SOIL AND WATER CONSERVATION IN KENYA

Report of a Workshop held at the
University of Nairobi,
21 - 23 September, 1977

Sponsored by the Land and Farm Management Division of the Kenya Ministry of Agriculture and the Departments of Agricultural Engineering of the University of Nairobi and of Egerton College

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SOIL AND WATER CONSERVATION IN KENYA: A WORKSHOP REPORT

ABSTRACT

A Workshop on Soil and Water Conservation was held at the University of Nairobi from 21 to 23 September 1977, sponsored by the Land and Farm Management Division of the Ministry of Agriculture and the Departments of Agricultural Engineering of the University and Egerton College. The objectives of this workshop were:-

1. To bring together research workers, teachers, extension officers and others who are concerned with problems of soil and water conservation,

2. To exchange technical information and discuss problems in assessing needs and in planning, implementing and evaluating conservation systems, and

3. To identify priorities for research and to seek ways to increase the effectiveness and relevance of teaching.

In keeping with these objectives, a number of papers were presented at the workshop and are included in full in this report. Topics covered include, among others, experiments with various cropping systems and tillage methods to determine which patterns of land use minimise soil loss, methods for reclaiming swampy or badly eroding land, studies of small experimental catchment areas, the physical and social problems involved in carrying out conservation programmes in semi-arid areas, and the Ministry of Agriculture's plans for a major soil and water conservation programme.

In addition to these discussions, field trips were conducted to Machakos and Murang'a which are described in this report, and a list of recommendations was drafted which is also included.

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PREFACE TO THE WORKSHOP REPORT

A Workshop on Soil and Water Conservation was held at the University of Nairobi from 21 to 23 September 1977, sponsored by the Land and Farm Management Division of the Ministry of Agriculture and the Department of Agricultural Engineering of the University of Nairobi and of Egerton College.

It seemed a particularly appropriate time to hold a soil and water conservation workshop in Nairobi, just after two major conferences on desertification, one sponsored by the Kenya National Environmental Secretariat and the other by the United Nations Environment Programme. A growing public concern about the conservation of natural resources on a worldwide level has been combined in Kenya with an increasing awareness that crop and livestock production have expanded and intensified greatly in this country, often without proper land use planning and management. Allegations have been made that tons of Kenyan top soil have been washed from cultivated slopes and overgrazed pastureland, silting up the rivers and lakes, and ultimately flowing into the Indian Ocean. Some areas, such as parts of Baringo District, have been described as ecological end zones or disaster areas.

In some cases, our understanding of the process of erosion and the best means of combatting it has been incomplete, particularly our knowledge of conservation techniques which would be appropriate to Kenya's small-farm areas. In some cases, we know what should be done, but have lacked the manpower and material resources and the organisational framework necessary to carry out conservation measures on a broad scale. Finally, in some cases we know what should be done and the resources are available, but the problem is to educate the nation's farmers and to motivate them to carry out erosion control measures which may require a considerable labour input and whose benefits may only become apparent over a long period of time.

Given these problems and needs, the objectives of the Workshop on Soil and Water Conservation were:-

1. To bring together research workers, teachers, extension officers and others who are concerned with problems of soil and water conservation,
2. To exchange technical information and discuss problems in assessing needs and in planning, implementing and evaluating conservation systems, and
3. To identify priorities for research and to seek ways to increase the effectiveness and relevance of teaching.

In keeping with these objectives, a number of papers were presented at the workshop and discussed by the participants. These papers describe specific research projects as well as the operations of government agencies responsible for soil and water conservation work in the field. They are presented in full in this workshop report.

It is recognised that the problems of soil and water conservation are highly complex and involve more than immediate measures to prevent the most serious local cases of erosion. The reclamation of swampy or badly eroded land is an important topic which is discussed in two of the papers presented here. The special problems of maintaining conservation structures on large farms which have been purchased by companies or co-operatives are discussed, as well as the special problems of semi-arid areas such as Machakos District and large parts of Coast Province. Two papers are presented on the Machakos area, one covering some of the physical problems of building and maintaining effective conservation structures and the other focussing on the attitudes of the local farmers as determined by a social survey.

Three papers deal with experiments in cropping systems and tillage methods to determine which patterns of land use minimise soil loss by providing a leafy canopy at different times of the year. Two of these papers focus on the semi-arid areas of eastern Kenya, and one deals with the production of tea. A fourth paper describes a project designed to provide the Kenya government with practical methods for assessing water resources in semi-arid areas by focussing research on a carefully selected number of small catchment areas.

In one paper specifications are given for constructing a simple metric line level, used for laying out conservation structures in the field. In another paper, the problem of soil erosion in the Upper Tana catchment area is viewed from the perspective of the rivers and reservoirs which are silting up.

The activities of the Kenya Soil Survey are described in one paper and a useful list of all the survey's publications is given. Finally, the Land and Farm Management Division of the Ministry of Agriculture has prepared a paper describing the ministry's plans for a major conservation programme to be implemented throughout Kenya.

In addition to the presentation of papers, the workshop participants were able to visit Machakos and Murang'a Districts to view conservation problems and solutions at first hand. These visits added considerably to the general understanding of the issues discussed during the workshop sessions. Our thanks to Mr. S.M.A. Wambua of the Ministry of Agriculture and Prof.Phillip Mbithi and Dr. Diana Kayongo-Male of the University of Nairobi for organising the trip to Machakos and serving as guides. In the same way, thanks to Mr. E.O. Wanga of the Ministry of Agriculture who organised the field trip to Murang'a and explained the conservation work in that district to the workshop participants. Thanks also to the University of Nairobi which provided transport for the Machakos visit and to the Ministry of Agriculture which provided transport to Murang'a.

During the final sessions of the workshop, the Ministry of Agriculture's proposed Amendments to the Agriculture (Basic Land Usage) Rules were discussed, and a number of recommendations were made for the organisation of soil and water conservation programmes at the national level, for the implementation of conservation work in the field, for conservation research, and for teaching. These recommendations are included in this report. The proposed legislation will be issued by the Kenya government when it reaches its final form. One major recommendation of the workshop was the establishment of a National Soil and Water Conservation Committee on a permanent basis, to include representatives of appropriate government ministries and non-government organisations. This committee would be responsible for planning and co-ordinating the various soil and water conservation activities and projects carried out by different agencies throughout Kenya.

It is appropriate here to thank all those participants who presented papers at the workshop and in this way added to our knowledge of various conservation research projects and implementation programmes. Our special appreciation goes to Mr. P.K. Gota, the Director of Agriculture, who opened the workshop. The success of the workshop was also greatly enhanced by a number of people who chaired the discussion sessions. Finally, thanks to the members of the Steering Committee, and particularly to Mr. D.B. Thomas, the secretary, for doing the necessary arranging and organising to make this workshop possible, and to the University of Nairobi's Faculty of Agriculture which has subsidised the production of this report.

Dr. P.A.M. Misiko,
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Chairman, Steering Committee

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WELCOME TO THE PARTICIPANTS

by

Dr. P. A. M. Misiko
Chairman of the Steering Committee

Mr. Director of Agriculture, distinguished guests, friends, ladies and gentlemen, on behalf of the departments of Agricultural Engineering at the University of Nairobi and Egerton College, and the Land Development Division of the Ministry of Agriculture, I wish to thank the Director of Agriculture, Mr. P. K. Gota for kindly accepting the invitation to open this workshop on Soil and Water Conservation. I wish also on behalf of the Steering Committee to thank the Dean of the Faculty of Agriculture, Prof. Karue, for accepting us all here and offering us the use of the faculty's facilities for our various needs in the days ahead.

Mr. Director, sir, your presence here today amidst your many duties in this dynamic and growing country, is a measure of the importance you attach to the theme of this workshop and is a great encouragement to those of us who believe that soil and water conservation is of vital importance to our country.

This workshop has been long in the making. We fully agree with the call of the Minister of Agriculture, the Hon. J. J. Nyagah, this time last year when he stressed the need to conserve our vital natural resources - soil and water. We are very conscious of the need to keep ourselves fed and clothed, and maintain a practical emphasis in all that we do. However, there are many problems related to our neglect to conserve our soil and water resources.

In deciding on the theme of this workshop, we were very conscious of the fact that there is already a lot of information on soil and water conservation in the country which many of us are not aware of because or poor communications and a variety of other reasons. We felt that it would serve a useful purpose to bring together research workers, teachers, extension officers and others who are concerned with problems of soil and water conservation. This is to enable participants to exchange technical information, and discuss the problems of assessing needs and of planning, implementing and evaluating conservation systems.

This workshop is also intended to identify priorities for research and to seek ways to increase the effectiveness and relevance of teaching in the field of conservation. Let me emphasise that in doing so we do not underrate the efforts already going on now in the field. We wish to make a practicial and modest contribution to these efforts.

This workshop has been designed with two major components. First papers, drawn from the experience in the field, will be presented with the intention of generating discussion on the technical, agronomic, economic, social and administrative aspects of soil conservation practices. Secondly, field trips have been arranged to enlighten the participants and help us to formulate appropriate soil and water conservation measures to be recommended for future action.

Mr. Director, sir, we wholeheartedly desire that this workshop should not end here in a few days time, but that it should be the beginning of something lasting. To encourage this, after the workshop is over we plan to document the conclusions and recommendations reached and publish them together with the papers which are presented.

Finally, I would be most remiss if I did not thank the members of the Steering Committee, and especially the secretary, Mr. Thomas, for their tireless personal efforts to make this first soil and water conservation workshop in Kenya possible.

Thank you.

OPENING ADDRESS
by
Mr. P.K. Gota
Director of Agriculture

Mr. Chairman, Ladies and Gentlemen:

I would like, on behalf of the Ministry of Agriculture, and indeed myself, to welcome all of you to this Soil and Water Conservation Workshop. The purpose of this workshop is to bring together participants from various disciplines and professions in order that we may all discuss and appreciate the problems of soil and water conservation in our development efforts.

The land is many things to many persons - to the farmer, a livelihood; to the urban man, a place to build his house; to many of us, a home; and land is the soil under our feet, the materials in that soil and the slope that determines the ease of cultivation - the mother earth. Land is our entire natural environment - the forces or the opportunities that exist independently of man's activity. One basic problem, however, continues to exist with respect to the use of land. That is the solution to the soil and water conservation problem: the planning for more efficient use of a non-expanding resource, not only to feed the nation, to produce for export and to provide employment, but also to maintain this irreplaceable resource in an ever-increasing productive state.

In all our lives we have had direct experiences of the importance of soil. To a certain extent we learnt what every farmer knows - that each of the thousands of different kinds of soils requires its own care and skillful use, which also changes from season to season as conditions of moisture, temperature and crops change.

Soil- and water-conserving husbandry practices should become a permanent feature of the agricultural production process. This requires a comprehensive and long-term approach to planning. Soil conservation is not a final objective in itself, but a means of attaining economic objectives such as the increase of production, and through these economic objectives, of reaching still wider social and political objectives which we shall be able to enhance through a sound national development plan. These wider economic and social objectives have to be defined, at least in general terms, before the Ministry of Agriculture can legitimately revive the now partly lapsed planning procedures for soil and water conservation in the Republic.

The main point is that if these economic and social objectives are to dominate from the outset the more narrow engineering and planning considerations, then they should have a decisive influence on any engineering proposals. Policies related to soil and water conservation should, in my opinion, have a wide application in our varied production system. Therefore, during the early stage of development of the guidelines for soil and water conservation in Kenya, consideration should not be limited to engineering factors alone, but proper weight should be given to all planning factors: economic, social, political, legal, organisational and administrative.

I hope that in the couse of this workshop definite guidelines will emerge, which will enable the Ministry to develop a master plan. Looking at the list of participants in this workshop, I am satisfied that useful interaction will take place so that definite recommendations can be drawn up. A master conservation plan, based on an integrated planning approach and periodically brought up to date in the light of changing conditions and accumulating data, is, in my judgement, the proper framework for any long-term or short-term development plan intended for implementation.not only to conserve the natural resources, soil and water, but to feed the nation for generations to come. In the last three years experts in my department have achieved some significant results in a few areas where they have, with the co-operation of farmers, reintroduced some well-known soil conservation practices. Also in progress are the ammendments to the existing Basic Land Use Rules and other relevant sections of the Agricultural Act. All such activities will be discussed during this workshop. The Head of the Land and Farm Management Division has brought with him to this workshop senior officers responsible for land development and farm management, and I have no doubt that they will share their experiences with you in this important field of soil and water conservation.

It is not only government policy and action that is required in order to support proper land-use intensification, but you in the institutions of higher learning devoted to agriculture must continue to cooperate with government in improving the extension services in such a way that soil and water conservation becomes a profitable proposition from the farmer's point of view. The promotion of soil and water conservation practices at the farm level, however, is not enough. Additional educational activities, research and government policies are required. Experience has indicated clearly that farmers cannot be expected to apply conservation measures voluntarily unless they are profitable, realising that labour input is usually high while the returns require considerable time to become apparent. Hence a strong system of incentives must be provided so that a growing proportion of the farming community becomes aware of the need for conservation of land and water resources.

The various aspects of technical, social and planning innovation, in the matters I mentioned above, Mr. Chairman, are all very important issues which are of particular interest to the Ministry of Agriculture and Kenya as a whole.

On the other hand, in the past efforts to encourage appropriate use of the land and water resources to respond to various conservation problems have been isolated, patchy, unco-ordinated, out-dated and somtimes have lacked a sense of seriousness. During the colonial era soil conservation work instituted in the smallholder areas encountered many problems.

The approach was mainly technical and coercive, with little emphasis on transforming the land use system. As such, insufficient thought was given to the fact that, in a number of cases, soil conservation practices were not profitable and often not practical, if not totally repugnant to the farming community. Invariably this led to the drastic failure of these practices as soon as the colonial era ended. The general coercive enforcement of soil conservation by agricultural staff made effective extension work difficult. Inevitably, after independence soil conservation activities slowed down significantly, as most farmers believed that soil conservation was a cumbersome and meaningless activity imposed by the colonialists.

Today we are experiencing pressure on the land. Road sides are being tilled; slopes and river banks are also being intensively cultivated. We cannot measure in tons or in shillings, or even in terms of hunger and bodies to be clothed, the effect of soil erosion. This is a challenge facing us - academics, agricultural extensionists, and the Ministry of Agriculture as a whole. The government's first priority after independence was self-sufficiency in food production, and I am proud to say that Kenyan farmers have adequately met this challenge. They have opened more and more land that they had previously been forbidden to cultivate. All that is true, and we are grateful. But this is not the time for boasting; the increase of soil erosion since independence should be a matter of great concern to all Kenyans.

Rather, as we enter a new era, our productive genius and the men, women and natural resources that underlie our progress, with the abundance they have given us, impose on us new opportunities and responsibilities. Our goal is adequate production without waste so that nobody in the nation need lack food and clothing. Hence conservation of land and water resources demands action of several kinds - emergency measures whenever the food supply in any part of the nation is disrupted, cooperation between farmers, agricultural institutions and the government, and a long-range programme aimed at the best use of land and other natural resources.

Because our knowledge of soil physics and chemistry has expanded greatly, emphasis and needs have changed. This workshop should address itself to the management of the soil itself as a subject of growing importance. The extension service has tried to help farmers appraise their own requirements and decide which of the many available practices, materials and even machines are best for each situation. We should explain tirelessly all the many techniques for more efficient soil management on a permanent basis - how the soil on steep slopes or river banks can be farmed more intensively without waste.

We emphasise that for best results all aspects of soil management must fit together into a system of crop, livestock and forest management geared to the characteristics and requirements of both soil and plants. This underlines the whole basis for sound land use planning.

This soil conservation workshop should look not only at the technological and academic advances in agriculture, the changing face of rural Kenya, and the growing importance of Kenya's role in world agriculture, but it should also look to some extent at long-term future prospects. It should be our purpose to supply information about soil and water conservation in a practical and useful way for farmers. The workshop should emphasise that more practical information and more wisdom are needed. This need has been mentioned again and again in my discussion today. The realisation of ignorance is the beginning of wisdom. The statement of a problem is the first step in its solution. It is a duty to discover facts in a truly scientific, unbiased, unselfish spirit - a duty for us who are here today.

Research on soil conservation is therefore to be intensified. It should include crop and animal husbandry research, soil surveys, soil erosion studies, irrigation and drainage research in most of our areas where erosion problems are severe. This workshop should be able to generate even more new research topics. I would like to suggest that consideration should be given to the establishment of integrated land use, mixed cropping, contour cropping and fodder crops, as well as to the agricultural engineering, economic and human sides of land-use patterns.

More research is also called for in relation to the use of river banks, especially now that more land is being cultivated in these areas as pressure on the land intensifies. We know from experience that we should not cultivate a certain distance from river banks. This may be wise, but is it feasible today? In the past, farmers were also not allowed to cultivate beyond a certain grade on steep slopes. The possibilities for cultivating these areas must be reconsidered as the livelihood of some farmers depends on cultivating these steep slopes and river banks. What information is available to aid these farmers to use these areas without soil loss?

It is therefore apparent that for any sound programme to be initiated by the Ministry of Agriculture, the participants at this workshop must gather information, analyse it and feed the Ministry with facts.

Last but not least, let me wish you a demanding but pleasant task ahead of you, and I hope you will come out with recommendations which the Ministry, the Government and the Kenyan population will be able to implement.

I would like to thank you, Mr. Chairman, the Steering Committee and all the participants and guests for your participation in this workshop. And I trust all of you will find the few days you will be spending with us in Nairobi meaningful, enjoyable and worthwhile.

Mr. Chairman, it now gives me pleasure to declare this important workshop open.

Thank you.

THE KENYA SOIL SURVEY AND SOIL CONSERVATION

by

H.M.H. Braun and F.N. Muchena
Kenya Soil Survey

SUMMARY

This paper describes the major activity of the Kenya Soil Survey, i.e., the various soil surveys and related mapping scales, together with the observations, measurements and analyses carried out during the surveys. Also it outlines how the legends of the soil maps are built up. Attention is given to the supporting maps, especially the soil erosion hazard map, which are produced for reconnaissance soil surveys only.

INTRODUCTION

The intention of this workshop is to bring together various organisations and people who are involved in soil and/or water conservation and to inform each other about their work. The purpose of this paper is to outline the work carried out by the Kenya Soil Survey with emphasis on aspects which are of importance for soil and water conservation.

TYPES OF SOIL SURVEYS AND MAPPING SCALES

The Kenya Soil Survey carries out five types of soil surveys. Exploratory surveys (mapping scale 1:500,000 to 1:1,000,000) are intended to give an idea of the distribution of the major soil types in large areas. Intensive use of aerial photographs and particularly satellite images facilitate the mapping. Field observations are widely scattered. The exploratory soil map of eastern Kenya is ready in draft, while the map of the western part of Kenya might be ready early in 1978 (Sombroek et al. forthcoming).

Reconnaissance surveys (mapping scale 1: 100,000 to 1: 250,000) are intended to provide systematic inventories of the soil and land resources for land-use planning purposes. The surveys are done by quarter degree or degree sheet. Aerial photograph interpretation and a substantial number of field observations on soil, vegetation and land use form the basis of these surveys.

Areas mapped at a scale of 1:100,000 are Nairobi-Thika-Machakos (Scott et al. 1963), Kindaruma (van de Weg and Mbuvi, eds. 1975), Kapenguria (Gelens et al.1976), Kwale-Mombasa-Lungalunga (Michieka et al. forthcoming) and Kisii (Wielemaker et al. forthcoming). The Makueni area (Muchena et al. forthcoming) is being surveyed at the moment. Rangeland areas are mapped at a scale of 1:250,000. The following rangeland areas are being surveyed: Amboseli, with quarter degree sheets 173,174,181 and 182 (Touber forthcoming); Mtito Andei, with sheets 175,176,183 and 184; and Voi, with sheets 190,191, 196 and 197 (van Wijngaarden forthcoming).

Semi-deailed surveys (mapping scale 1:20,000 to 1:50,000) are carried out in areas which have been selected for a particular type of land use, for instance irrigation. The soil survey generally leads to or is the major component of a feasibility study. Aerial photographs, particularly on a scale of 1:25,000 or larger, can still be of use, but field observations, generally in a grid system, form the basis of this kind of survey. One semi-detailed survey carried by the Kenya Soil Survey was for the Kiboko Range Research Station (Michieka et al. forthcoming).

Detailed surveys (mapping scale 1:10,000 or larger) are carried out in areas where detailed information is required for planning purposes, often for irrigation projects, and several detailed soil surveys have been carried out for agricultural research stations. Aerial photographs are of little use for these surveys; field observations supply virtually all the information. The area involved in a detailed survey is generally small. Detailed surveys carried out by the Kenya Soil Survey are, for instance, one for the Kampi-ya-Mawe Experimental Station of 49 hectares (Muchena 1975) and surveys for various minor irrigation projects.

Site evaluations (various mapping scales) are intended to gather preliminary information for areas which might be selected for a particular land use or for areas where a particular problem occurs. The interpretation of aerial photographs generally plays an important role, and the amount of field work is kept to a minimum. Some 35 site evaluations have been carried out by the Kenya Soil Survey, most of them concerned with irrigation.

WHAT IS OBSERVED, MEASURED, ANALYSED OR STUDIED

The Kenya Soil Survey.largely follows the Soil Survey Manual of the U.S. Department of Agriculture (1951) and the F.A.O. guidelines for soil profile description (1967). In any survey the slope, soil depth and soil type are observed. In most surveys many samples are analysed chemically, while infiltration is measured in the field and water retention in the field and laboratory. Generally a study of climatic aspects, using the existing data, is carried out. In some surveys vegetation and land use are observed. Some more details about these various aspects are given here.

Slope Classes

Slope is measured with a simple slope meter and graded in six classes: A (0 - 2 per cent), B (2 - 5 per cent), C (5 - 8 per cent), D (8 - 16 per cent), E (16 - 30 per cent), and F (more than 30 per cent). These classes can be described as flat to very gently undulating, gently undulating, undulating, rolling, hilly and mountaineous respectively.

Soil Depth Classes

Soil depth is measured in augur holes or profile pits. The five classes are: very shallow (0 - 25 cm), shallow (25 - 50 cm), moderaterly deep (50 - 80 cm), deep (80 - 120 cm), and very deep (120 - 180 cm).

Soil Types

These are classified according to FAO/UNESCO's legend for their Soil Map of the World (1974). Soils are described in terms of drainage, depth, colour, consistence, texture and stoniness.

Chemical and Physical Analyses

Chemical analyses include analyses of carbon and nitrogen content, cation exchange capacity, exchangeable cations, pH, and fertility of the topsoil. Physical analyses are carried out of texture and water retention at pF 2.3, 2.7, 3.0, 3.7 and 4.2.

Other Observations

Infiltration is measuredin the field with rings or by simple sprinkling from a hosepipe. Vegetation is described in terms of woody and herbaceous cover and its composition. Land use is described in terms of the amount of land cleared, the degree of rotation, the kinds of farming systems and the specific crops and animals observed. The climate is described in terms of ecological zones based on the ratio of rainfall to potential evaporation (r/Eo) and in terms of the observed seasonal rainfall probability.

