.* Nairobi: Ministry of Agriculture, Animal Husbandry and Water Resources.

MoA, 1976; *Soil and water conservation project (SIDA) annual report 1975/6.* Nairobi: Ministry of Agriculture.

MoA, 1988; 'Soil and water conservation project (SIDA) annual report 1988/89.' Nairobi: Ministry of Agriculture.

MoA, 1990; 'Soil and water conservation project (SIDA) annual report 1989/90.' Nairobi: Ministry of Agriculture.

Moore, T.R., Thomas, D.R. and Barber, R.G., 1979; 'The influence of grass cover on runoff and soil erosion in the Machakos area, Kenya.' *Tropical Agriculture (Trinidad),* 56(4):339-344.

Muchiri, G., 1977; 'Soil conservation tools and equipments.' Technical Supplement 2, 'Evaluation of Machakos Manual Terracing Programme by Mwethia groups.' Unpublished manuscript.

Muchiri, G. and Gichuki, F.N., 1982; 'Conservation tillage in semi-arid areas.' Paper presented at National Soil and Water Conservation Workshop, held at Faculty of Agriculture, University of Nairobi.

Muya, F.S., 1990; 'Reservoir sedimentation and catchment land use.' MSc thesis, Department of Agricultural Engineering, University of Nairobi.

ODI, 1982; 'Machakos Integrated Development Programme: Phase 1: Evaluation.' Report [by Adams, M. et al] prepared for the Ministry of Economic Planning and Development by Overseas Development Institute under assignment by the Commission of the European Communities, 1982.

Peberdy, J.R., 1958; 'Machakos District Gazetteer, Parts 1 and 2.' Machakos: District Agricultural Office.

Peberdy, J.R., 1961; 'Notes on some economic aspects of Machakos District.' Machakos: District Agricultural Office.

Pereira, H.C. and Beckley, V.R.S., 1952; 'Grass establishment on eroded soil in a semi-arid African reserve.' *Empire Journal of Experimental Agriculture,* 21(81):1-14.

Pereira, H.C., Hosegood, P. and Thomas, D.B., 1961; 'The productivity of tropical semi arid and thorn scrub country under intensive management.' *Empire Journal of Experimental Agriculture,* 29:269-86.

Pole-Evans, I.B., 1939; *Report on a visit to Kenya.* Nairobi: Government Printer.

Rocheleau, D., Weber, F. and Field-Juma, A., 1988; *Agroforestry in dryland Africa.* Nairobi: International Council for Research on Agroforestry.

Thomas, D.B., 1956; 'Annual report of the agricultural officer (experimentation), Southern Province.' In: Ministry of Agriculture, *Annual report 1956.*

Thomas, D.B., 1977; 'Soil conservation methods.' Technical supplement 1, 'Evaluation of Machakos Manual Terracing Programme by Mwethia groups.' Unpublished manuscript.

Thomas, D.B., 1978; 'Some observations on soil conservation in Machakos District, with special reference to terracing.' In: *Soil and Water Conservation in Kenya: Report of a workshop held at University of Nairobi 21-23 Sept 1977.* Occasional paper No.27. Institute for Development Studies and Faculty of Agriculture, University of Nairobi. pp.25-39.

Throup, D.W., 1987; *Economic and social origins of Mau Mau, 1945-53.* London: James Currey.

Wenner, C.G., 1981; *Soil conservation in Kenya.* Nairobi: Ministry of Agriculture.

Young, A., 1989; *Agroforestry for soil conservation.* Wallingford, UK: Commonwealth Agricultural Bureau International.

TABLES

Table 1: **Reconditioning of grazing land in the late 1930s and early 1940s**

Year	*Area closed (ha)*	*Grass planted (ha)*	*Napier grass (ha)*	*Land demarcation (ha)*
1937	10,121	n/a	136	n/a
1938	n/a	n/a	405	n/a
1939	13,283	460	n/a	164,991
1940	6,579	3,230	n/a	1,300
1941	10,407	1,360	n/a	17,761
1942	7,822	1,864	n/a	7,817
1943	7,609	620	n/a	n/a
1944	10,574	1,986	n/a	n/a