WHAT IS MAPPED

In most surveys only a soil map is produced by the Kenya Soil Survey. In some surveys, particularly the exploratory and reconnaissance surveys, the soil ma are given an ecological zone overprint. In the reconnaissance surveys, separate maps are made for vegetation, land use, geology (simplified from existing maps) and geomorphology, and a soil erosion hazard map is also compiled.

The first sub-division in the legend of the soil map is physiographic: mountains and major scarps, hills and minor scarps, footslopes, plateaus, uplands, piedmont plains, plains (erosional, river alluvial, coastal, lacustrine, volcanic), flood plains, bottomlands and miscellaneous landforms, which may include coastal sand bars, swamps, lava flows, badlands, talus, tidal flats, lagoons and quartz ridges. The second subdivision is on the basis of rock type: igneous, metamorphic or sedimentary. The igneous rocks are further subdivided on the basis or their silica content, the metamorphic rocks on the basis of their degree of metamorphism and mineral composition, and the sedimentary rocks on the basis of their mode of formation and texture. This subdivision is followed by the descriptions of the soils in terms of drainage condition, depth, colour, consistence, rockiness, stoniness, texture and other characteristics. For soil correlation purposes, the F.A.O. classification is added in brackets. On the soil map each unit has a code for soil type, depth class and slope class.

The Soil Erosion Hazard Map

On the basis of slope class, susceptibility to sealing and climate, an evaluation of the soil erosion hazard for cleared land is made and mapped. The three factors are each rated and the three ratings are added up. The final rating is a measure of the soil erosion hazard. It is compared with field observations and if necessary adjusted.

The ratings for the slope classes are:-

slope classes	slopes	rating
A and AB	0-5%	1
B and BC and C	5-8%	3
CD and D	8-16%	5
E and F	> 16%	7

The subrating for susceptibility to sealing consists of a combination of ratings for organic matter content, flocculation index and silt/clay ratio in the A horizon.

(a) [illegible]	> 2%	 1	
	1 - 2%	 2	
	< 1%	 3	
(b) flocculation index	> 70%	 1	in cases of doubt, because topsoil analyses are often not reliable due to local variation because of land use, the ratio of the B can be taken into account, as well
	50–70%	 2	
	< 50%	 3	
(c) silt/clay ratio	< 0.20	 1	in case of doubt the ratio for the B can be taken into account
	0.20 - 0.40	 2	
	> 0.40	 3	

Final Subrating for Susceptibility to Sealing	Combined Ratings	Compared to Field Structure	Infiltration Rates Uncultivated	Infiltration Rates Cultivated
1 none	< 5	strong subangular blocky to crumb	very rapid	very rapid
2 slight	6	moderate sub-angular blocky	moderately rapid	very rapid
3 moderate	7	moderate sub-angular blocky	moderate	very rapid
4 strong	8	weak sub-angular blocky	moderate to slow	rapid to moderate
5 very strong	9	massive	slow	moderate

The climate is rated according to the ecological zones:-

Zone	Rating
I and II	1
III and IV	2
V and VI	3

The combination of the three subratings gives the following rating for sheet erosion hazard:-

Combined Subratings	Erosion Hazard	Final Rating
3, 4, 5, 6	very slight	1
7, 8	slight	2
9, 10	moderate	3
11, 12	high (severe)	4
13, 14, 15	very high (very severe	5

The susceptibility to gully erosion is still to be elaborated but could be estimated on the basis of high infiltration rates and stability of the subsoil. It should be noted, however, that the empirical subratings and weighing of the importance of each rating is done taking into account the field observations in soil behaviour by the surveyor. These ratings have been applied to three reconnaissance soil survey areas. It is hoped that by applying the same rating system to other parts of the country with different enviromental conditions a more elaborate system of rating for soil erosion hazard will be developed.

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6. United States. Department of Agriculture. 1951. 'Soil Survey Manual'. U.S.D.A. Handbook No. 8. Washington, D.C.

7. Van de Weg, R.F. and Mbuvi, J.P., editors. 1976. 'Soils of the Kindaruma Area'. Reconnaissance Soil Survey Report No. 1. Kenya Soil Survey. Nairobi, Government Printer.

APPENDIX: LIST OF PUBLICATIONS OF THE KENYA SOIL SURVEY FROM 1972 TO JUNE 1977

For details of soil investigations prior to 1972, see:-

Ableiter, J.K. and van Baren, J.H.V. 1971. 'Soil Survey Data and Methods: A Report to the Government of Kenya'. Report No. TA 2914. Rome, F.A.O.

Nyandat, N.N. 1972. 'Bibliography of Papers Which May Relate to Soil Formation and Distribution in Kenya'. Nairobi, N.A.L. Soil Survey Unit.

Reconnaissance Soil Survey Reports

Serial No.	Author(s)	Title	Date of Issue
R 1	R.F. van de Weg and J.P. Mbuvi (eds.)	'Soils of the Kindaruma Area (Quarter Degree Sheet 135)'	1975
	(mimeographed edition 1975; printed edition 1976; available at KShs. 30/- from KSS or Government Printer)		
R 2	H.F. Gelens, H.C. Kinyanjui and R.F. van de Weg (eds.)	'Soils of the Kapenguria Area (Quarter Degree Sheet 75)'	1976
	(mimeographed edition 1976; printed version forthcoming)		
R 3	D.O. Michieka, J.J. Vleeshouwer and B.J. van der Pouw	'Soils of the Kwale Area (Quarter Degree Sheets 200, 201, 202)'	forthcoming
R 4	Training project in Pedology/Kisii	'Soils of the Kisii Area (Quarter Degree Sheet 130)'	forthcoming
R 5	F.N. Muchena et al.	'Soils of the Makueni Area (Quarter Degree Sheet 163)'	forthcoming

One reconnaissance soil survey was carried out before the Kenya Soil Survey was set up:-

	Scott et al.	'Soils of the Nairobi/Thika/ Machakos Area '	1963
	(Nairobi, Department of Agriculture, out of stock)		

Semi-detailed Soil Survey Reports

Serial No.	Author(s)	Title	Date of Issue
S 1[a]	J. Thorp et al.	'Soil Survey of the Songhor Area'	1960

a. Carried out by NAL/USAID personnel before the Kenya Soil Survey was set up.

Serial No.	Author(s)	Title	Date of Issue
S 2[a]	F.T. Miller et al.	'Soil Survey of the East Konyango Area'	1961
S 3	D.O. Michieka, J.R. Rachilo, H.M.H. Braun and B.J.A. van der Pouw (eds.)	'Soils and Vegetation of the Kiboko Area'	forthcoming (maps ready in 1975)

Detailed Survey Reports

Serial No.	Author(s)	Title	Date of Issue
D 1	F.N. Muchena	'Soils of the Kampi-ya-Mawe Agricultural Experimental Station'	1975
D 2	F.N. Muchena and G. Ngari	'Soils of the Proposed Wamumu Extension of Mwea Irrigation Settlement Scheme'	1975
D 3[b]	E.N.K. Mugai H. Bonarius and P.N. Njoroge	'Detailed Soil Survey of the Proposed Extension of Kimala Irrigation Scheme, Taita-Taveta District'	1976
D 4[b]	H. Bonarius and E.N.K. Mugai	'Detailed Soil Survey of the Jara-Jara Irrigation Scheme (Mbalambala)'	1977
D 5[b]	E.N.K. Mugai and H. Bonarius	'Detailed Soil Survey of the Kainuk I Irrigation Scheme (Turkwell River)'	1977
D 6[b]	P.J.K. Kanake and E.N.K. Mugai	'Detailed Soil Survey of the Mnazini Irrigation Scheme (Lower Tana Area)'	1977
D 7	W. Siderius and R.M. Muriuki	'Detailed Soil Survey of Lanet (Nakuru)'	forthcoming
D 8[b]	E.N.K. Mugai and P.J.K. Kanake	'Detailed Soil Survey of the Wema and Hewani Irrigation Schemes (Lower Tana)'	forthcoming
D 9[b]	E.N.K. Mugai and P.J.K. Kanake	'Detailed Soil Survey of Malka Daka Irrigation Scheme (Ewaso Ng'iro)'	forthcoming

a. Carried out by NAL/USAID personnel before the Kenya Soil Survey was set up.
b. These papers were prepared by the Special Task Force on Minor Irrigation Development.

Serial No.	Author(s)	Title	Date of Issue
D 10	O.O. Oswaggo	'Detailed Soil Survey of Kibirigwi Irrigation Scheme'	forthcoming

Site Evaluation Reports

Serial No.	Author(s)	Title	Date of Issue
P 1	R.F. van de Weg and W.G. Sombroek	'Report of a Site Evaluation of Cat Clay Hazards in the Yala Swamp, Western Kenya'	June 1972
P 2	R.F. van de Weg	'Report of a Site Evaluation Trip to Lake Kenyatta Cotton Scheme, Lamu District'	June 1972
P 3	H.M.H. Braun and S. M. Wokabi	'Irrigation Suitability of the Olkeramatian Experimental Area'	Dec. 1972
P 4	H.F. Gelens and G. Ngari	'Report of a Site Evaluation of the Proposed Location of Alupe Substation'	Jan. 1973
P 5	N.N. Nyandat	'A Reconnaissance Survey of Arable Land in the Area East of Meru Town'	April 1973
P 6	H.M.H. Braun and N.N. Nyandat	'Report of a Visit to the Experiment Area of the Ishiara Irrigation Scheme'	Dec. 1972
P 7	W.G. Sombroek, J.H. Vleeshouwer and S.M. Wokabi	'Report of a Site Evaluation of Irrigation Suitability of the Soils and Waters of the Merti Area, Isiolo District'	Jan. 1973
P 8	H.F. Gelens and G. Ngari	'Report of a Site Evaluation for a Proposed Irrigation Project at Kunati, Meru District'	March 1973
P 9	N.N. Nyandat and R.A. Leyder	'A Preliminary Survey of the Utilization of Nairobi Sewage Effluent for Irrigation'	Aug. 1973
P10	W.G. Sombroek, H.M.H. Braun and J.M. Kibe	'A Preliminary Evaluation of the Irrigation Suitability of the Soils in the Mandera-Ramu Area, North Eastern Province'	Sept. 1973
P11	H.M.H. Braun and H.W. Okwaro	'Drainage Problems of Planosolic Soils in the Bomet Area'	April 1974
P12	J.J. Vleeshouwer and J.P. Mbuvi	'A Preliminary Evaluation of the Irrigation Suitability of the Soils and the Waters of Katilo Irrigation Scheme, Turkana District'	Sept. 1974

Serial No.	Author(s)	Title	Date of Issue
P13	J.J. Vleeshouwer and J.M. Kibe	'Suitability as Sports Grounds of Some Sites on the Terrains of the Kiambu Institute of Science and Technology'	August 1973
P14	W.G. Sombroek, J.P. Mbuvi, J.M. Kibe and H.W. Okwaro	'A Preliminary Evaluation of the Irrigation Suitability of the Lands in the Middle-Lower Tana Valley (Mbalambala-Garissa-Bura)'	March 1974
P15	W.G. Sombroek, J.P. Mbuvi and H.W. Okwaro	'A Preliminary Evaluation of the Irrigation Suitability of the Lands in the Pre-delta Tana Flood-plain'	Dec. 1973
P16	J.P. Mbuvi, R.F. van de Weg and H.M.H. Braun	'A Preliminary Evaluation of the Soils of North West Machakos District'	July 1974
P17	J.J. Vleeshouwer and D.O. Michieka	'Irrigation Suitability of the Soils and Waters of the Flood-plain of the Kerio River North East of Lokori, Turkana District'	Oct. 1974
P18	J.P. Mbuvi	'A Preliminary Evaluation on the Suitability of the Area of Busia District for Sugar Cane Development'	Oct. 1975
P19	J.P. Mbuvi and R.F. van de Weg	A Preliminary Evaluation of the Soils around Nyangoma Mission, Bondo Division'	Dec. 1974
P20[b]	H. Bonarius and P.N. Njoroge	'A Preliminary Evaluation of the Irrigation Suitability of Lands in the Kanjoo Area, Meru District'	Oct. 1974
P21	W.G. Sombroek, J.P. Mbuvi and R.A. Leyder	'Preliminary Evaluation of the Soil Conditions on the East Bank of the Lower Tana (Bura-East Area) for Large-scale Irrigation Development (and Addendum)'	June 1975
P22[b]	H. Bonarius	'Preliminary Assessment of Irrigation Development in the Marsabit Area'	April 1975
P23	S.M. Wokabi, W.G. Sombroek and J.P. Mbuvi	'Evaluation of Tana Delta Soils for Large-scale Irrigation Development'	Nov. 1975

b. These papers were prepared by the Special Task Force on Minor Irrigation Development.

Serial No.	Author(s)	Title	Date of Issue
P24	W. Siderius	'Soil Resources of the Upper Kerio Valley - A Preliminary Investigation'	Sept. 1975
P25	J.P. Mbuvi and R.F. van de Weg	'Some Preliminary Notes on the Soils of Katumani, Kampi-ya-Mawe, Embu and Murinduko Agricultural Research Stations'	June 1975
P26	W. Siderius and E.B. Njeru	'Soil Conditions in the Muthangene Location (Meru District)'	March 1976
P27	F.N. Muchena	'Soil Resources of Maseno Division, Kisumu District - A Preliminary Investigation'	May 1976
P28	W. Siderius and E.B. Njeru	'Soils of Trans-Nzoia District'	June 1976
P29	J.P. Mbuvi and E.B. Njeru	'Soil Resources of the Melili Area, Narok District - A Preliminary Investigation'	1977
P30	R.F. van de Weg and W.G. Sombroek	'Soil Conditions of the Marafa-Magarini Area (Kilifi District) - A Preliminary Assessment'	July 1976
P31	B.J.A. van der Pouw, J.M. Kibe and C.R.K. Njoroge	'Soil Conditions of the Mitunguu-Materi Area, Meru District'	Jan. 1977
P32	R.F. van de Weg, R. Muriuki and E. Kinyanjui	'Soil Conditions at Three Proposed Sites for the Kenya Inspection Service for Seeds, Lanet (Nakuru)'	Nov. 1976
P33	W. Siderius	'Soil Conditions in the Kimalewa Area (Bungoma District)'	July 1977
P34	J.R. Rachilo	'Soil Conditions of the Kinangop Plateau'	forthcoming

Miscellaneous Soil Papers

Serial No.	Author(s)	Title	Date of Issue
M 1	H.A. Luning	'Land Suitability on the Basis of Reconnaissance Soil Surveys: Land Utilization Types of the Medium-Potential Areas of Eastern Province, Kenya'	1973

Serial No.	Author(s)	Title	Date of Issue
M 2	W.S. Sombroek, J.P. Mbuvi and H.W. Okwaro	'Soils of the Semi-arid Savanna Zone of North-Eastern Kenya' (Revised version of a paper prepared for the ISS-Ghana Government Conference on African Savanna Soils, held in Accra in November 1975)	1975
M 3	C. de Jong	'Land Use Alternatives in High-Potential Areas of Medium to High Altitude: The Kitale-Kapenguria Area'	1976
M 4	C. de Jong	'Land Use Alternatives for the Medium-Potential Areas of Low Altitude: The Kwale Area'	forthcoming
M 5	W. Siderius and F.N. Muchena	'Soils and Environmental Conditions of Agricultural Research Stations in Kenya'	1977
M 6	W. Siderius, J.P. Karanja and B. Kitonyo	'Guidelines for the Storage of Maps, Original Field and Laboratory Data, and Areal Photographs' (includes map catalogue)	1976
M 7	Staff of the Kenya Soil Survey	'Guide to the Standard "Soil Excursion in the Nairobi-Thika-Kindaruma Area"'	1977
M 8	N.N. Nyandat	'Use of Soil Survey Data: I. Soil Survey for Land Use Planning in Kenya. II. Soil Survey Data to Test the Wide Applicability of the Experimental Results of Kenya Research Stations' (Papers presented at ICRISAT Seminar on the Uses of Soil Surveys and Classification in Planning and Implementing Agricultural Development in the Tropics, held at Hyderabad in January 1976. Available as photocopy only)	1976
M 9	N.N. Nyandat	'Nitosols and Rhodic Ferrasols in Kenya: Their Characteristics, Properties and Management' (Paper presented at the Second F.A.O. Eastern African Soil Correlation Meeting, held in Addis Ababa in November 1976. Available as photocopy only)	1976
M10	W. Siderius	'Environment and Characteristics of the Nitosol at the National Agricultural Laboratory, Kabete, Nairobi'	1976
M11	H.O. Wamukoyo, ed.	'Proceedings of a Seminar on Land Evaluation for Rangeland Areas' (Held in January 1977)	1977

Serial No.	Author(s)	Title	Date of Issue
	B. van der Pouw and R.A. Leyder	'Soil Correlation in the Hola Bura Irrigation Scheme'	forth-coming
M12	H.M.H. Braun	'The Reliability of the Rainy Seasons in Machakos and Kitui Districts'	forth-coming
M13	H.M.H. Braun	'Seasonal and Monthly Rainfall Probability Tables for the East Central, Northwestern and Coast Region of Kenya	forth-coming
	D.O. Michieka and B.J. van der Pouw	'Grain Size Distribution of the Sand Fraction in Soils Derived from Sedimentary Rocks in the Kwale-Mombasa-Lunga Lunga Area'	forth-coming
M14	H.M.H. Braun	'Trends of Seasonal Rainfall in Kenya and Tanzania, with Particular Reference to the Kenya Coast'	forth-coming

Internal Communications

1	R.A. Leijder	'The Electrometrical Determination of pH and Electrical Conductivity'	February 1977
2	D. Legger	'A CEC-carbon Correlation of Several Profiles of the Kindaruma, Kapenguria and Makueni Areas'	May 1977
3	H.M.H. Braun	'Rainfall Stations in Kenya with Twenty or More Years of Records'	May 1977

Internal Technical Documents

Stencil No.	Title
S 117	'Standard Table for Comparison of Soil Profile Descriptions' (RW)
S 121	'Infiltration Measurements Form' (WMB)
S 123	'Guidelines for Map References on Not-Coloured Base Maps' (JJV)
S 139	'Approaches to Soil Mapping' (WGS)
S 142	'Summary of Essential Soil and Land Qualities' (WGS)
S 167	'Guidelines for Legend Sequence of the Reconnaissance Soil Maps'
S 169	'Procurement, Storing and Indexing of Aerial Photographs' (HFG)

Stencil No.	Title
S 185) S 186)	'Definitions and Diagnostic Horizons' (WGS)
S 190	'Key to Soil Units' (WGS)
S 202	'Guidelines to Soil Profile Description Form (RW), Part 1'
S 215	'Profile Characteristics Description (RW), Part 2'
S 264	'A Glossary of Definitions of Common World Soils and their Relation to Kenya Soils' (NNN)
S 266	'Kindaruma Paper' (RW)
S 269	'Proposals for Rating Land Qualities' (RW)
S 285) S 287) S 292)	'Land Evaluation: 1, 2 and 3 Lectures' (RW)
S 299	'Definition Land Types (RW) - First Draft' (see also 328)
S 300	'Geological Subdivisions (RW) - First Draft' (see also 314)
S 314	'Scheme for Subdivision on Geology/Richness of Parent Rock in Map Legend Construction' (RW)
S 328	'Definitions of Standard Land Forms' (RW)

SOME OBSERVATIONS ON SOIL CONSERVATION IN MACHAKOS DISTRICT, KENYA, WITH SPECIAL REFERENCE TO TERRACING[1]

by

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SUMMARY

Information obtained from a survey of soil conservation practises on 121 farms in Machakos District is presented and discussed. The main conservation measures are cut off ditches and bench type terraces. The majority of the latter are forward sloping and constructed by the method known locally as fanya juu. There is a need for more detailed specifications for terraces and for research into alternative methods of conservation on steep slopes. The importance of vegetative cover to prevent erosion both on terrace banks and on grazing land is stressed.

INTRODUCTION

The problem of soil erosion in Machakos District was first reported in the early part of the present century and had reached serious proportions by the 1930s due to a combination of overgrazing, which was aggravated by drought and locusts, and the lack of conservation measures on cultivated land (Maher 1937, Pole-Evans 1939, Peberdy 1960). Among the conservation measures which were introduced were narrow based terraces which were made by digging a channel on the contour and throwing the soil to the lower side to form a ridge. Experience showed that the channel silted up rapidly and a new method, known locally as the fanya juu method, was adopted in preference. With this method, soil is thrown uphill to form a ridge and the accumulation of soil due to slope wash on the upper side of the ridge leads to the partial formation of a bench terrace. Most of the work is done by hand and is

1. The author would like to acknowledge the excellent help of Mr. A.B. Mutebwa, graduate of Makerere University, in carrying out the survey, and also to thank Mr. H. B. Kikuvi, former student at Machakos High School, who assisted with the field work. Thanks are also due to Dr. N. M. Fisher who made many useful comments on the detailed report of the survey on which this paper is based.

usually carried out by traditional self-help Mwethya groups which were active for a number of years before independece and have become very active again, partly due to the growing awareness of the seriousness of the erosion problem and partly due to the stimulus of government aid.

A survey was carried out in May 1977 to obtain some preliminary information on how soil conservation methods vary in different altitude zones and on different slopes, to evaluate the effectiveness of the methods and to identify problems requiring further investigation or research. This survey forms part of a larger investigation carried out by the Departments of Agricultural Engineering and Sociology of the University of Nairobi into the problem of soil conservation and the activities of Mwethya groups. The work was funded by the Canadian Government.

METHOD

The findings presented here were obtained from a survey of 121 farms selected at random from members of Mwethya groups in the following locations in Machakos District: Wamunyu, Kasii, Kalama, Kilungu and Mukaa (Figure 1). The main features of the areas chosen are shown in Table 1. Data were collected on the main cultivated area of each farm and on cutoffs where present observations on the grazing land were noted in passing. A total of 745 terraces were examined and the information obtained was recorded on pre-coded forms for computer analysis. The two main variables which were thought to have the greatest influence on potential erosion were climate, for which altitude, measured with an altimeter, provides an approximation (Trapnell et. al. 1960), and land slope which was measured with an abney level. Observations on terraces were confined to a transect 10 metres wide running from the top to the bottom of the main garden. Bank height was measured with a tape to the nearest 10 cm. Spacing was determined to the nearest metre by pacing, and errors were reduced by periodic checks against the tape. Information on certain features, e.g., erosion on banks, erosion between banks and adequacy of the lip, was recorded by scoring from 0 to 5. It would be difficult if not impossible to find satisfactory quantitative measures for erosion, and scoring seemed to offer the best alternative. Observers compared their individual estimates in order to maintain consistency as far as possible. Soil samples were taken from a number of farms and a record was made of soil colour, presence of stones or laterite, soil clodiness and whether drainage appeared to be free or impeded. The method of cultivation was ascertained from the farmer and a note was made of ridging where it occured. The main crop or crop combination growing on each terrace was also recorded.

Table 1. Altitude zones and ecological factors.

Altitude zone	Location	Estimated Rainfall	Approximate Correspondence with Kenya Atlas Zones of Ecological Potential (Survey of Kenya, 1972)	Characteristic Vegetation
I: 1000- 1199m	Wamunyu	500-625 mm	Semi arid-arid (zones IV & V)	Acacia/Commiphora on slopes & Combretum/Acacia on ridge tops. Common grasses include Chloris roxburghiana and Enteropogon macrostachys.
II: 1200 - 1399	Masii	625-750mm	Dry sub-humid/semi-arid (zones III & IV)	Combretum/Acacia. Terminalia brownei common.
III: 1400 - 1500	Kalama	625-750mm	Dry sub humid (Zone III)	Upland Acacia woodland and hill combretum. Common trees - Acacia gerardii, Acacia nilotiia, Acacia seyal, Acacia hockii. Lantana Camara locally common.
IV: 1600 - 1799	Kalama Kilungu Mukaa	750-875 mm	Sub-humid (Zones II & III)	Evergreen bushland characterised by Dodonea viscosa. Acacia hockii common. Euclea sp., Scutea sp. & Carissa edulis found in thickets.
V: 1800 - 1999	Kalama Kilungu Mukaa	875-1125 mm	Humid - subhumid (Zone II)	Forest scrub with remnants of indigenous forest. Plantations of wattle are common. Kikuyu grass occurs locally. Pennisetum catabasis and Digitaria scalarum common.

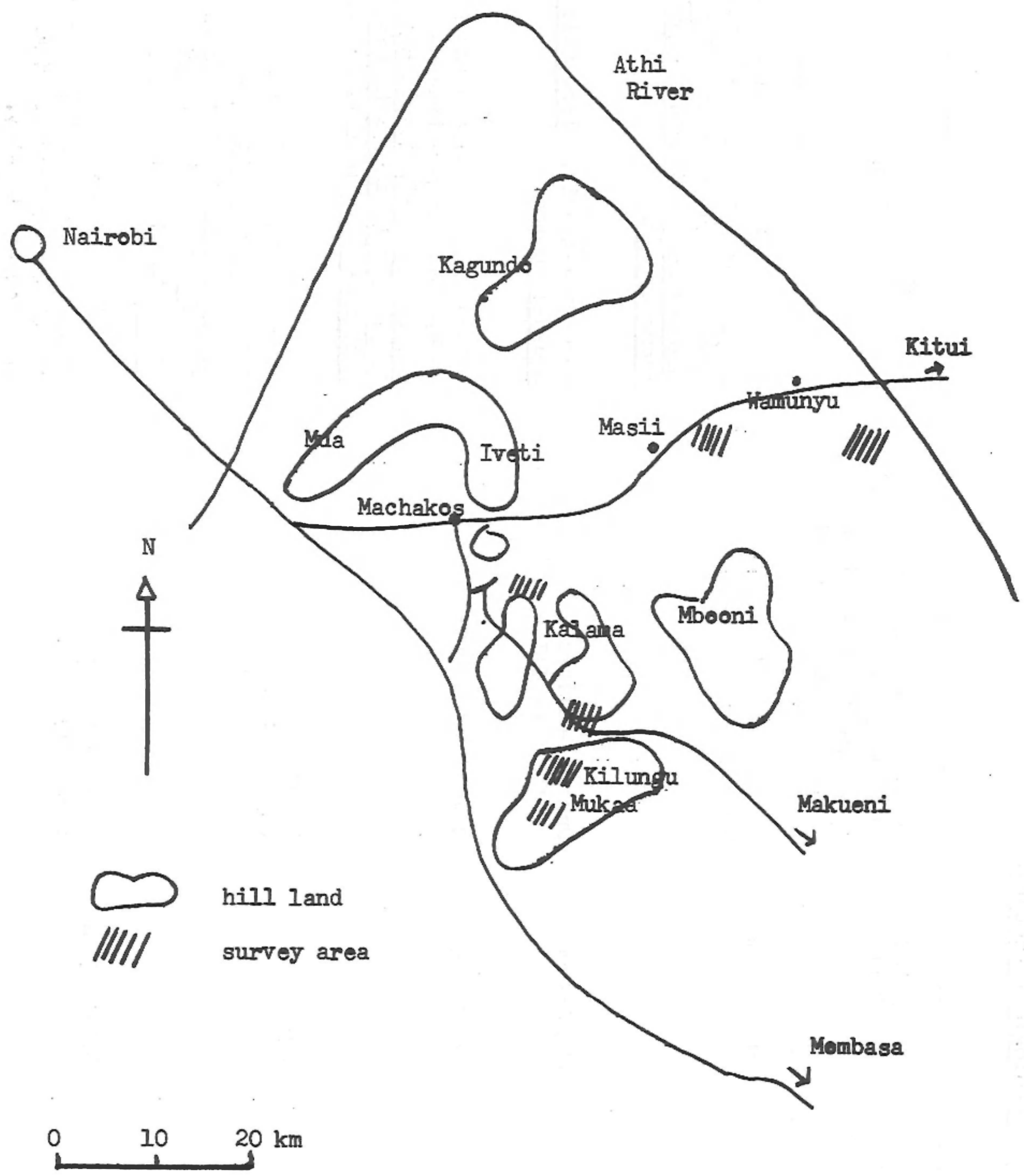

Figure 1. Location of survey.

RESULTS

The main results of the survey are summarised and discussed in four sections. The first deals with the slope of the cultivated land, the second with cutoffs, the third with terraces and the last summarises observations on grazing land. Rainfall during April 1977 was much above average and erosion was more evident than usual. This helped to indicate the relative seriousness of the erosion problem in different zones and on different farms.

Slope of Cultivated Land

The distribution of farms according to slope class is given in Table 2. The slope referred to is the overall land slope from the top to the bottom of the main garden, ignoring any modifications which may have been made by terracing. The figures show that all cultivated land is sloping, that 31 per cent of all farms surveyed had cultivated land over 9^{o} (approximately 16 per cent slope) and that in altitude zone V (represented by higher parts of Kilungu and Mukaa) 91 per cent of the cultivated land surveyed is over 9^{o}. The significance of a 9^{o} slope is that it represents roughly the upper limit for tractor cultivation. The system of land capability classification developed in the U.S.A. would place such land in the non-arable category, but as most of the practices of soil conservation were developed there for mechanised farming on lower slopes they cannot be applied to the problems of the steeper areas surveyed in Machakos.

Farms in slope class 6 are either at or over the present legal limit of 35 per cent for cultivated land. Out of the total of 121 farms surveyed, 13 per cent are in this class, and of the 22 farms surveyed in the highest altitude zone where rainfall is greatest, 50 per cent are in this class. Of the farms surveyed, the steepest land under cultivation had a slope of 26.5^{o} (50 per cent) but some cultivated land which was not included in the survey was even steeper than this. The problems of land use and soil conservation on such slopes urgently need investigation, particularly in view of the fact that proposals have been made to legalise existing practices and allow cultivation on up to 55 per cent slope.

Cutoffs (Diversion Ditches)

Most of the farms which appeared to need cutoffs actually had cutoffs. Out of 52 cutoffs examined 22 (42 per cent) were completely adequate,

Table 2. Distribution of farms according to slope class (figures for % slope are approximations).

ZONE	SLOPE CLASS 1 $\leq 1^{\circ}$ $\leq$2%	2 1°–2.5° 2–4%	3 2.6–4° 4–8%	4 5–8° 8–16%	5 9–18° 16–34%	6 $>18^{\circ}$ $\geq$34%	TOTAL FARMS
I 1,000 - 1,199m	0	0	8 36%	14 64%	0	0	22 100%
II 1200-1399m	0	4 16%	16 64%	5 20%	0	0	25 100%
III 1400-1599m	0	1 3%	8 21%	20 52%	9 24%	0	38 100%
IV 1600-1799	0	0	0	5 36%	4 28%	5 36%	14 100%
V 1800-1999m	0	0	0	2 9%	9 41%	11 50%	22 100%
TOTAL FARMS	0 0%	5 4%	32 27%	46 38%	22 18%	16 13%	121 100%

but 30 (58 per cent) were deficient for a variety of reasons, of which the most common was siltation of the channel. Twenty-nine (56 per cent) of the cutoffs were open at the end to permit discharge of water, but of these 9 (31 per cent) discharged onto bare or nearly bare earth and 4 (14 per cent) discharged onto a stock track or foot path.

In general, the need for cutoffs has been accepted and the problem of siltation and discharge areas are closely linked to the failure to maintain adequate cover on the grazing land. The importance of regular maintenance needs to be emphasised, as failure of a cutoff can easily lead to gully formation. In a previous study using aerial photos (Thomas 1974) one gully was observed which had extended approximately 200 metres between 1948 and 1972 as a result of the failure of a cutoff.

The problem of cutoff maintenance is complicated where cutoffs pass through land belonging to different land owners, and it would be an advantage if Mwethya groups could take responsibility for conservation on a catchment basis to facilitate coordination. The problem of finding suitable discharge areas needs investigation. In some places there is difficulty in demarcating and protecting grassed waterways especially where most land is under cultivation. If no natural waterway exists, the use of stone lined channels and drop structures will be required. (Sheng 1977)

Terraces

Terrace type and conformation. For the purpose of the survey, terraces were classified as follows:-

1. Narrow based

   (a) Ridge type: in which there is no change in the ground slope and no excavated channel on the upper side, either because it has never been constructed or has become silted up.

   (b) Channel type: in which there is no change in the ground slope but there is a definite channel on the upper side of the ridge. The largest are similar to cutoffs.

2. Bench type

   (a) Forward sloping: in which there is a bank of sufficient height to reduce the slope of the cultivated land. Most of these terraces have been constructed by the fanya juu method.

   (b) Level: in which banks are of sufficient height to completely level the cultivated area.

   (c) Backward-sloping: in which any runoff accumulates at the rear of the bench. This is often considered to be the ideal arrangement (Sheng 1977) but is rarely found in practice.

The classification is based on the existing conformation of the terrace at the time of the survey, rather than on the initial conformation or method of construction. (See Figure 2.) Only 2 out of 121 farms visited were found to be without terraces. This indicates the almost total acceptance of terracing as a method of soil conservation on cultivated land. Out of 745 terraces examined, 708 (95 per cent) were bench type, but of these only 38 per cent were level, the balance being forward sloping. There were no backward sloping terraces. With increasing ground slope the proportion of level bench terraces drops from 100 per cent in slope class 2 to 18 per cent in slope class 6 (Table 3).

Table 3. Slope of bench type terraces in relation to ground slope.

Slope Class	Number of terraces in each slope class						
	1	2	3	4	5	6	Total terraces
	<2%	2-4%	4-8%	8-16%	16-34%	>34%	
Forward sloping terraces	0	0	72 40%	218 71%	91 76%	56 82%	437 62%
Level terraces	0	30 100%	110 60%	90 29%	29 24%	12 18%	271 38%
Total terraces	0	30 100%	182 100%	308 100%	120 100%	68 100%	708 100%

The main objective of terracing should be to reduce slope length and/or slope angle. Forward sloping bench terraces are only a partial answer to the erosion problem. Runoff inevitably accumulates at the front edge and unless there is an adequate lip or ridge, water will pass over the edge and may erode the bank in the process. At least one third of all bench type terraces had no lip or a lip which was very inadequate, and the importance of this feature is often overlooked. The ideal bench terrace for humid areas has a slight backward slope (Sheng 1977) but in sub-humid or semi-arid areas a level bench with an adequate lip is probably ideal. One farm was visited near Kola which had very well constructed level terraces and also excellent crops. The terraces were designed to catch and retain all rainfall and the owner had even diverted runoff from a neighbour's land to the benefit of his own pigeon peas!

The spacing of terraces is generally less than 15 metres and in slope classes 5 and 6, 86 per cent are less than 10 metres wide and 35 per

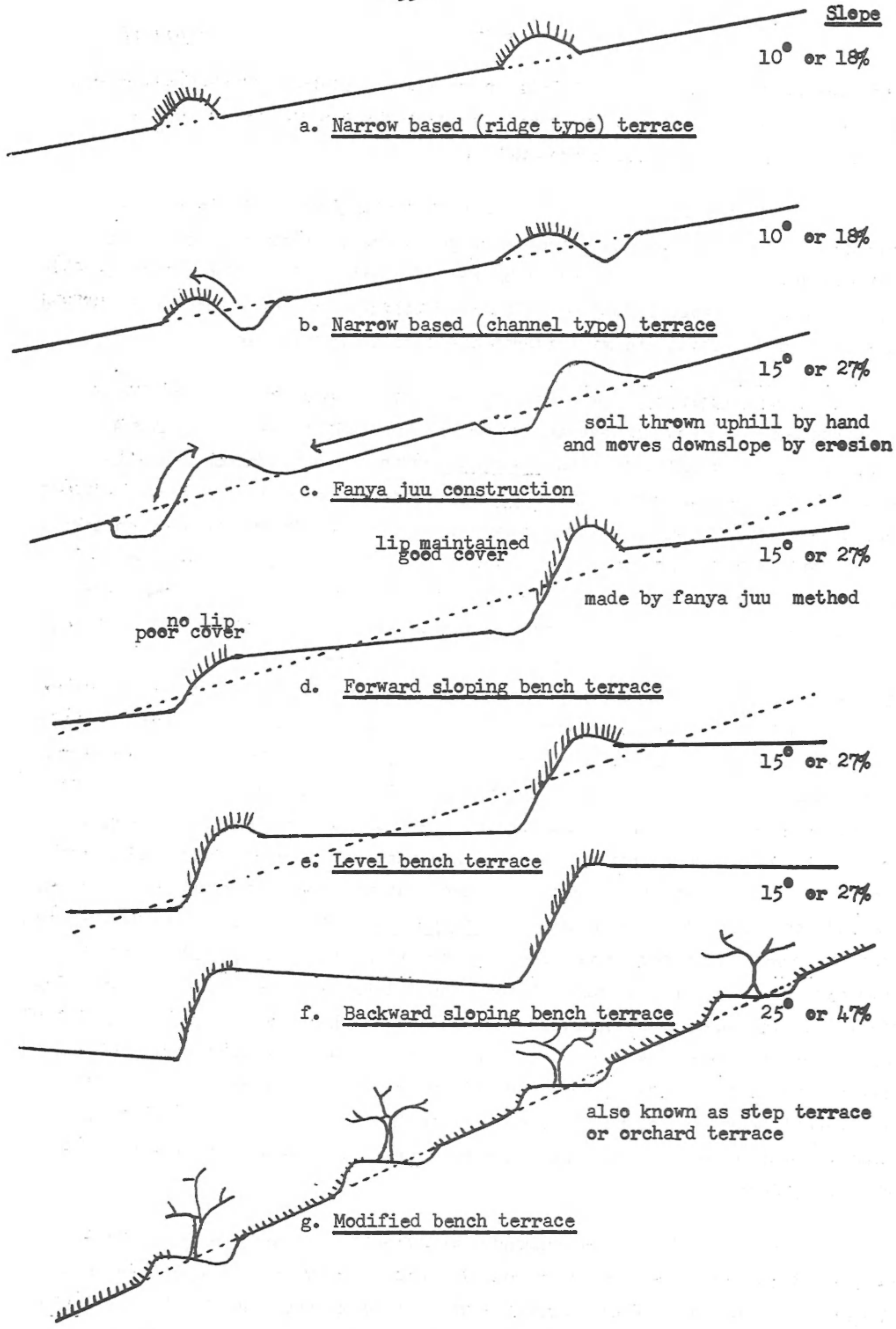

Figure 2. Alternative methods of terracing.

cent less than 5 metres wide. This is no doubt one reason for the fact that in the hill areas cultivation is mainly by hand whereas in the lower and flatter areas ox cultivation predominates.

In slope class 2 (2 to 4 per cent) the height of most banks is in the range of 0 to 50 cm. On steeper slopes there is a wider range of bank heights and in slope class 6 (over 34 per cent) most of the banks (86 per cent) fall in a broad range from 50 to 200 cm in height. One farm (not in the survey) has ladders to facilitate moving from one terrace to the next!

There appears to be a need for specific recommendations on terrace construction. To what extent and under what circumstances is the forward sloping bench constructed by the fanya juu method a satisfactory solution, and what priority should be given to the construction of level terraces? Level bench terraces were originally thought of as the solution to erosion on steep slopes and were recommended for slopes of 20 to 35 per cent. However, they are in fact more common on low slopes (Table 3) and there are several reasons why they may not always be appropriate on steeper land. On the flatter land, which is mainly in the drier areas, level bench terraces encourage maximum infiltration where lack of water is often the main factor limiting crop growth, and they promote uniform infiltration which a forward sloping bench with a lip at the front does not. There is good reason for putting emphasis on the construction of level terraces in these areas. In the hill areas however, where slopes are steeper and rainfall higher, there are three problems in making level bench terraces. First, if soils are shallow, level terraces will reduce the rooting depth at the rear of the bench and may expose the subsoil or rock. Second, construction in stages by the fanya juu method leads to a considerable risk if heavy rains come soon after construction, and third, banks which are too high or too nearly vertical become unstable in periods of heavy rain. One farm (not included in the survey) was visited which had well-made level terraces on a slope of approximately 29° (55 per cent). The banks, which were over 2 metres high but well vegetated, had collapsed in a number of places due to the recent heavy rains and the same problem had been experienced in 1961. A similar problem was encountered after heavy rain in the Uluguru mountains in Tanzania (Temple 1972).

Wenner (1976) has recommended modified bench terraces (also known as step terraces or orchard terraces) for slopes between 35 and 55 per cent (Figure 2). In this method, narrow level strips are constructed for planting fruit trees and the intervening land is left in grass. This appears to be a sound approach, but so far no attempt at implementation has been observed. Present policies need to be re-evaluated, as there is some uncertainty among field staff on what recommendations to make for conservation on steep slopes and there is a strong case for experimental work to evaluate different methods. The height, angle and vegetative cover are all factors which influence bank stability and for which recommendations are needed when constructing bench terraces.

Vegetative cover of banks. In zones I and II (1000 to 1400 metres) the cover of banks is provided mainly by self sown grasses and weeds. The white flowered, trailing weed *Ipomea sp.*, was conspicuous on banks in zone I at the time the farms were visited; Makarikari grass assumes increasing importance in zones III and IV, and in zone V other grasses, particularly *Brachiaria sp.* and *Setaria sp.*, play an important role. Makarikari grass sometimes forms a poor cover on account of drought, termites and/or overgrazing. *Brachiaria* and *Setaria* are preferred in the hill areas because of their more erect habit, which acts as a mechanical barrier to the downward movement of soil, and because of their value as fodder for animals. However, on account of their tufted habit *Setaria*, and to a less extent *Brachiaria*, are not entirely satisfactory for stabilising banks. Other grasses which are used include *Panicum maximum*, *Cenchrus ciliaris*, Napier grass, *Hyparrhenia lintonii* and *Panicum trichocladum*. The last variety was only seen on one terrace (in Kilungu), but appears to give a very effective cover.

A small number of farmers had crops growing on the banks - a practice which should be firmly discouraged as it defeats the whole purpose of bench terracing. A rather alarming proportion (22 per cent)of terraces in zone V had virtually no cover on the banks. Some of these may have been constructed recently, but the erosion which occured on such banks during the recent heavy rains serves to emphasise the urgency of establishing a proper vegetative cover. In the lower altitude zones, establishment of cover is also important but the risks of erosion are much less because of lower bank heights.

In an experiment carried out at Katumani (Thomas 1961), the edge effect of different bank covers was studied and it was found that Makarikari grass was very competitive and affected crop growth for up to 1.8 metres from the edge of the bank. Stone proved to be a much more satisfactory cover. It has been widely used in parts of Europe, the Middle East and Ethiopia (Maher 1973, Huffnagel 1961) and there may be some situations where it could

Table 4. Vegetative cover of banks.

ZONES	Bare	Cropped	Self sown grass/weeds	Napier/ Bana	Makari-kari	Other	Not ascer-tained	Total Terraces
	Number of terraces with different types of cover							
I 1000-1199m	12 9%	15 11%	101 72%	0	7 5%	5 3%	0	140 100%
II 1200-1399m	3 2%	8 5%	132 86%	0	10 6%	1 1%	0	154 100%
III 1400-1599m	29 11%	9 4%	93 36%	0	97 38%	25 10%	3 1%	256 100%
IV 1600-1799m	5 8%	1 1%	13 20%	1 1%	38 58%	8 12%	0	66 100%
V 1800-1999m	22 24%	5 5%	17 18%	2 2%	11 12%	36 39%	0	93 100%
Total terraces	71 10%	38 5%	356 50%	3 1%	163 23%	75 11%	0	709 100%

be used in Machakos District. However, its use is likely to be limited, and further work on the suitability of different covers for different zones is needed. A proposal has been made to encourage tree planting along the edge of bench terraces, but the effect on the adjacent crops should be evaluated before such a policy is advocated. One farmer in Kangundo is proposing to remove macadamia trees planted along the edge of terraces because of competition with the adjacent coffee crop.

Extent of erosion on terraced land. As mentioned earlier, it is not possible to quantify erosion in this kind of a survey but it is possible to say that erosion is greatest where terraces are forward sloping, where the lip is inadequate and where vegetative cover of banks is poor. On a number of farms erosion of cultivated land has been almost eliminated by attention to these points, and it should be possible to reduce erosion markedly if the general level of conservation measures could be raised to that of the best farmers. However there are a number of problems, particularly with regard to terracing on steep slopes, for which further investigation is needed. Whereas terracing and control of erosion on cultivated land in the lower and flatter areas is relatively straightforward, the problem of erosion on grazing land in these areas is serious and appears to be much harder to solve.

THE GRAZING LAND

Although the survey was concentrated on the cultivated land where Mwethya groups have been most active, it was noticeable that much grazing land is bare, that degradation is taking place quite rapidly and that little is being done about it. The drought which occured during the last few years in combination with overgrazing and damage by termites has caused many grass plants, even very drought resistant ones like Cenchrus ciliaris, to die out. The extent of erosion by raindrop splash is shown by the way in which roots are exposed. Inspite of heavy rain during April 1977, revegetation has been very slow - a problem which has been noticed also in Northern Kenya (Lamprey 1977) - and in very few places was any attempt seen at re-establishing grass. On some denuded land a series of cutoffs had been constructed, but these would doubtless silt up rapidly due to lack of cover on the intervening ground. The problem of termites appears to be acute. They were seen attacking some live grasses and even bushes. Leparge (1977) quotes instances where the biomass of termites can equal that of livestock, and the destructive potential appears to be aggravated by overgrazing (Lee and Wood 1971). An additional obstacle to the re-establishment of grass is the capped surface of the ground which provides a hostile environment for seedlings. On a number of farms, grazing has been protected and the contrast with the surrounding denuded areas provides a useful reminder that the land is capable of supporting a good cover of grass. It is worth remembering that the potential quality of grassland is very high, particularly in the lower areas, and one of the main grasses, Cenchrus ciliaris, has been used extensively to establish pastures in the drier parts of Australia. The effort at present devoted to digging cutoffs on grazing land would have a much greater impact on the erosion problem if it were devoted to re-establishing grass cover. The prime cause of erosion is the impact of raindrops and not water flowing over the surface (Hudson 1971), and control measures on grazing land should emphasise the importance of vegetative cover. However, on cultivated land where annual crops are grown, mechanical methods of control such as cutoffs and terraces are of great importance because of the difficulty of maintaining cover by means of perennial crops or the use of grass in rotation.