Source: DoA Reports (1937-44). n/a - not available

Table 2: **Conservation of grazing lands (1955-79)**

Year	*Roofed cattle sheds*	*Sisal along boundaries (ha)*	*Bush clearing (ha)*	*Paddocks (ha)*
1955	4,610	761	n/a	n/a
1956	5,588	308	n/a	n/a
1957	2,458	354	n/a	96,985
1958	2,617	198	n/a	4,067
1959	1,781	115	10,409	12,398
1960	740	287	6,503	2,577
1961	116	642	2,488	2,041
1962	60	175	1,021	1,500
1963	33	245	935	3,949
1964	23	847	1,523	292
1965	n/a	n/a	2,062	75
1966	n/a	n/a	2,825	917
1967	n/a	n/a	3,864	858
1968	n/a	n/a	265,836	6,782
1969	n/a	n/a	286,896	200
1970	n/a	n/a	22,527	1,771
1971	n/a	n/a	7,825	1,247
1972	n/a	n/a	n/a	n/a
1973	n/a	n/a	n/a	n/a
1974	n/a	n/a	n/a	n/a
1975	n/a	n/a	15,208	n/a
1976	n/a	n/a	n/a	n/a
1977	n/a	n/a	8,373	n/a
1978	n/a	n/a	3,348	n/a
1979	n/a	n/a	2,639	n/a

Source: DoA Reports (1955-79). n/a - not available

Table 3: Conservation structures

Year	*Bench terraces (km)*	*Narrow base terraces (km)*	*Grass strips (km)*
1955	1,283	4,416	23,053
1956	2,307	2,544	6,461
1957	2,520	3,091	4,304
1958	4,274	1,741	1,691
1959	4,293	1,565	8,253
1960	1,690	1,162	1,028
1961	1,155	830	651
1962	952	1,397	71
1963	459	248	43
1964	398	158	840
1965	410	395	232
1966	1,542	1,149	170
1967	3,141	2,552	9,136
1968	950	1,026	226
1969	932	479	84
1970	531	652	2,605

Source: DoA and MoA Reports (1955-70).

Table 4: Soil conservation tools issued

Year	*Shovels*	*Mattocks*	*Picks*	*Crowbars*	*Forked jembes*	*Plain jembes*
1981	3,000	1,500	1,500	100	1,000	1,000
1982	2,328	877	773	n/a	659	850
1983	n/a	n/a	n/a	n/a	n/a	n/a
1984	4,567	1,420	288	600	2,239	737
1985	7,898	1,071	425	399	1,398	1,129
1986	3,975	208	593	34	3,141	2,745

Source: DoA Reports (1981-86). n/a - not available

Table 5: Soil and water conservation training activities, 1987-90

Activity	*Year* 1987/88	1988/89	1989/90
Training budget (Ksh)	134,000	240,000	292,000
Number of people trained:			
Technical Assistants	27	51	23
TAs' retraining	30	60	39
Teachers	28	-	105
Chiefs		27	
Local Leaders			31

Source: MoA Soil and Water Conservation Annual Reports (1988-90).

Table 6: SIDA supported activities in 1982

	Activity	*Achievements*
1.	Cut-off drains	447 km
2.	Bench terrace	751 km
3.	Narrow based terraces	379 km
4.	Fanya juu terraces	416 km
5.	Bush clearing	2,033 ha
6.	Grass planted	2,044 ha

Source: Kenya. District Agricultural Officer, 1982.

Note that most of the early work was concentrated on structural measures of soil and water conservation.

Table 7: Soil conservation work undertaken by Mwethya groups in 1976

	Type and length of conservation structures constructed			
	BT	*NBT*	*COD*	*FJT*
Eastern	897	112	231	225
Central	136	253	59	143
Northern	369	117	42	366

BT Bench terrace
NBT Narrow base terrace
COD Cut-off drain
FJT Fanya juu terrace

Source: Kenya. MoA 1976 Annual Report.

Table 8: Types of terraces, 1980-90

Terrace type	*Number of Terraces*			
	Muya	*ODI*	*Total*	*Percentage*
Narrow based channel	7	5	12	2
Broad based channel	8	-	8	2
Fanya juu	143	24	167	33
Forward sloping	240	20	260	52
Level bench	37	6	43	9
Backward sloping	8	5	13	2
Total	443	60	503	100

Source: Muya (1990); Current Study.

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