CONCLUSIONS

The survey described gives some preliminary information on the problems of soil conservation in Machakos District. Much work has been, and is being, done to control erosion, and the example of the best farms shows that erosion can be greatly reduced. Methods of conservation appropriate to different situations and specifications of structures such as terraces need to be more clearly defined and a number of problems need investigation, particularly appropriate conservation methods for steep slopes. The importance of plant cover in reducing erosion both on grazing land and on terrace banks should be emphasised.

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SPECIFICATION, CONSTRUCTION AND USE OF THE METRIC LINE LEVEL

by

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INTRODUCTION

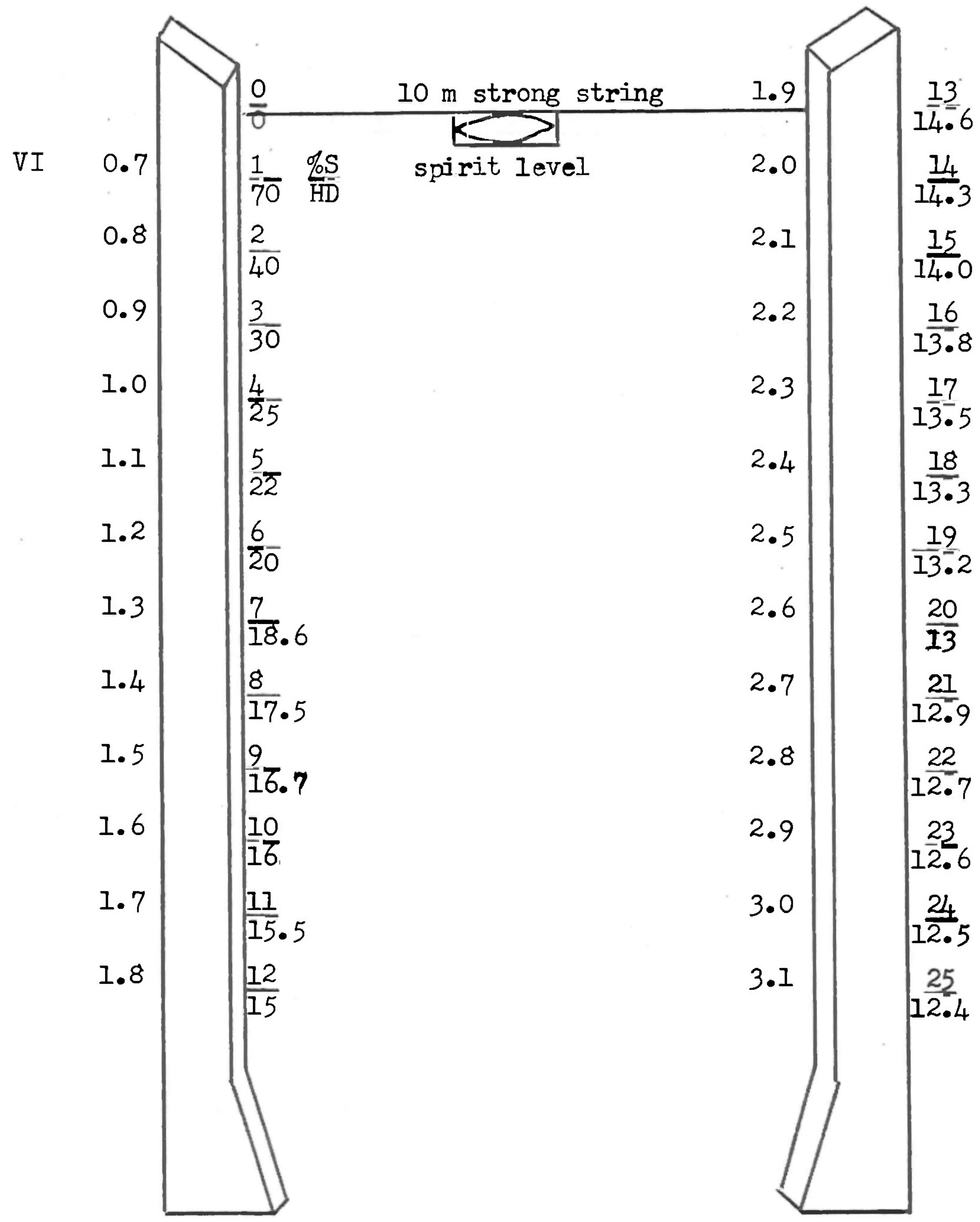
This paper gives some simple specifications and instructions for the construction and use of the line level, originally designed by D. Layzell, then the Provincial Surveyor, in April 1968. A completely new version is presented here, intended for use by agricultural training institutions, colleges and schools and by field extension workers who are responsible for laying out various soil and water conservation structures.

The advantage of the line level described here is that it can be manufactured very simply using inexpensive materials. Imported equipment of this type is extremely expensive, and even repairing old equipment with imported parts involves considerable expense. Yet it is essential to have a line level to check and maintain pre-existing conservation structures and to site and lay out new, badly needed structures and other measures such as terraces, drainage lines, bench terraces, strip or contour cropping, field drainage and irrigation systems.

In addition to being inexpensive and simple to construct, a line level to be used in Kenya must conform to the metric system, as specified by government policy. Most of the maps, plans and sections used today for field extension work are expressed in metric units. For example, contour intervals are expressed in metres, so that graded contours or terraces must be designed, set, laid out, constructed and finally checked in terms of metres. The cross section of a broad based terrace is calculated in square metres; the soil excavation required to construct such a terrace or a dam embankment is measured in terms of cubic metres; data collected for a watershed or catchment area are expressed in terms of hectares; the quantity of water expected to be available behind a dam or from a borehole is expressed in terms of litres. Absolutely everything has 'gone metric', and the metric line level is designed specifically to be used with the metric system.

Because it is an inexpensive and simple piece of equipment, the metric line level can be widely used to carry out field extension work in Kenya. In particular, the use of this tool should help to implement government soil and water conservation measures, as very rightly advocated by His Excellency, The President Mzee Jomo Kenyatta, who has said: 'Save our mother soil, our natural heritage'.

CONSTRUCTION AND USE OF THE METRIC LINE LEVEL



Specifications

- 10 metres fine strong string (plus a little extra for tying on sticks), hooking spirit level, 4 screws
- 1.53 m long (high)
- 4 cm wide
- 2 cm thick
- 3 cm bevelled
- 10 cm handle
- 12 x 10 cm graduations
- 20 cm screwed stand
- 10 cm bottom stand width

Spacing of Terraces

The metric line level can be used for all setting and laying out of terraces and other conservation, irrigation and drainage structures. The spacing (setting) for graded and retention terraces is calculated in two steps:-

(1) $\frac{S}{10} + 0.6 = VI$, and

(2) $\frac{VI}{S} \times 100 = HD$[1]

The spacing (setting) for bench terraces is calculated as follows:-

(1) $\frac{S}{20} + 0.3 = VI$, and

(2) $\frac{VI}{S} \times 100 = HD$[1]

Where: $S = \%$ slope = gradient x 100 = $\frac{VI}{HD} \times 100$,

VI = vertical interval between terraces, and

HD = horizontal distance between terraces.

For graded terraces where the land is at a 5 per cent slope, the following is an example of the calculation of spacing:-

$\frac{5}{10} + 0.6 = 1.1\text{m VI}$

$\frac{1.1}{5} \times 100 = 22\text{m HD.}$

This relationship is expressed for a number of gradients in the following table.

Percent Slope	VI	HD[1]
30	3.600	12.00
35	4.100	11.71
40	4.600	15.50
45	5.100	11.33
50	5.600	11.20
55	6.100	11.09

1. Note that the distance on the ground is often used instead of the horizontal distance because it is easier to measure and, for slopes below about 15 per cent, there is little difference between the two measures.

Land with a slope of between 25 and 55 per cent often requires bench terraces to control erosion. For bench terraces the vertical interval and the horizontal spacing is normally half the intervals and distances given in this table, e.g., for 50 per cent slope VI would be 2.8 and HD would be 5.6.

Land sloping at an angle of 45° is said to be at 100 per cent slope, i.e., VI = HD = 1.

Procedure

The two sticks are first used to measure slope by placing them 10 m apart on the ground in the direction of the slope (i.e., at right angles to the contour). The string is fixed to the top notch of the lower stick and is then moved down the upper stick until it is level. With the sticks 10 m apart, each division on the sticks represents 1 per cent slope and, as there are 12 divisions, slopes up to 12 can be measured. For steeper slopes the string is reduced to 5 metres (or 2.5 metres) and each division then represents 2 per cent (or 4 per cent) slope.

The figures shown are marked on the sticks to save calculating VI and HD. The figures above the lines on the right side of the sticks are percentage slope. Those below the lines are horizontal spacing between terraces. The figures shown on the left of the sticks are vertical intervals between terraces.

SOIL AND WATER CONSERVATION ON SUBDIVIDED LARGE-SCALE FARMS IN UASIN GISHU

by

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Soil Conservation Service
Eldoret

The large-scale farms in Uasin Gishu District originally were set out with terraces, ditches and other soil conservation structures. The planning and designing of these structures was done separately for each farm, rather than regionally as was done in other parts of Kenya. Waterways were, in many instances, laid out along farm boundaries.

Many of these large farms have recently been subdivided into small individual plots, and, on company and society farms, the layout of these plots often fails to take account of pre-existing conservation works, so that plot boundaries are found crossing terraces and ditches. In an effort to ensure that every partner is allotted the exact acreage which he paid for, no attention is given to the proper planning of the drainage system, access roads, livestock dips or other public utility areas. This is in contrast to the settlement schemes, which have been properly planned and demarcated by the staff of the Soil Conservation Service.

During recent heavy rains, there were serious soil losses on some of the company and society farms, and many requests were received by the Soil Conservation Service for help in the construction of terraces. On these farms, the Soil Conservation Service finds it difficult to carry out conservation work now because of the haphazard way in which development took place in the past. For example, some houses have been constructed in what are natural waterways. Ideally, the plots should be redemarcated and land use replanned on proper conservation lines. In view of the rate at which new buildings are being constructed, it is imperative that sound conservation planning be implemented immediately.

WORK DONE BY THE SOIL CONSERVATION STATION AT MARIAKANI, COAST PROVINCE

by

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It was recently reported in newspapers around the world that the Sahara Desert is expanding at the rate of 30 miles a year, and similarly the arid areas of Coast Province in Kenya seem to be expanding so quickly that the Province could turn into a desert before the turn of the century. The measures which have been applied to control this situation up until now seem to have had very little effect.

The solution to this urgent problem is conservation of the soil and the provision of an adequate supply of water. Every possible measure must be taken to conserve the soil and water resources of the province, and this must be done quickly if it is to be effective. The soils tend to be sandy and thus are easily washed away by heavy rains, and ultimately into the sea. As a preventative measure, the Kenya Government opened the Mariakani Soil Conservation Unit at the Coast in 1966 under the Land and Farm Management Division of the Ministry of Agriculture. At first the station only carried out soil conservation measures, such as terrace building, farm planning, bush clearing and levelling. Over the years, however, the need for water conservation became clear, and so the station became involved in dam construction and to some extent in irrigation projects along the Sabaki and Tana Rivers. Together with the Ministry of Lands and Settlement, the station has assisted with land demarcation programmes, particularly in Lamu District at the Lake Kenyatta Settlement Scheme (Mpeketoni) and in Kwale District at the Ukunda and the Salim Road Schemes. Although originally planned as a temporary measure, the station has by now demonstrated its importance as a permanent institution at the Coast. In fact, the station receives so many demands for assistance with soil and water conservation work that the staff finds it difficult to meet them all.

Realising the seriousness of erosion problems, especially in the agricultural areas, the Kenya government has decided to equip the Ministry of Agriculture's Soil Conservation Services with modern machinery. As more land comes under agricultural production in Kenya, the danger of soil erosion becomes more acute, and the level of agricultural output is threatened. For example, farmers who have no other land are forced to cultivate on steep slopes and river banks, and overgrazing becomes a more serious problem in arid and semi-arid areas. Soil erosion caused in this way leads directly to the silting up of beaches at the Coast and inland lakes such as Baringo and Nakuru.

Althought this is a national problem, soil and water conservation measures must be carried out at the local grassroots level. The Soil Conservation Service Units around the country, with their heavy earth moving equipment, can only actively intervene in the large farming areas, as the measures they undertake are not suitable for small plots. However, these units are ready to give technical advice to all farmers throughout the Republic. Our most important natural resources, the soil and water, can be safeguarded if individual farmers, the communities and government agencies at all levels make every effort to implement conservation measures.

CROPPING SYSTEMS FOR SOIL CONSERVATION IN KENYA

by

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SUMMARY

In the Eastern Province of Kenya, approximately 70 per cent of the erosive rainfall occurs during the first thirty days of the rainfall season. No annual crop can provide efficient leaf cover during this time. There are practical disadvantages with alternative means of covering the soil. Great emphasis must therefore be placed on mechanical measures for soil and water conservation. In areas with a longer rainy season, the growing of mixed crops would improve soil cover in the early part of the season when pure maize is deficient in cover.

INTRODUCTION

The principles of crop management for soil conservation have been derived largely from work in the U.S.A., but seem to be applicable in most parts of Africa. Hudson and co-workers (see the many examples in Hudson 1971)have carried out extensive work at the Henderson Research Station in Rhodesia, and Elwell and Stocking (1973) have analysed the erosivity of rainfall in this environment. Kowal and associates (see Kowal and Kassam 1976) have studied erosivity in northern Nigeria, and Lal (1974) has given some interesting comparisons of runoff under different crops and crop mixtures in South Western Nigeria. Within East Africa, Rensburg (1955) showed much heavier soil loss under cultivation than under grass in Central Tanzania, and Pereira et al. (1967) studied the effects of tied ridges, terraces and grass leys on the deep red volcanic soils typical of Kenya's Central Province. Ahn (1975) gives a useful discussion of erosion hazard in relation to farming systems in East Africa, concentrating on observational rather than experimental studies.

1. The author is grateful to Mr. O.I.J. Ogombe for leaf area data for pigeon peas and to Mr. D.B. Thomas and Mr. R. Barber for many discussions on soil conservation, the fruit of which is undoubtedly to be found in this paper. The stimulus was provided by Professor N. Hudson on his recent visit to Nairobi.

From this and similar work, emerge two general principles of management of annual crops for reduced soil erosion, and these are well summarised by Hudson (1971, chapter 11). They are firstly to grow crops in such a way as to maximise the soil cover by the leaf canopy, which means the use of high plant densities and fertilisers, and secondly to use the residues of the crop to provide some soil protection after harvest and into the early part of the subsequent season. Admirable as these principles are, there are major problems in applying them in the marginal, bimodal rainfall areas of Eastern Province, and it is on these problems and their possible solutions that this paper will concentrate.

THE RAINFALL SEASONS IN EASTERN KENYA

In the parts of Eastern Province which are intensively settled by crop farmers, the most important crop is early-maturing maize, with bulrush millet (*Pennisetum typhoides*) and sorghum common in the lower and drier areas. Pigeon peas of about 240 days duration, cowpeas and at higher altitudes, beans (*Phaseolus vulgaris*) are the most important legumes. Annual cash crops are not well developed but include cotton, tobacco and some sunflower. Kitui (altitude 1,117m) is fairly typical of the wetter parts of the area which are used for crop production. Only in November, December and April does the monthly median rainfall exceed $\frac{2}{3}$ Eo, an estimate of the water requirement (Figure 1). Even in December, the rainfall is less than $\frac{2}{3}$ Eo more often than one year in four, and in some years March rainfall exceeds this figure. In the wet months, November and April, there is a considerable surplus of rainfall almost every year, and much of this at present runs off. There is a long dry season from May to September or October and a relatively short, though hotter dry season in January, February and in some years, March.

There are two cropping seasons: the most reliable one begins in late October or early November with reasonable chance of rain through December and sometimes into January; the other begins in late March or early April, but rainfall in May is unreliable and in June is usually absent. In each season, maize, millet, cowpeas and beans are planted but frequently fail. Pigeon peas, cotton, and long duration sorghums are generally planted in October or November. The sorghum is often ratooned so that fresh tillers can take advantage of the April rains. Pigeon peas and cotton become quiescent during January and February and then flower and fruit during or after the April rains. Complete failure on these double-season crops is comparatively rare, but yields are often low.

EROSIVITY IN RELATION TO THE RAINFALL SEASON

Thomas (1974) pointed out that in Eastern Province the heaviest rainfall usually occurs early in the season before crops can establish a leaf cover. Observation of Figure 1 would appear to substantiate this view because the months of heavy rainfall are November and April, the first months of each season. However, erosivity is a function of short-duration rainfall intensities and monthly rainfall figures are not necessarily a good guide to erosivity. Rainfall intensity recordings are rather sparse, however. A recent compilation (Lawes 1974) includes only one station in the area, at Makindu which is more representative of rangeland than cropland. However, the maximum rainfalls for one-fourth, one-half, one and three hours all occurred in April, and for six and twenty-four hours they occurred in November. Hudson (1971) considered the threshold intensity at which rainfallbecomes erosive as 25 mm/hour. Lawes reports seventeen storms with this intensity or more during nine years at Makindu, but does not indicate the date of their occurrence. The same frequency (seventeen per nine years) of total daily rainfall corresponded to a figure of 55 mm rainfall per day. Casual observation at Kabete suggests that whenever daily rainfall has exceeded about 50 mm, there has been destruction of the soil surface structure, and as it has approached or exceeded 100 mm, rills have appeared on bare land. However, short-period rainfall intensities generally decrease with increasing altitude in East Africa (Lumb 1971) which would mean a more frequent occurrence of erosive rainfall at Kitui than at Kabete. In the apparent absence, therefore, of rainfall intensity records, I have attempted to get some idea of seasonal erosivity based on daily rainfall records from Kitui, assuming an erosive threshold of 50 mm/day.

The onset of the rainfall season is here defined as the first occurrence of 50 mm of rain in not more than four days, after the first of March or the first of October. This is assumed to be sufficient to germinate the seed of an annual crop. The mean date of onset of the rains over thirty years at Kitui was the twentieth of March and the fourth of November, and the standard deviation was fifteen days in both seasons. Since there is such variation of date of onset, erosivity has been related to days from the start of the rains rather than to calendar dates. In both seasons, the probability of daily rainfall being greater than 50 mm (Table 1) is greater during the first ten days of the rains. Rainfall in excess of 50 mm/day is a very crude estimate of comparative erosivity, and again it is apparent that the greatest hazard is during the first ten days. Cumulatively, approximately 70 per cent of the erosive rain may be expected to occur within thirty days of the onset of each rainfall season. This situation is in marked contrast to that prevailing in other parts of Africa with a single much longer season, where peak erosivity coincides approximately with peak rainfall at least ninety days after the season begins. (See Elwell and Stocking 1973 for Henderson, and Kowal and Kassam 1976 for Samaru.) The corollary of this difference is that effective ground cover in annual crop production at the time of maximum erosivity in Eastern Kenya is impossible to achieve by simple improvements in management as advocated by Hudson (1971).

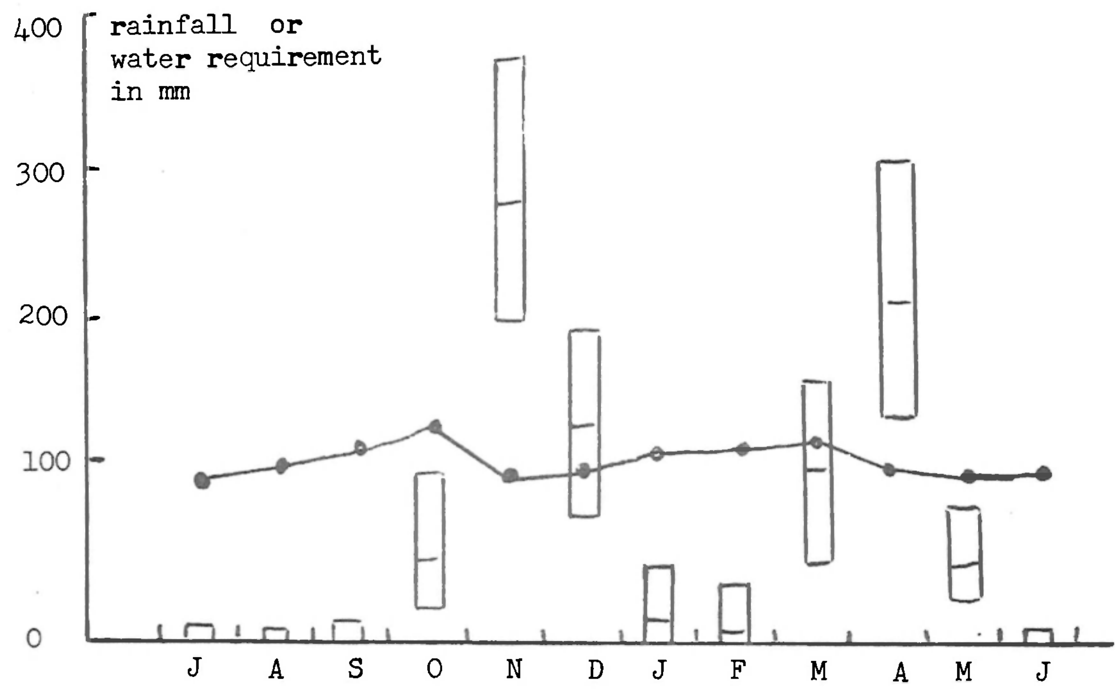
Table 1. Erosivity in relation to the rainfall season at Kitui. (Met. station No. 91.38000, altitude 1177 m, based on 30 years data between 1935 and 1970).

	Days from the start of the rains	Mean number of days per year when rainfall was more than 50 mm	Mean rainfall in excess of 50 mm/day, mm/year	Rainfall in excess of 50 mm/day, % seasonal total
March to May	1-10	0.97	28.6	51
	11-20	0.17	4.4	8
	21-30	0.27	4.4	8
	31-40	0.33	10.4	19
	41-50	0.27	5.9	11
	>50	0.13	2.0	4
	Total	2.14	55.7	
Oct. to Feb.	1-10	1.03	25.7	40
	11-20	0.40	9.6	15
	21-30	0.43	10.5	16
	31-40	0.23	7.6	12
	41-50	0.20	4.8	7
	>50	0.33	5.9	9
	Total	2.62	64.1	

GROUND COVER BY CROPS AND RESIDUES

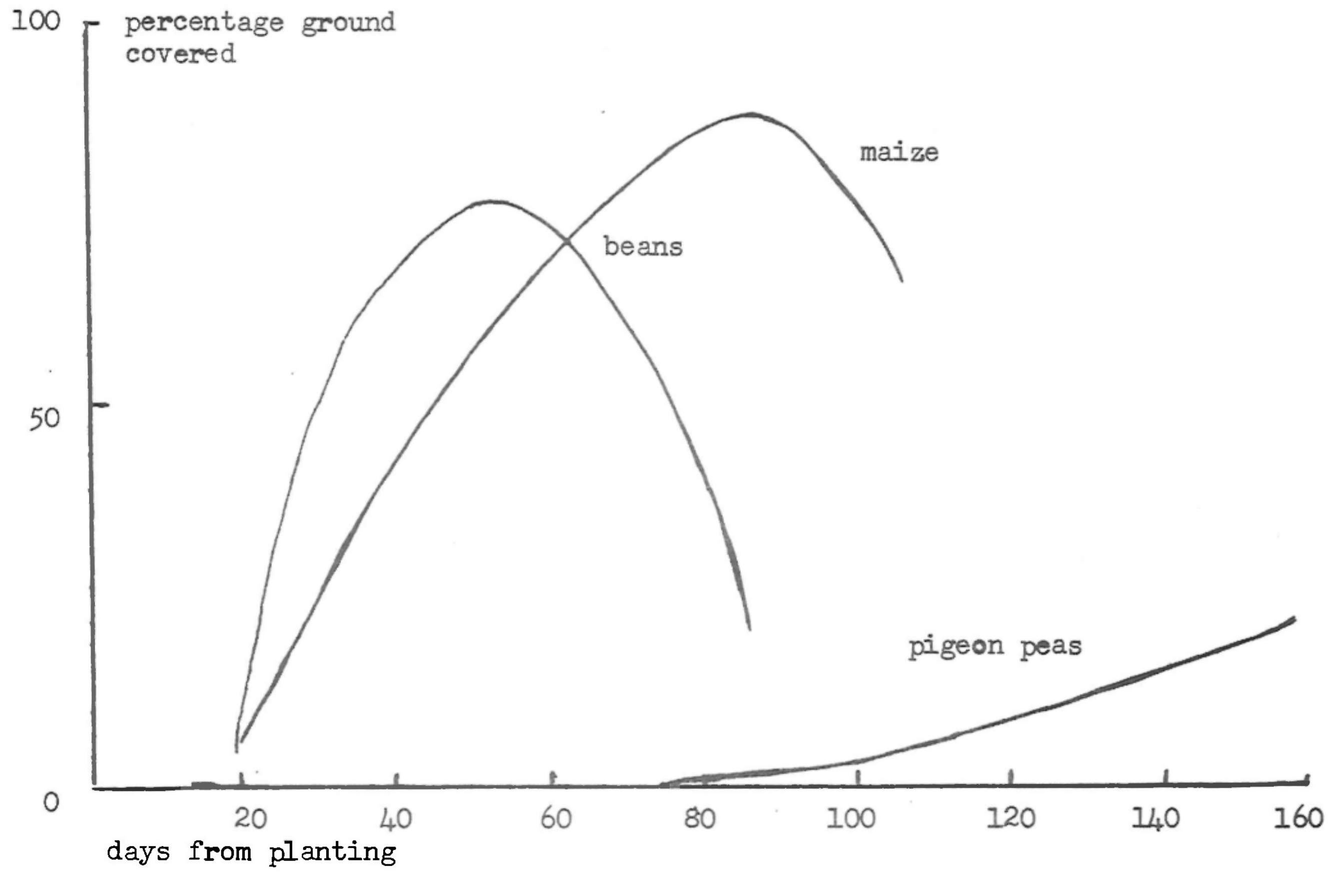
Hudson (1971) suggests a method of determining ground cover from photographs taken vertically downwards over the crop. As far as is known to the author, no such determinations have been made in Kenya. However, ground cover is analogous though not equal to light interception, and crop physiologists have ways of relating light interception with leaf area indices (L). (See for instance Monteith 1969.) Briefly, ground cover (C%) may be estimated from: $C = 100 - \exp(4.605 - kL)$, where 4.605 is the natural logarithm of 100 and k is a constant which may be considered not to vary with stage of development but does vary with the geometry of the crop, being greatest for prostrate crops and least for erect ones. It is analogous to the light extinction coefficient, but the actual value is rather lower because light, unlike rainfall, is incident in part at angles departing greatly from the vertical. Figure 2 shows the variation of ground cover with days from planting, assuming

Figure 1. Monthly rainfall and water requirement at Kitui.



Note: The upper and lower extremeties of each bar represent the upper and lower quartile of rainfall respectively. The horizontal line dividing the bar is the median. Rainfall is based on 39 years of records (1930-1971) which have been transformed to correct for skewedness. The crop water requirement, shown as joined points on the graph, is two-thirds of potential evaporation according to Penman as given by Woodhead.

Figure 2. Estimated percentage ground cover for three crops (estimated as described in text).



values of k = 0.54, 0.62 and 0.67 for maize, pigeon peas and beans respectively and using leaf area data from high-yielding crops of maize at Kitale (Law and Fisher unpublished manuscript), beans at Kabete (Fisher 1975) and pigeon peas at Kabete (unpublished data of O.I.J. Ogombe). Beans and maize began to give some cover about twenty days from planting, and between twenty and sixty days, beans were rather better than maize. Maize gave better cover later in the season. Pigeon peas were very slow to give effective protection. In this crop, at a density of ten thousand plants/ha, ground cover was never greater than 25 per cent, which was reached at 150 days after planting. A much higher density of 80 thousand plants/ha, which did not give a significantly higher seed yield achieved about 63 per cent ground cover at peak. At no stage in their life cycle, however, can pigeon peas be considered a good cover crop, though they are better than nothing. At the lower altitudes, with higher temperatures, the time scale of Figure 2 will undoubtedly be telescoped, but it is unlikely that even well-grown crops of beans can reach 50 per cent ground cover earlier than twenty days, and maize earlier than thirty days after the rains begin. They therefore contribute almost nothing to erosion control in those critical early days.

Soil cover in the early days might be provided by use of the residues of the previous crop or by the importation of mulch onto arable fields. Neither of these options is at present available however, nor will they be without drastic alteration of the people's attitudes, because any residue or mulching material also provides food for the animals which are often very short of dry-season fodder. White ants cause a very rapid destruction of crop residues, and the amount produced in these two-month growing seasons is inevitably very low; sometimes it is virtually zero. Even the exclusion of all livestock from the cropped areas might not therefore ensure adequate residues surviving to the next season. The maximum cash return available from such marginal lands is unlikely to allow for less conventional soil protection by plastic or soil additives. Long-duration crops might give some protection to the soil early in the April season, but after a dry January and February they are unlikely to carry much leaf.

One possibility which is worth examination would be the interplanting of a prostrate leafy species, possibly a legume, into the previous crop to remain as a living soil cover through the dry season and to be killed either by herbicide or by severance of the roots just before the new crop is planted by zero tillage. However, establishment difficulties would certainly occur in many seasons, the cover would need to be protected from grazing and would deplete soil moisture which might otherwise be available for the main crop. In areas as wet as Kitui, April and November rainfall is almost always in excess of water use, and the contribution of pre-season rainfall is probably not very important. Another possibility would be to harvest only the ears of grain crops and leave the straw standing until just before the next rains in the hope that this would reduce the devastation of the ants.

It is apparent that there are considerable difficulties in achieving soil cover at the most hazardous time, and this emphasises that even with good crop management mechanical measures for erosion control remain of paramount importance. Tied ridging could do much to improve infiltration and reduce soil loss, but would do nothing to protect the surface soil from the impact of raindrops which may contribute to declining soil productivity under arable cropping, as well as to actual soil loss. Nevertheless this method probably represents the most realistic option available.

MIXED CROPPING AND SOIL CONSERVATION

As long ago as 1934, L.S.B. Leakey was at pains to point out to agricultural officers in Kenya that their enthusiasm for pure stands might mitigate against good soil conservation. It is clear from Figure 2 that maize-bean mixtures might indeed give better soil cover than either crop grown separately. During the period 20 to 50 days from planting, beans provide most of the soil cover, and after the leaves are shed from the beans the maize takes over. This may be extremely valuable in some parts of Kenya with a longer rainy season and more broadly distributed erosivity, but is of little significance in Eastern Province. It may be pertinent to note that many of the components of the indigenous crop mixtures noted by the first European observers of African farming, such as the leafy and prostrate cucurbits and sweet potato which make excellent cover crops, seem to have declined in importance during this century. Change is not always progress. Although it is fashionable to stress that the management and not the crop is the crucial factor in soil conservation, it remains true that maize is much slower than many crops to establish a good soil cover. The trend to maize as the major staple in most parts of Kenya cannot be reversed, but the acceptance of the value of interplanting this maize with a more rapidly spreading species would be of great help in the wetter areas where the interplanted crop does not necessarily affect the maize yield (Fisher et al. 1976).

FUTURE RESEARCH

It is apparent that the basic information for estimating erosivity by one of the established indices is lacking for Eastern Province. This could be rectified by the establishment of one set of runoff plots at a site at fairly low altitude where the greatest rainfall intensities will occur. In addition to this site, at least five meteorological stations throughout the province need to be equipped to measure rainfall intensity. The information would be of great use, not only to the agronomist concerned with the erosion hazard of different cropping systems, but also to the soil conservation engineer concerned with the design of mechanical protection.

I have made a number of suggestions of cropping systems which might be examined. Beside yield, agronomists could make simple measurements of ground cover at different times of the season which, when combined with rainfall intensity data, would enable the quantitative comparison of cropping systems or agronomic variables for soil protection.

Nevertheless, the probability is that the problems are not amenable to solution by crop management. Most urgent of all is therefore a reassessment of the suitability of terracing techniques now practised and an examination of methods for improving the stability of the banks. Even this will be of no avail without continuing efforts to enlist the support of the local people in conserving their soil. Already the population is so great that the importance of crops in comparison with livestock must increase, and it is no longer realistic to argue that each family needs a minimum number of stock. Because of overstocking, the livestock enterprises are in competition, rather than in symbiosis, with the cropping. This is unfortunate because fewer, well-managed livestock could contribute considerably to the maintenance of soil fertility for cropping. The social problems of reducing stock numbers are well known, but if solutions are not soon applied voluntarily, the environment will enforce its own solution.

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SOME PROMISING NATIVE LEGUMES FOR REHABILITATING DEGRADED, SUBHUMID KENYA HIGHLAND SOILS

by

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Concern is increasing over the vast amounts of top soil lost annually in Kenya, summarised by statements from the National Environmental Secretariat (1975 and 1977). The economic and environmental consequences of soil erosion spread across all activities involving land resources, affecting primarily farm and range productivity on the one hand and surface/ground water quantity and quality on the other.

It is now well accepted that for purposes of land and water resource management the most crucial phase of the hydrological cycle is the vegetation/ soil interface and that removal of vegetation starts accelerated soil erosion. It is also accepted that where some top soil remains and other plant growth factors remain unchanged, a gradual regeneration of plant cover will occur naturally.

Where no top soil or very little top soil remains however, such natural recovery is immensely delayed, especially in areas of low and irregular rainfall patterns. The little soil remaining tends to be further washed away, ultimately exposing the parent rock material. This process of progressive reduction of biological productivity leading to accelerated soil loss and eventually to near barrenness is what is currently being referred to as a process of 'desertification' (Maizels and Warren 1977).

Any plants which are capable of colonising these excessively degraded areas before this final stage is reached must be utilised in order to halt the process and to re-establish some form of protective cover and thus initiate that natural healing process of soil/vegetation recovery called rehabilitation. Trees and shrubs do not provide the immediate physical protection necessary to halt further erosion, and in any case they can hardly be established in shallow, infertile subsoils. More success may be obtained by recruiting the indigeneous, herbaceous volunteer species which may often seem useless and weedy but are ecologically very efficient in utilising the extremely unfavourable growth factors of such degraded areas. This paper attempts to bring to the attention of workers in this field some native plant species which have been observed to have eminently desirable qualities for this purposes.

ECOLOGICAL CHARACTERISTICS

Over a period of three years from 1974 to 1977, extensive field observations were carried out in the region extending roughly from Thika/Ol Donyo Sabuk to the outskirts of Nairobi and including Kahawa and Ruiru. According to the National Atlas of Kenya (1970) this region lies between ecological zone II to the west and zone IV to the east, thus falling mainly in zone III but including lower limits of II and upper limits of IV. Climatically it is therefore a transitional region. In other words, during wet years the area approximates the characteristics of zone II and in dry years those of zone IV. The years 1974 and 1975 and most of 1976 received below average rainfall, while 1977 was unusually humid.

More particular attention has been directed to a site situated within the Kenyatta University College campus at Kahawa which has approximately average conditions for the entire region. At an altitude of 1,500 metres, Kahawa receives rainfall averaging 950 mm. annually, falling in two seasons. Estimated annual potential evapo-transpiration is 1620 mm., creating a deficiency of over 600 mm. a year. Over the year, surface soil at this site has been removed by a combination of human activity and rainstorm wash so that underlying strata are exposed. Originally, the soils were a reddish-brown loam of extrusive volcanic origin underlain by either an indurated 'lateritic' crust, sometime with unconsolidated nodules, or in some areas by the parent material. It is one of these two underlying layers that is exposed when the top soil is washed away. Provisional chemical analysis shows that the soil pH ranges between 5 and 6.4, and as expected there is an extreme deficiency in nitrogen (=0.08%), organic matter (C=0.5%), and particularly phosphorus (=7ppm.). Occasional plants do in fact exhibit the usual bluish-purple colouration indicative of phosphorus-deficiency.

Loose soil material is scanty, ranging between 0 cm. and 8 cm. in depth, tending more towards the shallower end of the range but evidently also having occasional fissures that afford some degree of tap-root penetration below this depth. In the absence of the storing capacity provided by a layer of soil, the moisture effectiveness for plant growth is reduced to the level of semi-arid zones, contrary to what the rainfall figures may indicate.

LEGUMINOUS COMPONENTS OF PIONEERING FLORA

During the period of observation the following leguminous plant species were seen among the initial voluntary colonisers of this extremely degraded area:-

1. Indigofera circinella Bak.f.
2. Indigofera volkensii Taub.
3. Zornia setosa Bak.f., subspecies obovata (Bak.f.) Le'on., Milno Redh.
4. Indigofera spicata Forsk.[1]
5. Indigofera brevicalyx Bak.f.

By no means are these species the only, nor necessarily the dominant, pioneers. Indeed, depending on the peculiarities of specific habitats, other non-leguminous species do dominate - in the case of Kahawa, the tough Dyschoriste radicans and Justicia sp. (both family Acanthaceae), or the many typically aggressive annual composites and grasses. The important difference is the facility unique to most members of plant family leguminosae for converting inorganic free nitrogen into organically useable nitrogen compounds and thus circumventing soil nitrogen deficiency. This means relatively faster rates of growth and greater accummulation of organic matter by these plants in the surface layer of soil which in turn means more rapid concentration of other plant nutrients released from this organic matter. Thus soil structure, moisture retention and fertility are rapidly enhanced, creating conditions for other plants to colonise the area which before was inhospitable.

All five species share the following highly desirable qualities for soil rehabilitation:-

1. Drought resistance in years with as low as 500 mm. annual rainfall,
2. Perennial growth,
3. Surface spreading, mat-like or procumbent, clumpy habit, affording intimate soil cover. Although none possesses the added advantage of striking roots on branches, I. circinella and Zornia setosa are particularly effective in 'hugging' the soil as they branch tightly and radially from the rootstock,
4. Adequate self-seeding. This is critical if sufficient quantities of seed are to be harvested. Although none is a spectacular seed producer under field conditions, it seems possible to increase seed production under improved growing conditions, i.e. seed gardens. Some pods, particularly I. circinella, seem vulnerable to insect borers while still green.

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1. As a precaution, it should be noted that I. spicata has been shown by Chagga folk science to be somewhat toxic to gestating livestock, inducing abortion (Gillet 1958). This should not, however, preclude its use for soil rehabilitation purposes.

5. Tolerance of extremely shallow, infertile soils deficient in organic matter, nitrogen and particularly phosphorus. It should be noted that most other legumes require large amounts of phosphorus in order to nodulate and grow successfully,

6. No necessity of Rhizobium innoculation, since the local soil microflora seem to satisfy this requirement, and

7. Deep, woody tap root.

DISCUSSION AND CONCLUSIONS

Research has been carried out in several countries concerning the economic use of legumes, emphasising farm, pasture and rangeland management for both conservation and vegetative productivity. Most of this work was summed up as early as 1936 by the International Institute of Agriculture, and again in 1953 by F.A.O. (Whyte 1953, pp. 127-130). Here in Kenya, pasture and range work with legumes, especially introduced ones, is considerable (Edwards and Bogdan 1951, Sands et al. 1970, pp. 49-57, Pratt and Gwynne 1977, pp. 247-54, and Bogdan 1976). A few attempts to cultivate indigenous species were reported in the 1950s (F.A.O. 1953, and Edwards and Bogdan 1951). Among others, I. brevicalyx, I. spicata and I. volkensii were evaluated for pasture use.

The greater emphasis on exotic species is understandable since the overriding consideration in these investigations has been such fodder qualities as palatability, productivity, protein content, nodulation, nitrogen fixation, etc. For purposes of soil rehabilitation, none of these qualities are of great importance, the essential aim being that a plant cover (sometimes any plant cover) should become established. Benefits that ensue, though not directly quantifiable in monetary terms, are quite obvious to any soil or water manager or conservationist - improved infiltration rate and less flood potential or silt loading of surface water systems, reduced loss of soil and instead its accumulation over time leading eventually to the economic use of these areas for pastures.

On preliminary evidence, these indigenous legumes offer an inexpensive yet ecologically efficient method of revegetating excessively degraded sites in this region. Capable of tolerating the harsh conditions imposed by such sites and requiring little prior site preparation and no chemical fertilisation, these species are perhaps superior to many introduced pasture legumes, including such drought resistant species as Phaseolus atropurpureus (Siratro) which require relatively larger amounts of phosphorus and deeper soils. The major activities necessary to introduce these local legumes seem to be gathering or growing the seeds, broadcasting and some protection from grazing. Of course for even higher rates of germination, some surface manipulation (breaking loose, furrowing, mounding) may be undertaken. This has proved advantageous in reseeding other denuded lands in Kenya (Bogdan and Pratt 1967).

Undoubtedly there are other local legumes in this region which are also capable of voluntarily colonising degraded soils. For example Cassia mimosoides L. and Trifolium semipilosum Fres. variety glabrescens Gillett[2] have both been observed in the same general region. But the first is an annual and not of vigorous spreading habit nor drought resistant. Evidence elsewhere (Lim 1977, pp. 135-41) also indicates that virtually no Cassia species nodulate. The latter legume, while capable of rooting at the nodes and thus spreading faster, requires higher rainfall and much more phosphorus. This may prove useful in rehabilitating degraded areas of the more humid ecological zone II where lava-based soils are often richer in phosphorus. In upland Nairobi it has been observed colonising rocky sites with mere shallow pockets of sub-soil during wet years. This species is reputed to be a good seeder and to be widely adaptable (Bogdan 1956).

The urgent need for reclaiming once productive land, now reduced to near barrenness by soil erosion and contributing nothing but silt to surface water systems, means that priority must be given to those plant species which have both economic and ecological advantages. The indigenous species described here have shown initial promise. In addition, the Indigofera species show a wide variation of habit and habitat indicating possibilities for selective breeding. This is particularly true for I. spicata.

Further observations and suitability tests under controlled field conditions have been planned and will be carried out, starting during the short rains of 1977 using wild seeds. In addition, small seed gardens will be cultivated to provide seed material for future trials. Preliminary results of these tests should be available within two years.

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AN ASSESSMENT OF SOIL EROSION ON A FIELD OF YOUNG TEA UNDER DIFFERENT SOIL MANAGEMENT PRACTICES[1]

by

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INTRODUCTION

Tea fields in East Africa are, in most cases, established on land with gentle to steep slopes. Generally the land is under primary or secondary forest prior to clearing for tea cultivation.

The land clearing operation and preparation prior to planting always leave the cleared land vulnerable to soil erosion until such time as the newly planted tea has developed enough canopy to protect the soil from the erosivity of the raindrops. This paper reports some of the results on soil erosion obtained from a soil conservation experiment conducted to give quantitative information on runoff and soil erosion on a field of young tea.

EXPERIMENTAL METHODS

The descriptions of the experimental site, design and treatments have been given elsewhere (Othieno 1975) but are reproduced below for the purpose of this workshop.

Experimental Site

The experimental site is on land with a ten per cent slope at the Tea Research Institute headquarters, Kericho, Kenya, about 40 km south of the equator at an altitude of 2175m. The rainfall pattern is weakly bimodal and totals 2160mm per year on average. A description of the geology and the chemical characteristics of the soils at the site was given by Scott (1962) and Table 1 gives some physical characteristics of the soil. The soil was derived from a massive sheet flow of phonolite lava. Kaolinite is the predominant clay mineral. The area was cleared in 1970 with a heavy crawler tractor and then planted immediately with oats as a cover prior to the establishment of the experimental plots.

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1. This is a draft of a paper prepared for the East African Agricultural and Forestry Journal special issue on catchment studies. It is published here with the permission of the Director of the Tea Research Institute of East Africa and the editors of the East African Agricultural and Forestry Journal. The author wishes to thank all the technical staff of the Crop Environment Department of the Tea Research Institute who have helped to make the experiment described here a success.

Experimental Design and Treatments

Sixteen plots, 18.3m x 3.7m (60ft x 12ft), divided into four blocks of four plots each in a randomised block design, were laid down (Figures 1 and 2). Wooden planks were used to demarcate and protect the upper and lower boundaries of each plot. At the lower boundaries, concrete troughs were constructed which served to collect runoff and eroded soil. From these, runoff and eroded soil were channelled through asbestos pipes, 10 cm in diameter, into collecting tanks in pits below the plots; each pit contained separate tanks for two adjacent plots. The capacity of the tanks was calculated on the assumption that the maximum daily rainfall was unlikely to exceed 150mm and that about 80 per cent of this might run off if the storm came when the moisture content of the soil was at or above field capacity. The tank system for each plot consisted of a first tank into which all the runoff and eroded soil were collected. A fraction (1/15) of the overflow, assuming that 80 per cent of 150mm rainfall ran off from the plot, was passed through a divisor (see Figure 1) into a second tank. It was assumed, and subsequently confirmed, that the eroded soil would settle in the first tank and that only runoff, with very little soil in suspension, would overflow through the divisor. The plots and collecting systems for soil and water were constructed by modifying existing designs of Hudson (1957) and Hendrickson et al. (1963).

After the demarcation of the plots and the installation of the tanks, the plots were cultivated and the soil uniformly levelled according to slope. After this the plots were planted, in September 1971, with clonal sleeved tea plants at 1.22m x 0.91m (4ft x 3ft) spacing. Before the imposition of the four soil management treatments mentioned below, the collecting tanks were calibrated using a dip-stick. Eroded soil during this period was collected and returned back to the plots from where it came. The soil management treatments were applied in November 1971 as follows:-

1. Bare soil; weeds controlled manually by hoeing and hand-pulling (tillage),
2. Bare soil; weeds controlled by herbicides and hand-pulling (non-tillage),
3. Oats planted between the rows of tea; weeds controlled by herbicides and hand-pulling, and
4. Soil surface covered by a mulch of Eragrostis curvula; weeds controlled by herbicides and hand-pulling.

Measurements of runoff and eroded soil were made once a day after storms.

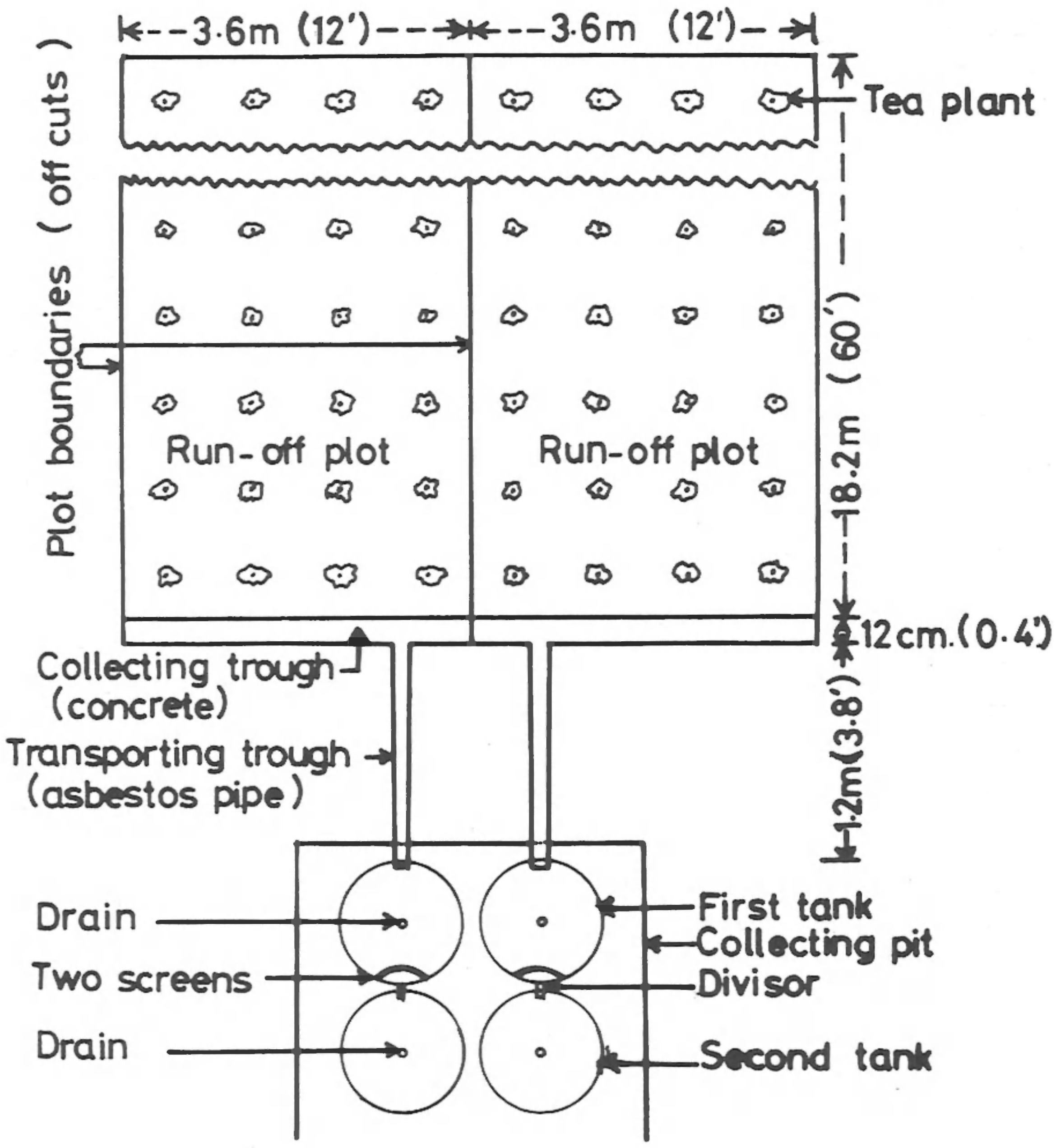

Figure 1. Plan view of two adjacent runoff plots served by one collecting pit.

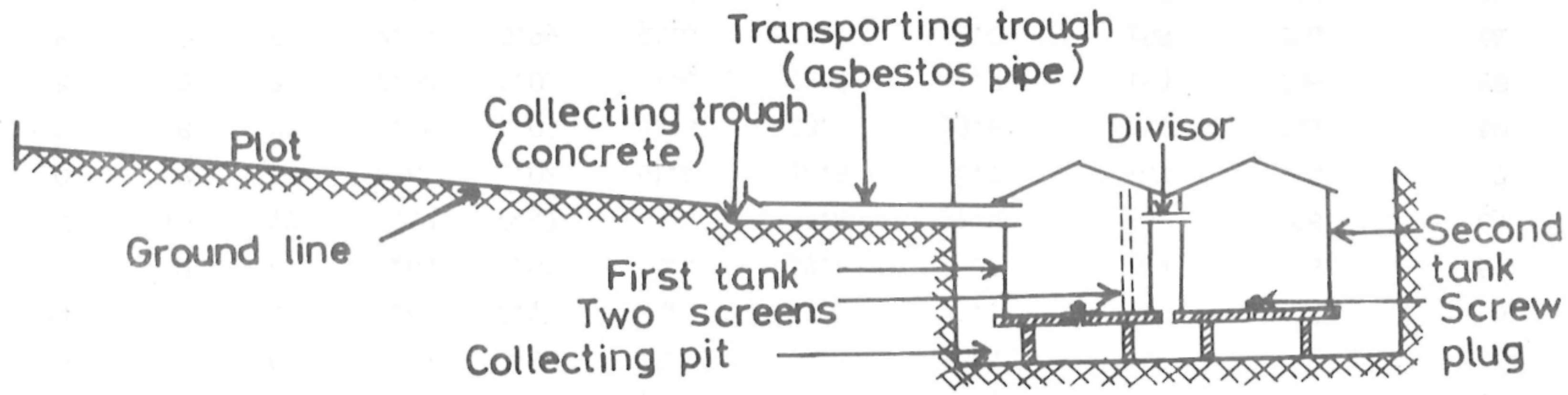

Figure 2. Profile view of a runoff plot installation.

Table 1. Physical properties of the soil at the experimental site.

Depth range (cm)	Mechanical composition: Sand (% of total weight)	Silt (% of total weight)	Clay (% of total weight)	Particle density (g/cm^3)	Bulk density (g/cm^3)	Pore space (% of total volume)	Moisture content at $\frac{1}{3}$ bar tension (% oven dry soil)
0 - 15	27	12	61	2.41	0.60	75.1	102.3
15 - 30	20	12	68	2.57	0.67	73.9	61.3
30 - 60	28	9	63	2.64	0.71	73.1	57.4
60 - 90	26	9	65	2.63	0.87	66.9	57.2
90 - 120	13	10	77	2.63	0.97	63.1	55.4
120 - 150	10	7	83	2.64	1.02	61.4	54.5
150 - 180	7	8	85	2.66	1.03	61.3	53.1
180 - 210	8	7	85	2.62	1.01	61.4	53.8
210 - 240	8	9	83	2.59	0.99	61.8	56.6
240 - 270	7	8	85	2.60	1.02	60.8	55.1
270 - 300	10	10	80	2.59	1.03	60.2	57.8
Total or mean				2.60	0.90	65.4	60.4

Moisture content at 15 bar tension (% oven dry soil)	Equivalent depth of water at ⅓ bar tension (mm)	Equivalent depth of water at 15 bar tension (mm)	Water available to plants (mm)	Permeability (cm/sec)
47.4	92	43	49	3.68
36.5	62	37	25	0.63
33.9	122	72	50	0.87
33.8	149	88	61	0.55
33.8	161	98	63	0.31
32.7	167	100	67	0.21
33.8	164	104	60	0.61
34.7	163	105	58	0.50
35.0	168	104	64	0.39
35.2	169	108	61	0.76
35.7	179	110	69	0.88
35.6	1596	969	627	0.85

RESULTS

Table 2 gives a summary of rainfall and the effects of four different soil management treatments on annual soil erosion for a period of three years.

First Year

Table 2 shows that soil loss was greatest in the first year following planting with all the treatments. The manual and herbicide treatments showed the greatest soil loss.

The manual weeding (tillage) treatment was intended for two reasons: to create a loose soil cap at the surface, with an assumption that cap would serve as an energy absorbing agent thereby reducing the erosivity of the raindrops, and to simulate the method of weed control used in the tea industry until recently when most of the large-scale growers moved to the use of herbicide (non-tillage) weed control. The majority of the small-scale growers still control manually. The operation as described was not carried out fully in the first year, in that only hand-pulling without hoeing was performed. The omission of hoeing in the first year was not intended. It appears that because of the very slight soil disturbance with hand-pulling of weeds, the first year's soil erosion from the tillage treatment was the same as the non-tillage treatment.

Soil loss from the oats treatment in the first month, immediately following planting amounted to 33.53 tonnes ha^{-1} out of a total of 34.90 tonnes ha^{-1} for the year. The very large amount of soil lost in the first month following planting was due to a delay in establishing oats caused by three consecutive storms which washed away oat seeds each time after seeding. However as soon as the oats were established, soil erosion was reduced to a very small amount.

Oats were planted and maintained as recommended in the Tea Growers Handbook (1969). Excluding the replantings after the seeds were washed away by storms, there were two replantings of oats and three cuttings in the first year. If the first month's soil loss is not considered, oats proved very effective in controlling erosion.

The annual application of mulch at the rate of 15 tonnes ha^{-1} (dry weight) was split into two equal applications. Its effectiveness in controlling soil erosion was marked, with soil losses amounting to less than one tonne per hectare compared to 161 and 168 tonnes per hectare in the tillage and non-tillage treatments respectively.

Table 2. Soil erosion (tonnes ha^{-1}) and rainfall (mm).

	Year			Total
	1971/72	1972/73	1973/74	1971 to 1974
Soil Erosion				
Manual (tillage)	161.28	48.28	1.23	210.79
Herbicide (non-tillage)	168.08	80.71	6.09	254.88
Oats	34.90	4.31	0.42	39.63
Mulch	0.46	0.14	0.08	0.68
LSD (P = 0.05)	17.01	19.66	2.32	37.36
C.V. (%)	9.31	29.50	59.50	14.75
Rainfall				
	2082.6	2045.2	1985.4	6113.2

Second Year

Both hand-pulling and hoeing were used to control weeds in the manual treatment plots in the second and third year. A total of seven weeding operations were performed during the year, at monthly intervals during the periods with rain and at less frequent intervals during the dry periods.

In the second year the non-tillage treatment lost 80.71 tonnes ha^{-1} of soil compared to 48.28 tonnes ha^{-1} of soil lost from the tillage treatment. The large difference in the amount of eroded soil between the tillage and non-tillage treatments observed in the second year, but not in the first year. is ascribed to the hoeing operation in the tillage treatment. As intended, this operation produced a loose soil cap at the surface which acted as an energy absorbing agent, thereby reducing the erosivity of the raindrops.

The possibility that reduced runoff was an important cause of the reduced soil erosion in this treatment, as compared with the non-tillage treatment, is not fully supported by the runoff data (Table 3).

Once again oats proved very effective in controlling soil erosion. A total of 4.31 tonnes ha^{-ha} of soil were lost from the oats treatment. Of this amount, 2.18 tonnes ha^{-1} were lost in the month of June 1973, following a replanting operation prior to the proper establishment of the rows. One replant of oats was performed during the year.

Mulch continued to be the most effective treatment against soil erosion. Only 0.14 tonnes ha^{-1} were lost with the mulch treatment, as compared with 48.28 or 80.71 tonnes ha^{-1} from the manual and herbicide treatments respectively. There was a single application of mulch at the rate of 15 tonnes ha^{-1}.

Third Year

Soil erosion in the third year was very much reduced with all treatments. The possible reasons for this reduction are presented in the discussion section of this paper.

Table 3. Runoff (mm) and rainfall (mm).

	Year			Total
	1971/72	1972/73	1973/74	1971 to 1974
Runoff				
Manual (tillage)	180.9	126.7	32.4	340.0
Herbicide (non-tillage)	159.5	162.3	90.2	412.0
Oats	65.1	79.8	38.9	183.8
Mulch	53.7	26.7	21.5	102.0
LSD (P = 0.05)	22.2	14.7	15.7	42.6
C.V. (%)	9.70	7.47	17.15	8.22
Rainfall	2082.6	2045.2	1985.4	6113.2

Although the amount of eroded soil was reduced in comparison with the second year, the patterns of erosion were similar. The tillage treatment lost 1.23 tonnes ha^{-1} of soil as compared with 6.09 tonnes ha^{-1} lost from the non-tillage treatment. The large difference in soil loss from the tillage treatment as compared with the non-tillage treatment is again attributable to the energy absorbing effect of the loose soil cap at the surface, produced by the hoeing operation.

The soil loss from the oats and mulch treatments dropped from 4.31 and 0.14 to 0.42 and 0.08 tonnes ha^{-1} respectively. Mulch, at the rate of 15 tonnes ha^{-1}, was applied in one single application and oats were planted once without a replant.

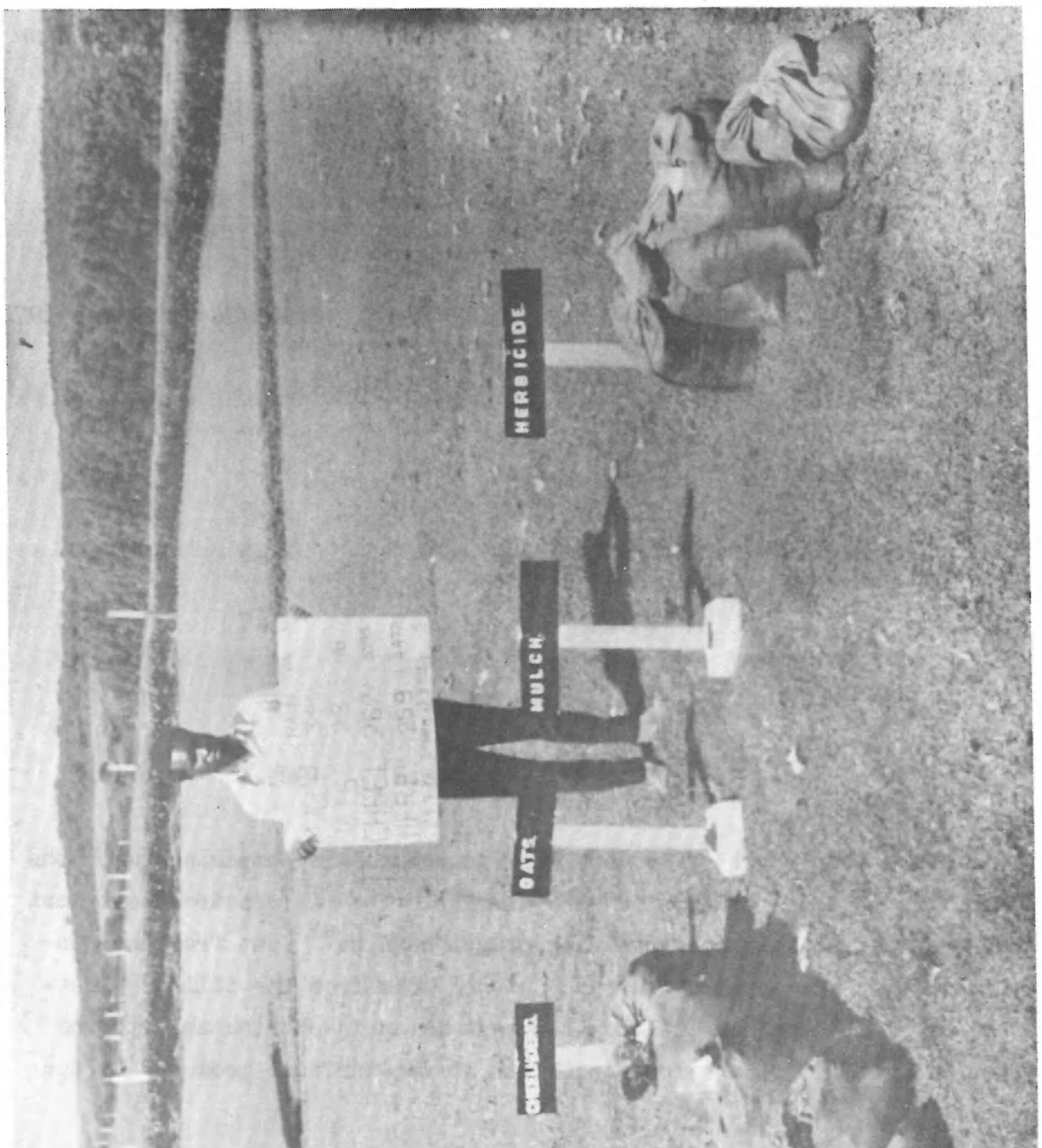

Figure 3. Bulked amount of wet soil lost from four experimental tea plots.

DISCUSSION

Soil erosion was greatest in the first year for the tillage and non-tillage treatments. Although a similar pattern was observed with the oats treatment, over 10 per cent of the total soil loss with this treatment was lost in the first month of the experiment prior to the establishment of rows of oats. Soil loss in the mulch treatment was negligible. A dramtic visual example of the magnitude of the differences in soil loss from one storm observed among these treatments (after the establishment of oats) is given in Figure 3. The figure shows the bulked amount of wet soil collected from the four plots, the manual tillage, oats, mulch and herbicide (non-tillage) treatments. The erosion occurred in the first year during a storm of 42.6 mm hr^{-1} maximum intensity, a very mild storm compared to some severe storms recorded at the site.

Soil erosion in the first year when the canopy cover above the ground developed from about 1 to 30 per cent was 76.5, 66.0 and 88.1 per cent of the total soil loss in the three-year period of the experiment for the tillage, non-tillage and oats treatments respectively. In the second year when the canopy cover developed from about 30 to 60 per cent, the losses were 22.9, 31.6 and 10.9 per cent of the total three-years' loss for the three treatments in the same order. In the third year when the canopy cover developed from about 60 to 70 per cent, the soil losses for the three treatments in the same order were 0.6, 2.4 and 1.0 per cent of the total soil loss. The importance of canopy cover in controlling soil erosion is therefore well demonstrated. The effect of the canopy was to intercept the energy of the raindrops before they could make an impact upon the soil surface below.

The fact that soil erosion was reduced by capping the soil with a layer of loose soil produced on the surfact to act as an energy absorbing agent, and the fact that soil erosion was reduced with the increase in the canopy cover, suggest very strongly that soil erosion in Kericho is mainly caused by the impact of the energy of raindrops, a factor which is being considered in a separate paper (Othieno and Laycock forthcoming).

It can also be argued that it was the increased infiltration and hence the reduced transport with the tillage treatment, rather than the energy absorbing nature of the surface, which was important in the reduction of soil loss from this treatment, as compared to the non-tillage treatment. The runoff data (Table 3) do not support this argument, however. First, the proportions of the annual runoff in relation to the total runoff for the three-year period of the experiment do not follow the same pattern as was observed for soil erosion. In the first year, runoff was 53.2, 38.7 and 35.4 per cent of the total runoff for the three-year period of the experiment with the tillage, non-tillage and oats treatments respectively. In the second year runoff was 37.3, 39.4 and 43.4 per cent, and in the third year it was 9.5, 21.9 and 21.2 per cent of the total runoff for the period of the experiment with the three treatments. Second, the effect of the canopy cover on soil erosion was obvious. For instance, runoff with the non-tillage treatment in the first and second year was about the same, and yet 168.08 tonnes ha^{-1} of soil were lost in the first year, as compared with 80.71 tonnes ha^{-1} lost in the second year. The reduced soil loss in the second year as compared to the first year, despite about equal volume of runoff, can only be ascribed to the interception of the energy of the raindrops. Third, the tillage operation produced a layer of loose soil particles which were easily erodible, and if transport were more important than the energy aspect then there should have been no large reduction in soil loss, particularly in the second year, with the tillage treatment as compared to the non-tillage treatment. In the second year, runoff was 126.7 and 162.3 mm and erosion was 48.28 and 80.71 tonnes ha^{-1} for the tillage and non-tillage treatments respectively.

The impact of raindrops detaches soil particles from their positions on the soil surface and they are then transported away from the field by surface runoff.

Mulch was found to be the most effective treatment for controlling soil erosion, followed by oats. The action of mulch was to intercept and absorb the energy of raindrops before they reached the soil surface. Rows of oats, on the other hand, stopped the detached soil particles from being transported further away from their original positions.

SUMMARY AND CONCLUSION

An experiment conducted in Kericho District on land with a 10 per cent slope designed to give quantitative information on runoff and soil erosion from a field of tea has demonstrated that grass mulch, followed by rows of oats interplanted between lines of tea, was the best treatment for controlling soil erosion. Hoeing to produce a cap of loose soil layer on the surface was found to be better for controlling soil erosion than non-tillage treatment. Hoeing is difficult in tea fields, however, because tea feeder roots can be damaged.

The very large amount of soil loss - 211 and 255 tonnes ha^{-1} in the tillage and non-tillage treatment plots in the first three years after planting - demonstrates very strongly the need for proper and adequate soil erosion control measures before or immediately after planting.

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THE EFFECTS OF CERTAIN TILLAGE METHODS AND CROPPING SYSTEMS FOR CONSERVING RAINFALL IN A SEMI-ARID AREA OF EASTERN KENYA

by

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INTRODUCTION

The medium potential areas of eastern Kenya are characterised by low and erratic rainfall. The mean annual rainfall ranges from 500mm to 850mm, divided into two rainy seasons of roughly equal duration, both of which are quite unreliable. Although both of these seasons are said to extend over a period of three-and-a-half months (Mid-March to June for the long rains and mid-October to January for the short rains), it has been shown that only the second month of any season is reliable (Dowker 1961). The first month is likely to provide enough moisture for crop establishment, while the third represents the 'tailing off' of the seaon. All in all, only two months are expected to be reliably wet (Harrison 1970). The date when rain may start is unpredictable, and the rains tend to come in short medium- to high-intensity storms (Ahn 1973).

The soils found in the arable areas (there are hillslopes and valleys which are not arable) are mainly friable clays, sandy clay loams and loamy sands which generally tend to be hard when dry but highly friable when moist. They also have a high tendency to cap under rain drop impact. The soils have been described as similar from as far as southern Machakos to the Kindaruma and Murinduko areas on the lower slopes of Mt. Kenya in the north (Mbuvi and Weg 1975), although those in the dryer areas are shallow due to the presence of petroplinthite (murram) horizons (Scott 1968, Muchena 1975).

It can be expected, therefore, that the climate and the soils of the medium potential areas of eastern Kenya will present a number of major problems for farming activities. Some of these are as follows:-

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1. Seedbed preparation is difficult during the dry season, and farmers have to wait until the first few showers have moistened the top 15 to 20 cm. of the soil. Oxen are the main source of power for ploughing and thus available power is limited. This results in late planting when the soils are more easily worked, so that the crops, given the short duration of the rains, almost certainly experience moisture shortages during later periods of growth, thereby reducing yields or leading to crop failure.

2. The tendency for the soils to cap rapidly reduces the infiltration capacity, and thus increases runoff and accompanying erosion. Also because of the prevalence of high intensity storms, the proportion of rainfall which eventually gets stored in the soil is reduced, except for the rare seasons when it is possible to completely wet the profile even with unrestricted runoff. For instance, Lal (1973) reports runoff losses of 11.9 c. out of 29.5 cm. of rainfall from unmulched maize on a 5 per cent slope over a period of four months (September-December) with structurally weak soils at the International Institute of Tropical Agriculture, Ibadan, Nigeria. This represented 40 per cent of the total rainfall and means that harvests may fail even though the rainfall has been adequate.

3. The shallow soils have a limited volume for storing moisture. This results in waterlogged conditions during the periods of excessive rain and soils depleted of moisture during the short dry periods which occur during the growing season. A soil like this will not give a crop if the distribution of rain in any season is poor.

This paper addresses itself to the efforts which can be made to increase the availability of moisture to crops in our semi-arid areas, thereby increasing crop yields and stabilising crop production.

METHODS FOR INCREASING MOISTURE AVAILABILITY AND PREVENTING EROSION

Different scientists have tackled the problem of moisture availability for successful cropping in marginal areas with various approaches, some of which are briefly described here.

The plant breeders have two possibilities open to them. By tailoring the time to maturity of a crop to the length of the rainy season, the crop's requirements for moisture are restricted to the period when it is available. This is the principle of breeding for drought escape, which has been very successful in Kenya. The Katumani maize varieties are a product of this approach. Alternatively, some crops can have the ability to withstand short (and sometimes considerable) periods of moisture stress. This trait can be encouraged through selective breeding. This is the principle of drought tolerance.

The agronomists have combined a number of cultural practices to ensure that the moisture supplied during the growing season is used with utmost economy. Usually early planting to enable the crop to utilise the full extent of the rainy season is combined with optimum spacing and a high standard of weeding to ensure that moisture is available during the later stages of crop growth.

These concepts are familiar and are followed to a greater or lesser extent in all the medium potential areas of Kenya. They represent an attempt to ensure that all the rainfall received during the rainy season will be available to the crop. Unfortunately, this has often not been the case. as Lal (1973) showed for Nigeria.

A third approach which has not yet gained prominence in Kenya is what is called conservation tillage (Erbach and Lovely 1974) in which tillage (reduced or otherwise) is carried out with a dual purpose of conserving water (together with control of erosion by moving water) as well as providing a suitable seedbed. The construction of soil and water conservation structures (terraces, cutoff drains, contour trenches, etc.) has been going on in Kenya since the 1920s (Peberdy 1958 and Clayton 1964), but these can only achieve a part of the objective. The structures aim at breaking the length of the slope of land in order to reduce the amount and velocity of runoff, and hence reduce the erosion caused by running water. Storage of rain water in the soil is not achieved by these structures since no attempt is made to restrict the rain water where it falls. However, tillage can be carried out in such a way that the surface structure of a field remains open, to allow a prolonged high infiltration capacity so that rainwater can be held where it falls and more water can percolate into the soil. Some of these tillage systems are mulch tillage (Rockwood and Lal 1974, Arnon 1972 and Hudson 1971), no tillage sod sowing (Jones et al. 1969 and Bennet et al. 1973)and tied-ridges (Le Mare 1953, Pereira et al. 1967 and Prentice 1946) which are practised in other areas with semi-arid climates but have not gone beyond the experimental stage in Kenya. Now that the medium potential (semi-arid) areas are increasingly being opened for extensive and semi-intensive agricultural activities, particularly crop production, there is more need to integrate these tillage systems into local agricultural practices.

The fourth approach, which unfortunately is rarely related to the problem of moisture availability, is the cropping system of the farms. Crop rotations are best known as a means of maintaining soil fertility, especially when legumes are included, and possibly as a means of controlling diseases. However, carefully planned rotations may help increase moisture availability, because the total amount of water used by a crop is related to the period in which a crop remains actively growing in the field. It follows therefore, that slow growing crops require and use more water than relatively faster growing crops. The latter are also likely to leave residual moisture in the soil after harvest, e.g. from silage, hay, cowpeas, beans, etc. (Bennison and Evans 1968 and Arnon 1972). In some parts of the world, such as Australia, rotations are designed which alternate slow growing, high water consuming crops (which are also main crops), e.g., maize, sorghum, wheat, etc., with fast growing, less water demanding crops such as Panicum spp. (Proso millets), cowpeas and possibly barley (Bott 1968). When the fast growing crops do not leave any useful residual moisture, fallows are planted before the main crop. In temperate areas fallows are introduced into the cropping systems when the annual rainfall is between 250mm and 500mm (Arnon 1972, Baradi 1974, Nelson 1975 and Janssen 1972). This range should be adjusted upwards in order to realise the benefits of fallowing in the tropics, since the temperatures and evaporation rates are high throughout the year. However, it appears that fallowing works well in tropical areas with one long rainy season per year (Pereira et al. 1958), since at Kongwa, Central Tanzania both soil and moisture conservation were achieved on fallow plots planted with dense teff grass. Clean weeded fallow plots conserved moisture but did not control soil erosion. The experimental results have not been encouraging in areas with bimodal rainfall distribution (Bennison and Evans 1968). In this case, it was concluded that the increase in crop yields following a clean fallow was associated more with accumulated nitrates than the stored moisture. However, fallows managed through tillage have proved worthwhile in the low and medium altitude wheat areas of Kenya, where a short, unreliable rainy season precedes the main season (Mulamula et al. 1976 and Poulsen 1975).

Crop management requires special mention. With high intensity storms some cropping patterns and post planting cultivation may encourage runoff and hence erosion, while a combination of conservation tillage with proper cropping patterns can reduce erosion risk considerably. For instance, if all tillage is done on the contour and crop rows oriented along the contour then all the weeding cultivation can be done along the contour. At Muguga, control of accelerated erosion on slopes of 10 to 12 per cent was achieved in this way (Pereira, Hosegood and Dagg 1968), and in Australia similar success has been reported (Glavimans 1972). With widely spaced crops such as maize, ground cover isinadequate for a part of the growing season. The interplanting of a quick spreading cover crop has proved successful at least in controlling soil loss (not runoff) in India (Bhola, Khybri and Dayal 1975).

Zero tillage was also shown effective in preventing soil erosion in the U.S.A., whether the crop had wide rows such as maize or more narrow rows such as soyabeans and wheat (McGregor, Greer and Gurley 1975). This confirms the view that it is tillage practises rather than the crop itself which are responsible for soil erosion (Hudson 1971).

EXPERIENCE IN THE FIRST YEAR AT KATUMANI WITH CONSERVATION TILLAGE AND CROPPING SYSTEMS

A research programme was started at Katumani on four different tillage methods and three cropping sequences with the following objectives:-

1. To test the effectiveness of different tillage methods in conserving water, which would be reflected partly in the soil moisture differences during the growing season and partly in the crop yields achieved, and

2. To test the effectiveness of different cropping sequences in conserving moisture, as reflected by soil moisture at the start of the second season and the performance of a succeding test crop.

The tillage methods tested were:-

1. Minimum tillage (T1): no deep tillage, only surface cultivation at the time of weeding,

2. Conventional tillage (T2): the usual deep tillage followed by harrowing to produce a suitable tilth,

3. Cloddy tillage (T3): same as conventional tillage, except that harrowing is done along the rows, and

4. Tied ridges (T4): Deep tillage is followed by ridging and cross-tying.

The cropping sequences were maize followed by maize (C1), beans followed by maize (C2) and managed fallow followed by maize (C3).

All combinations of tillage methods and cropping sequences were planted in a randomised block design, replicated three times at each of the two sites within the station. The trial was started during the long (March-June) rains of 1976, and the second crop grown during the short (October-January) rains of 1976/77.

Results: The Effects of Tillage Methods

The seasons turned out to be very poor and there were widespread crop failures in the medium potential zone of eastern Kenya. The trials were no exception, and maize dry matter and some beans were all that could be harvested. The rainfall records at Katumani gave a total of 171 mm for the long rains and 222 mm for the short rains.

The effects of different tillage methods could be seen best at the beginning and the end of the season. Runoff was observed on two occasions from minimum and conventional tillage plots, the only times when rainfall exceeded 15 mm. This illustrates how rapidly soil capping occurs, even with light showers. Table 1 gives a summary of the main effects on some of the crop parameters observed during the long and short rains.

The Effect on Germination. Germination after two weeks was measured during the short rains only because results were so poor during the long rains. Under the warm conditions prevailing in eastern Kenya, maize germination is normally complete by the end of the first week after the start of the rains. Table 1 shows that at the end of the second week germination was nearly complete in minimum (T1) and conventional (T2) tillage plots but below 50 per cent in tied-ridges plots. Both cloddy and tied-ridges delayed germination at one site to a greater degree than at the other. The explanation for both cloddy and tied-ridges reducing germination is that the light showers were unable to wet the clods and the ridges sufficiently in order to supply moisture to the seeds. In the case of ridged plots, at one site the seeds were planted on the lee side of the ridge in relation to the direction of the prevailing wind. Germination continued until the stand in every plot was over 75 per cent as shown by the stand count at harvesting dry matter, but germination in cloddy and tied ridges plots remained significantly less than in minimum and conventional tillage plots. Stand count during the first season (long rains) was influenced in the same way by tillage methods in the case of maize, but the beans were not affected.

The Effect on Drymatter and Bean Grain Yield. Maize was harvested for dry-matter only during the long rains, while beans were harvested for grain. In the long rains tied ridges gave the highest drymatter yield, followed closely by minimum and conventional tillage methods. However, only cloddy tillage reduced drymatter yield significantly (at the one per cent level). Similar

The grain yield (taken at one site only) was affected in the same direction as drymatter yield by the tillage methods. Yield from tied ridges plots was highest and could be attributed to higher cob count and larger cobs (as reflected by grain weight per cob).

The Effects of Cropping Sequence

It is not expected that one crop would influence the rate of emergence (germination) or the stand count of the crop which follows. Instead the effect of the first crop should be reflected in the yield of the second crop. Table 2 gives the crop parameters taken for the short rains crop, which were used to test the effect of the preceding crop.

Table 2. The effect of the preceding crop on the maize crop.

Crop Parameter	Preceding Crop				
	C1	C2	C3	Mean	SE
Stand count at harvest (%)	77.9	82.9	79.9	80.2	1.9
Drymatter yield tonnes/ha	1.87	1.81	1.83	1.48	0.08
Cob count per M^{-2}	0.50	0.33	0.79	0.54	0.07
Grain yield Kg/ha	301	204	460	322	44
Grain wt per cob (g.)	25.2	21.8	30.0	25.7	1.6

Effects on Drymatter Yield. Since the preceding crop had no effect on stand count at harvesting, it was assumed that it would not influence drymatter yield or grain yield either. Indeed, Table 2 shows that the preceding crop or fallow did not affect drymatter yield. This was expected since the rainfall in the preceding season was not high enough to contribute to any moisture storage. Even if there were any accumulation of nitrates in the fallow plots, this could not be expressed when the drymatter yields were so low. The normal drymatter yields range from six to eight tonnes per hectare according to the 1971 Annual Report of the Maize Research Section in Kitale.

Effects on Cob Count and Grain Yield. The effect of fallowing showed up in these parameters. Cob count was higher with preceding fallow than with preceding maize or beans. It is interesting to note that preceding beans depressed cob number significantly compared with preceding maize. This is probably because beans extracted moisture from the rooting range more thoroughly than maize - hence maize following beans grew under drier conditions than maize following maize.

Grain yield from plots which had a precrop fallow (C3) was highest, more than twice the yield of maize after beans (C2). The higher yield of maize after fallowing was due to higher cob numbers and larger cobs (highest grain weight per cob).

DISCUSSION AND CONCLUSIONS

A decision to carry out water and moisture conservation measures is based on the assumption that a given crop requires a certain minimum rainfall spread over the growing period. Any extra water (rainfall) results in higher yield response. Indeed the yield has been shown to increase linearly with rainfall until some other factors become limiting, after which the relationship is curvilinear (Stanhill 1970). It is also assumed that the rainfall in the medium potential (semi-arid) areas of eastern Kenya often supplies enough moisture, but due to a lack of suitable water and moisture conservation measures a considerable proportion of this moisture is lost as runoff, hence the actual rain water which is stored in the soil and eventually becomes available to the crops is often inadequate. For instance, if 40 per cent of the moisture was lost as runoff from unmulched maize in Nigeria (Lal 1973) and if maize requires a minimum of 240 mm to give a yield, then rainfall had to be in excess of 400 mm to supply the basic minimum of water. The farmer can therefore reduce the amount of rainfall required to supply his crops' minimum water needs by reducing runoff losses. In this way crop failures would become less frequent. From the results presented here and evidence from the literature, it is clear that initial crop establishment is affected by three factors acting simultaneously: the nature of the seedbed, the amount of rainfall at the start of the rainy season, and the soil types. Germination can be significantly reduced if the seedbed cannot provide enough cover to facilitate adequate moisture supply to the seed, either due to the cloddy nature of the seedbed (Griffith et al. 1973) or when in extreme forms of minimum tillage (as in micro-seedbeds) enough soil is not available to cover the seed (Macartney et al. 1971). The tillage methods which produce these less favourable seedbed conditions happen to be some of the conservation tillage methods. This means a farmer may fail to increase yields if the reduction in stand due to poor germination is not more than compensated for by better crop performance later in the season. If the reduction in the stand is not very great, a better moisture regime later in the season leads to higher yields, as is the case with tied-ridging and listing (Macartney et al. 1971, Amemiya 1968 and Le Mare 1953).

Minimum tillage requires special mention because it has been practised in various forms in eastern Kenya for a long time, such as by clearing bush, burning and planting, or clearing stover and weeds and planting. Yields were not depressed significantly when compared with conventional tillage. This result seems to be valid only in seasons when rainfall is light, as then the crop has the advantage of early establishment, comparable to conventional tillage methods as opposed to conservation tillage methods. With higher rainfall, however, minimum tillage gives much lower yields than conventional tillage (Ofori and Nandy 1969). Minimum tillage, especially without any water or soil conservation structures, leads to serious erosion problems. With adequate conservation structures, a combination of minimum tillage and conventional tillage would be suitable for the medium potential areas of Kenya. It is not known, however, for how long minimum tillage should be practised before switching to conventional tillage.

Tied ridging brings about water and soil conservation, provided the ridges are built along the contour and are high enough. Considering that people in the medium potential areas of Kenya invariably keep cattle and tend to use oxen and bulls for ploughing, forming tied ridges would not present any mechanical problems. A recent survey in Machakos showed that over 90 per cent of the farmers had an ox plough, while only 20 per cent used a tractor for cultivation (Heyer 1975). However, the types and sizes of the ploughs and cultivators available might not be adequate to achieve various seedbed characteristics, since the mouldboard plough is universally used for oxen and discs for tractors.

There is no doubt that cropping systems can be used to increase the moisture available to a succeeding crop. If the rainfall during the season is unlikely to provide adequate moisture, then a precrop moisture conservation measure should be used, either a crop that can leave useful residual moisture or a fallow. Unfortunately, fallowing presents immediate problems since it always represents a crop lost during the fallowing season. However, with well balanced fallow and crop rotations, yields would be stabilised from season to season and at higher levels. Yet fallowing has its own limitations. Unless the rainfall during the fallow season thoroughly wets the soil profile to the full rooting depth, it is unlikely that any useful moisture will be stored. This happened during 1976 so that soil at the beginning of the second season after the first crop or fallow was equally dry. Secondly, if the rainfall at the beginning of the season or immediately prior to the cropping season (but after harvesting the preceding crop) completely wets the soil depth, then the advantage is lost (Bennison and Evans 1968). However, this much rainfall at the beginning of the season is rare in the medium potential areas of Kenya.

In a small-scale agricultural area such as eastern Kenya, the alternation of a short-duration crop with the main crop should be highly recommended, rather than growing long-duration, high water consuming crops continuously in expectation of an occasional good season. Growing long-duration crops continuously results in unstable and fluctuating crop yields and increases the frequency of crop failures.

With all these measures to increase the amount of water available to the crops through tillage methods and cropping systems, a good standard of crop management is required. For instance, if weeds are allowed to grow during the off season this will use up all the residual moisture and the potential benefits will be lost.

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PROBLEMS OF SOIL AND WATER CONSERVATION WITHIN THE UPPER TANA CATCHMENT

by

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STATEMENT OF THE PROBLEM

A study was initiated in July 1974 to provide a systematic and quantitative evaluation of the sediment yields in the streams of the Tana River basin and thus to arrive at an estimation of the rates of soil erosion in different parts of the catchment area under different climatic conditions. This project should be completed in December 1977, and the results will be published in 1978.

Prior to this study, a limited number of suspended sediment analyses had been made for the Upper Tana catchment area, mainly in connection with the planning of hydropower development. However, no systematic sediment transport analysis had been carried out in the area which could give an indication of soil erosion rates and their impact on water resources. Earlier suspended sediment analyses were carried out by Sir Alexander Gibb (1959) and Acres/ILACO (1971), but these were done mainly to provide information for the design of the resevoirs now constructed on the Tana River and the Gitaru Dam which is currently under construction. In addition to the author's more recent work in collaboration with T. Dunne, a study has been carried out by Watermeyer, Legge, Piesold and Uhlmann, Consulting Engineers, in connection with the proposed upper resevoir along Tana-Kamburu.

In order to make a quantitative evaluation of the rate of soil erosion based on sediment yield data, information not only on suspended sediment, but also on the bedload is required. However, prior to this study no bedload measurements were available, not only for the Upper Tana catchment area, but for anywhere in Kenya. In fact, no systematic investigation had been carried out in the basin which would relate the process of soil erosion to the quality of the water resources, given a variety of environmental factors such as geological and topographical factors, the climate, soil types and land use patterns. EAAFRO has carried out useful investigations of the impact of various land-use patterns on hydrological conditions in selected East African catchment areas, but the Upper Tana was not included in these studies. By carrying out a detailed analysis of hydrological data, the present study aims to identify the best soil and water conservation strategy for the Upper Tana catchment area.

OBJECTIVES OF THE STUDY

Although the objectives of this study have already been described in general terms, they will be spelled out here in more detail. The study should provide a systematic, quantitative evaluation of the sediment yields in streams of the Upper Tana basin, and these data will be related to various environmental conditions such as geological and topographical factors, soil types, climate, runoff, land-use patterns and other drainage characteristics. An estimation of the rates of soil erosion in the area will be made for given sets of environmental conditions. Here an attempt will be made to relate soil erosion rates to land productivity and to various soil and water conservation methods.

The major variables governing hydrogeological and geomorphic processes in the area will be isolated as they lead to the siltation of the water bearing bodies in the region, including irrigation canals. The spacial distribution of sediment concentration in the basin will be determined. This involves a quantification of the amount of sediment originating on the cultivated slopes of Mount Kenya and the Abedares where rainfall is relatively high and the amount of sediment originating in the drier, lower parts of the basin which are mainly used for grazing. This information should enable planners to decide in which areas limited funds for soil and water conservation should be allocated, taking local social and economic factors into account as well.

The quality and quantity of the surface and groundwater resources of the area will be determined in relation to the controlling variables of the environment. In particular, the impact of human activities on the quality and quantity of water will be assessed. Finally, systematic hydraulic studies of bed material will be carried out in order to compute the proportion of bedload material in the sediment yields of the area.

PRACTICAL AND THEORETICAL SIGNIFICANCE OF THE RESEARCH PROJECT

A great deal of the information generated by this study will be useful in planning a soil and water conservation strategy for the Upper Tana basin. For one thing, precise information on the siltation rates in the reservoirs, irrigation canals and other water-bearing bodies is needed for planning the economic development of the area. The amount of ground and stream water available, and its quality, must be assessed before planning the allocation of water among a number of competing uses. Secondly, the degree of land degradation should be measured as it affects the productivity of the land and the quality of the water resources. Finally, in more theoretical terms, this study will further our understanding of the process of soil erosion, transportation and sedimentation in a tropical environment.

METHODOLOGY

Thirteen sediment monitoring stations were set up in the Upper Tana basin, largely, by necessity, coinciding with the river gauging stations which were already established. The citing of these stations was intended to take into account the variety of environmental conditions in the area. Field and laboratory measurements of about 1,000 suspended sediment samples have been completed during a period of over two years, using a DH - 48 Suspended Sampler. During the last two years water chemistry analyses of about 1,000 samples have also been carried out.

Twenty bed material samples are now being analysed, and over 400 field measurements of discharge (current meter gaugings) have been made over a two-year period at the 13 stations using an OTT Current Meter. Information on discharge rates will be supplemented by data already available from the Ministry of Water Development.

In addition, ten experimental soil erosion plots have been established with different rock and soil types, land use patterns and degrees of slope. Using artificial rainstorms, it is hoped to determine a soil erosion index related to these different factors. Finally, ten soil chemistry samples have been analysed and await final computation, and a limited number of rain chemistry analyses have been completed.

PRELIMINARY RESULTS OF PRACTICAL IMPORTANCE

The total annual sediment production of the Thiba River near the Tana has been estimated at about 156,000 tonnes per annum, giving a rate of soil loss of 80 tonnes per square kilometer a year. For the Tana, a figure of 300,000 tonnes total annual sediment production was suggested by the F.A.O. in 1965. However, the suspended sediment analyses of the present study indicate that the rates are now actually much higher. The data for 1948-65 suggest a sediment yield of around 3.5 million tonnes per annum, but preliminary results using data from up to June 1977 indicate that the sediment yield figures are now well over 4 million tons per annum.

There has been indiscriminate destruction of the vegetation cover in the catchment area feeding the Tana River from the Abedares. This area covers parts of Murang'a and Nyeri Districts where the soil conservation measures introduced during the colonial period were never widely accepted. Since independence the rate of soil erosion in these areas has increased considerably, due to expanded cultivation, charcoal burning and overgrazing. By contrast, in the catchment area feeding the Tana Kamburu River from Mount Kenya the suspended sediment figures are relatively low. This area falls in Kirinyaga and Embu Districts where the acceptance of soil conservation measures during the colonial period was more widespread. However, these differences in sediment levels must also be seen in part as reflecting different drainage and environmental factors in the areas.

With increasing soil erosion and the trasportation and deposit of sediments within the catchment area, the silting rates are expected to increase at the Tana River dams and the economic life of the dams will be considerably reduced. Kindaruma dam, for example, has only been in operation for seven years, but considerable sediment has already been deposited in the reservoir. Unfortunately, there are many economic and environmental arguments against setting up sediment traps further upstream from the existing reservoirs. For one thing, considerable siltation occurs right around the reservoirs themselves - for example, due to the destruction of trees for charcoal - and this would not be dealt with by siltation traps further upstream. In the final report on this research, the siltation rates of the three existing reservoirs will be computed taking into account the efficiency of their sediment traps. Once all the sedimentation data have been computed and analysed, it should be possible to predict the economic life span of the dams in terms of their capacity for power production.

If the present erosion and sedimentation rates are permitted to continue, this may also affect the biotic life in the reservoirs. Experience elsewhere has shown that the deposit of large amounts of silt reduces the penetration of light in the water which may disrupt the ecosystem of a reservoir and damage the fish population.

With increasing siltation in the reservoirs, ultimately the main streams feeding these reservoirs may start to silt up. This could change both the hydrologic and hydraulic parameters of the streams, leading to flooding and other problems which would affect the productivity of irrigated and other cultivated land. The aquatic life in the streams can also be disturbed, and health hazards may be created such as the formation of bars and pools where mosquitos can breed. Of course the high levels of soil erosion will lead to a drop in the productivity of the soil, creating economic and social problems for the area's rapidly increasing human population.

The water chemistry analyses indicate that the surface water in the Upper Tana basin is of excellent chemical quality, but traces of organic pollution have been detected. It is likely that the source of this pollution is waste from the coffee and sisal factories located upstream, especially on the lower slopes of Mount Kenya and the Abedares, but this can only be ascertained when the final analyses have been carried out. It was also noted that during high flow periods the waters of the Tana River contain more that 2500 mg/l of suspended sediment; more than half of this is contributed by the Thika River and the rest by the Sagana. This water, with its high level of suspended sediment, would be unsuitable for certain industrial and domestic purposes.

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REPRESENTATIVE AND EXPERIMENTAL BASIN PROGRAMME

by

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INTRODUCTION

This programme is jointly funded by the Kenya government and the U.K. Ministry of Overseas Development as a technical cooperation project. It started in October 1976 with the arrival of the Project Leader at the Ministry of Water Development. Counterparts were designated in December 1976 and the second expatriate hydrologist arrived in Kenya in May 1977 after overseeing the purchase and dispatch of instruments and equipment in the U.K. The project has a duration of three years, but the programme will continue as part of the ongoing special investigations activities of the Hydrology Section in the Ministry of Water Development.

AIMS

The primary objective of the project is to provide the Kenya government with practical methods of assessing water resources in the medium potential zone. With a stated national goal of supplying water to all sections of the population by the year 2000, the need for developing more domestic supplies is apparent. A major constraint to this development is the lack of adequate resources data for water projects in the drier medium potential areas which are characterised by having a potential evaporation considerably in excess of rainfall (potential evaporation c. 1800 - 2000 mm, mean annual rainfall c. 625 - 875 mm), an erratic and variable rainfall and heavy sediment concentrations in the streams and rivers. The optimum development of available water resources depends to a large extent on their accurate assessment and also on the prediction of possible effects of changes in land use on future water supplies.

Population growth and poor land management have produced environmental problems within the medium potential zone. Intensification and expansion of agricultural activity have affected the water balance as a direct result of soil erosion and decreased infiltration. In particular, the peak flows of the rivers have increased, dry season flows decreased and sediment yields have become so high that surface reservoirs for rural water supply schemes are no longer a viable proposition in many areas.

In silt-laden, seasonal rivers, routine monitoring of flows as part of the national network is difficult and expensive. An alternative is to establish a small number of representative basins, i.e. well - instrumented drainage basins which can be said to reflect the main hydrological features of a region, and to study the hydrological cycle in depth within these basins. General rules can then be developed which can be used to assess the water resources of ungauged areas.

The representative and experimental basin programme of the Ministry of Water Development aims at establishing such basins, analysing data from them and data available from existing networks and developing simple techniques for assessing water resources and sediment yields which have regional application.

The following paragraphs outline some of the important aspects of this programme.

ESTABLISHMENT OF REPRESENTATIVE BASINS

Four basins were selected in the Machakos - Kitui - Embu region which were suitable for instrumentation as representative basins. This region was chosen in view of its development potential, its proximity to Nairobi and the need for water supply projects. There could be expansion of this work into other medium potential regions as and when manpower becomes available within the Section.

Selection was accomplished with the advice and collaboration of the Ministry of Agriculture and the Land Resources Division of the Ministry of Overseas Development. Initial soil and land use surveys were also carried out by the Land Resources Division.

The four catchments are situated as follows:-

1. Kune (Siakago), Embu District	(11.3 km^2)
2. Kitimui, Kitui District	(7 km^2)
3. Utangwa, Machakos District	(10.5 km^2)
4. Iuni, Machakos District	(11 km^2)

All catchments are on basement complex derived soils and have varying intensities of cultivation. Utangwa, for example, is cultivated over most of the catchment, whereas Kune has less than 25 per cent of the catchment under cultivation. The altitudinal range of the catchments is similar, with all four lying between 1200 and 1900 metres above sea level. The hydrological characteristics are as yet unknown.

Rainfall networks have been established. Weir construction is taking place and automatic weather stations are being installed. Construction work is accomplished by means of a small team from the Ministry using direct labour from each of the catchments.

Automatic suspended sediment samplers will be installed at each river gauging site on completion of the structures. Bed load will be measured by periodic levelling behind the weir walls or similar sediment traps upstream. The sediment samplers are designed to trigger at predetermined stages so that a sequence of samples can be taken at half-hourly intervals during the peak flows.

Soil moisture will be measured by the neutron scattering technique.

PHASING

The first phase of the programme covers the three years of the initial project. During this time the representative basins will become operational and yield preliminary data for mathematical modelling of water balance and sediment. Particular emphasis will be given to the following associated topics:-

1. Study of secular variations in annual rainfall,
2. Rainfall frequency and intensity studies,
3. Analysis of rainfall areal distribution patterns,
4. Derivation of sediment rating curves,
5. Soil moisture budget calculations and the assessment of actual evaporation,
6. Analysis of recession curves,
7. Derivation of flow duration curves, and
8. Analysis of peak flows.

A second phase will be undertaken by the Kenya Government to expand Phase I into other areas, to monitor the effects of land use change within experimental basins, to produce maps of hydrologic regions within the medium potential zone, and to apply the predictive conceptual models to practical problems of water resources management.

ANALYSIS OF DATA FROM THE REPRESENTATIVE CATCHMENTS

Catchment research is the technique of measuring individual components of the hydrological cycle within a closed system, the drainage basin, so that unknown or unmeasurable components can be estimated by difference. In catchments where there is a pronounced dry season and rivers are seasonal, actual evaporation is considerably less than potential evaporation. The difficulty in measuring actual evaporation is one of the major problems of assessing water resources from rainfall data.

By monitoring soil moisture in the catchments, soil moisture budgets can be used to assess actual evaporation. Alternatively, the index of catchment wetness derived from the soil moisture data can be used in mathematical models to predict storm flow or to assess actual from potential evaporation.

By choosing catchments with different degrees of erosion hazard, the effect of infiltration on the water balance can be ascertained and, in particular, the recession characteristics of the rivers can be related to land management features.

The detailed measurements of total sediment load will be used to derive the relationship between sediment yield and rainfall intensity and duration. Simple predictive models of sediment yield will be produced for estimating rates of reservoir sedimentation and rates of regional soil erosion.

ANALYSIS OF EXISTING DATA

Work has already started on the analysis of existing rainfall and suspended sediment data which are available in the departmental archives.

The sediment analysis has revealed heavy losses of suspended sediment of the order of 600 tonnes per square kilometre per annum from areas of Machakos and Kitui Districts. Bed load has also been estimated from the rate of silting of water supply reservoirs. It appears that from small catchments (around 20 km^2) developed on the light sandy soils of the basement complex, bed load losses are of comparable magnitude to suspended sediment losses. This is a much higher figure that had previously been suspected. Total losses in excess of 1000 tonnes/km^2/annum should be expected, therefore, and this would imply erosion rates from individual fields of between three to five times this figure, depending on the exact form of the sediment delivery ratio curve applicable to the region.

TRAINING

An important part of the programme involves the training of counterpart staff to take over in 1980 and implement Phase II. It is anticipated that catchment research will continue to form an important part of the activities of the Hydrology Section. In addition, it is hoped that routine monitoring of suspended sediment will be intensified and expanded within the Section with a view to providing data for water resources studies. Training of the sediment monitoring staff will also be undertaken by project personnel.

LIAISON WITH OTHER RESEARCH ACTIVITIES

The project staff work closely with the National Master Water Plan consultants and with associated sections within the Ministries of Water Development and of Agriculture. The opportunity for collaborating with the University of Nairobi and outside bodies is welcomed and any suggestions for further integration of this programme with other ongoing projects would be favourably received.

SOIL CONSERVATION IN NYANZA PROVINCE

by

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Nyanza Province is not deficient in rainfall. In fact, the plentiful rainfall in the highlands of the eastern and northern regions of the Province, combined with poor farming and livestock management practices and the destruction of forests and scrub, is primarily responsible for the gully and sheet erosion which affects the lower slopes of the hills and the Lake Victoria Basin. The same factors are also responsible for the heavy silting of the Sondu, Migori, Yala, Kuja, Nyando and Kibos Rivers and their consequent 'perching' and the resultant perennial flood risk in their lower reaches.

The Provincial Development Committee has attempted consistently to view the problems of soil conservation not in isolation, but as an integral part of the larger economic and social development of the province as a whole. For instance, it would not be sufficient to combat a problem such as gully erosion in Nyakach and Karachuonyo Locations with a programme of terracing, grass and tree-planting and stream protection. Measures of this sort will, of course, be necessary, but they must be introduced in the broader context of programmes for farmer training in improved crop and livestock husbandry practices. Such programmes as market expansion, supply of agricultural inputs, provision of credit and the improvement and construction of roads and water supplies must also be planned with full consideration of conservation issues.

It is estimated that by the year 2000, given present farming techniques, the province will be unable to support the projected agricultural population at subsistence level. This is assuming that the population will continue to increase at the present rate of 3.5 per cent a year and that well over 90 per cent of the population will continue to derive its subsistence, and in an increasing number of cases some cash income, from farming. There is thus a strong case to be made in favour of directing available resources to the rehabilitation of land that has been allowed to deteriorate in productive

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1. This paper was originally prepared jointly by the Provincial Director of Agriculture and the Provincial Planning Officer, Nyanza Province, under the general direction of the Chairman of the Nyanza Provincial Development Committee, for the National Conference of Desertification, held in Nairobi in July 1977. This shorter version was prepared by P.A.M. Misiko and Sidney B. Westley.

capacity and of emphasising measures to raise the levels of crop and animal husbandry techniques.

A PROGRAMME OF AFFORESTATION

Given an estimated population growth rate of 3.5 per cent a year, the projected domestic consumption of forest products for fuelwood and building poles will increase from 2.596 million cubic metres of round wood equivalent in 1976 to 3.610 cubic metres in 1985. In addition to domestic consumption, the growing tobacco industry in the province is expected to increase its woodfuel requirements considerably over the next few years. Consumption of bush fuel at the projected rates will seriously affect the ecology of the tobacco growing areas, very likely leading to soil conservation problems.

By projecting future timber requirements in the province and calculating the average productivity of indigenous bush and of eucalyptus plantations, it is possible to estimate the magnitude of the replanting which will be necessary to meet the anticipated demand without creating serious deforestation problems. The Provincial Development Committee is in the process of preparing a comprehensive provincial forestry plan which will, inter alia:-

1. Assess current demand and project future demand for forest products,
2. Assess current and future production based on on-going planting programmes,
3. Assess natural regeneration rates of indigenous and exotic forests,
4. Analyse soil and rainfall data for prospective forest sites,
5. Recommend tree species suited to each zone, as determined by soil and rainfall data,
6. Draw up costed planting programmes for a fifteen-year period, including the costs of soil conservation projects,
7. Formulate proposals for public land planting, school projects, urban centres, etc., and
8. Draw up seedling production programmes geared to the projected needs of the planting programmes.

SURFACE EROSION

Considerable areas of the province, in particular parts of Nyanza, Karachuonyo, Muhuro Kadem and West Nyokal Locations, are presently affected by medium to grave sheet and gully erosion. This erosion is caused by a combination of the following factors: agricultural malpractices, over-grazing, de-afforestation for wood fuel and charcoal, bush clearing for tse-tse control, cultivation on steep slopes or too near river banks, and un-controlled bush clearing. All these factors are aggravated by drought followed by intermittent heavy rain.

Numerous ongoing national and provincial programmes are directed specifically towards soil conservation. These programmes, and a proposed national plan of action to intensify soil conservation measures, are described in detail in the National Environment Secretariat paper OP/NES/200/261/02 of 23 March 1977.

At the Nyanza Provincial level, guidelines will be issued to District Development Committees outlining national programmes and measures and inviting each Committee to include appropriate district-level programmes in the 1978-82 district development plans now being drafted. The Provincial Development Committee will continue to exercise a co-ordinating role and to provide technical direction and will lay down financial parameters.

FLOODING

Perennial flooding on the Kano Plain and the Kuja River delta causes much suffering for the human population, destroys crops and damages infra-structures. Severe floods occur with increasing frequency, and they occur each time with lesser rates of discharge than those of previous floods. The causes are:-

1. Deforestation in the catchment areas, causing increased peak flows,
2. Erosion in the catchment areas, which increases the silt load of the rivers. As a result the bed levels in the lower reaches of the rivers are raised and this induces flooding, and
3. The clogging of the rivers' outlets into Lake Victoria. All rivers end in a swamp area so that there is no freee flow of water into the lake. This causes backing up of water and, as a result, floods.

The best solution to this problem is a reforestation and erosion control programme in the catchment areas. This will be a costly, long-term programme with the benefits only felt after a substantial period of time. In the meantime, some flood protection measures can be taken in the Kano Plain. As mentioned in the Gibb report, they consist principly of:-

1. The construction of flood prevention dykes along both sides of the rivers. These dykes should be constructed well outside the meander belt of the rivers. The design and construction of these dykes should be carefully studied before they are built: they will have to be of correct shape and height so that they will not break or overtop; they must be well compacted so that they do not collapse or leak (a frequent occurrence with recently built dykes),
2. Opening (clearing, deepening, widening) of river outlets or construction of outlet canals in or alongside the existing swamps (promoting the drainage of the swamps), and
3. Canalisation of river beds, either in the existing river beds or by creating new river courses, especially for the Nyando River. This measure is probably the most effective. It will make possible the fast evacuation of peak flows and limit as far as possible sedimentation in the lower courses of the Nyando River.

A diversion canal for the Nyando River could begin south of the Ahero bridge and proceed directly towards Lake Victoria. In this way, the existing swamps will also partially drain. A canal such as this can make better use of the available head of water and consequently sedimentation in this canal will be less than in the existing river course. The canal can be provided with dykes (built from the spoil) on both sides. The distance from the canal to these dykes depends on the area of flood plain necessary to pass extreme peak flows.

The Miriu River and the Ombei-Luanda Swamp could also be connected with this proposed canal, making use of the existing road crossings. The existing Ombei River course could then be used as a main drain. If, in addition, a small dam joins the natural levee between the Ombei and Luanda Rivers with the existing dyke of the West Kano Pilot Scheme, and if some culverts are increased in size and some parts of the rivers are cleaned, a resonable degree of flood protection will be provided.

With the limited information available at present, any cost estimate of these provisions must be approximate, but to serve as a guideline an outline of the cost is given here:-

Nyando Canal with dykes - 14 km: 1,000,000 m^3 at K. Shs. 20 per m	K.Shs. 20,000,000
Ombei-Miriu Canal - 7.3 Km including dykes: 82,000 m^3 at K.Shs. 20 per m.	1,640,000
Dam (West Kano-levee)	650,000
Increasing size of culverts, cleaning waterways	?
	K.Shs. 22,290,000

Note: Overhead costs are not included.

DEVELOPMENT OF LAKESHORE SWAMPS

In addition to soil and water conservation the successful drainage of the Yala Swamp has demonstrated that the cost-benefit ratio of bringing new land into production by this method is relatively favourable. There are over 12,500 hectares of swamps suitable for drainage on the Kano Plain. Within the province as a whole there is an area of nearly 100,000 hectares of swamps suitable for development.

Plainly the costs of such long-term development must be balanced against the increasing population pressure on available agricultural land.

LOCAL ENVIRONMENTAL PERCEPTION AND SOIL AND WATER CONSERVATION PRACTICES

by

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INTRODUCTION

The Role of Local Communities in Conservation

Many construction engineers are convinced that those personnel who are going to be involved in the long-term maintenance of structures must be intimately involved in their construction. In this way they will be familiar with the anticipated operational and structural weaknesses. With roads for example, those involved in construction will become familiar with every foot of the road, where the ballast is weak, where a culvert may be insufficient, etc.

In soil and water conservation structures, the basic unit involved is the farm. An adequate farm plan represents investments in dams, cutoff drains, terraces, windbreaks, woodland, permanent pastures and a cropping regime which is consistent with the goals of fertility build-up and conservation. The farmer and his household are the active agents in building such structures and in maintaining them. In cases where governments intervene to enforce the construction of such structures or even construct them with or inspite of farm household participation, the long-term goal is for the farm household to maintain such structures and integrate them into farming operations and farm resource utilisation. The need for this household to be involved and understand the environmental and economic rationale of such structures is obvious if they are to maintain them and integrate them effectively in their farm operations.

In certain cases, local villages or 'communities' are the basic units involved. In dealing with the special problems of a catchment zone, specific watershed, river course, inter-farm paths or tracks, then one involves more than one farm household and the need for community involvement is the same.

The participation of local communities in conservation is further supported by economic and sociological evidence. In current development funding, provision is made for mobilising local resources in the spirit of Harambee (self-help). Such local resources include local unskilled and semi-skilled labour, local farm tools and draught power, local organisational ability and leadership skills, and materials in kind such as sand, stones, grass splits and seeds. Participation of local populations in soil conservation is seen as critical in increasing local commitment and identity with the goals of the conservation programme. Such commitment eliminates suspicion, apathy and indifference and legitimises the sacrifice of personal energy and farm resources.

However, participation in soil conservation is itself influenced by a variety of socio-psychological and group level factors. One of the most important factors is the level of local understanding of the seriousness and causes of erosion and hence the nature of preventive action needed. Obviously, if a farmer perceives erosion as caused by a curse on the community, then sacrificing goats is going to be more relevant than making terraces.

The goal of soil conservation is ultimately to increase the farm productivity and population carrying capacity of a zone. Unless farmers grasp this linkage, and develop their own associations between family subsistence food requirements and conservation, then maintenance of structures will not compete successfully for resources with other farm activities. Thus, perception problems do not simply include environmental perceptions but the relation of terracing, for example, to manuring, fertilising, early ploughing, seed selection, etc. to increase yields.

A technical understanding of the effect of rain drops and runoff is also important to the perception of what structures are necessary and sufficient to halt erosion. If farmers perceive cutoff drains alone as sufficient, then the effectiveness of even these structures may be jeopardised. In this paper, we examine the local attitudes and perceptions in six locations of Machakos District which are relevant to a soil conservation programme and appropriate educational approaches.

DATA BASE FOR THE STUDY

There were two principal data collection techniques used in this study: a general survey and key informant interviews. The 310 respondents to the general survey were selected through a combination of stratified area sampling and random sampling. They were all members of soil conservation mwethya groups (self-help groups composed largely of women) operating in the locations of Kalama, Wamunyu, Kibauni, Masii, Mwala or Muthetheni in the Machakos area. Questions in the survey were focussed on the individual farmers, their attitudes towards conservation, general farm and conservation practices and other relevant socio-economic characteristics.

For each of fifteen mwethya groups, chosen both on the basis of level of group activity and ecological setting, five key informants were questioned. These informants were key persons in the mwethya group, either because they occupied an official leadership role or because they had a great deal of unofficial influence on their group. Key informant interviews attempted to assess the mwethya groups as completely as possible in terms of leadership, group activities and the problems facing the groups. Only part of the data generated in this study is discussed in this paper, although we attempt to raise as many relevant issues as possible.

SPECIFIC TYPES OF PERCEPTIONS

How people perceive or understand their environment and how their perceptions are related to their actions—these questions are not fully understood by social psychologists. By perception we mean the appreciation of phenomena in one's environment and the development of cognition or mental images and evaluative criteria about them. Bateson (1942) argues that the human individual is endlessly simplifying, organising and generalising his own view of the total environment and constantly imposing his own constructions and meanings through his behaviour. Thus such 'meanings' or 'constructions' define an individual's attitudes to phenomena and determine his views and criteria for action. If we define perception as the sum of knowledge, understanding and attitudes, then the relationship between perception and action is determined by the degree to which such knowledge is used in decision-making. Thus we are concerned not only with what local people know - how they respond to environmental factors - but also with the degree to which this knowledge is an important factor in determining their soil conservation activities.

PERCEPTION OF THE CAUSES OF SOIL EROSION

Table 1. Perceptions of the causes of soil erosion (percentages).

Ploughing down slope	21
No terraces	34
Not cultivating deeply	25
Overstocking	5
Hand cultivation (no ploughing)	4
Other, e.g., destroying terraces, burning bushes, no crop rotation	11
	100
Total n (number of group members interviewed)	310

In the locations studied, casual observation would indicate that the most serious factors leading to soil erosion are overstocking, lack of conservation structures and destruction of vegetation, in that order. The most seriously affected regions are the grazing lands. The first response in Table 1 appears to be an echo of extension advice rather than actual observation, because one does not see anyone ploughing down slope in this area.

Table 2. Perceptions of the best way to combat soil erosion (percentages).

Terraces	44
Tools, machines	37
Unity of people	14
Other, e.g., training leaders, provision of grass, seeds, etc.	5
	100
Total n	310

Tables 1 and 2 indicate that people do not have very concrete perceptions of the causes of soil erosion. These tables show that the the solutions which have been put forward to stop erosion may in some cases be oversimplified. Provision of tools is certainly necessary for a good conservation programme, for example, but the strong, almost exclusive emphasis on terraces means that the majority of local people perceive soil conservation in a very limited way.

A review is also needed of the attitudes towards special problems of soil erosion, such as bare grassland areas. Also, more comprehensive education on causes of soil erosion is necessary. Knowledge deficiencies appear to be critical in the following areas:-

1. Causes of erosion. This includes soil exposure, the effects of rain drops and crater formation, runoff, wind erosion and the intensity of sheet erosion. In some areas we found small plants growing on islands of soil one foot above the general ground level for which farmers had no explanation.

2. Preventive measures. We found that most farmers feel that one method of conservation is sufficient. For example, farmers felt that cutoff drains were sufficient for the reclamation of bare grassland and there was no need to plant grass on bare ground. The need to see conservation as a carefully designed package programme is critical. For example on denuded ground, slowing the runoff of water is only a first step which must be followed

by planting grass, weeding pasture, controlling grazing, applying manure or fertiliser, fencing, etc. The design of carefully prepared training materials on these relationships is an important educational approach to the conservation programme.

Table 3. Perceptions of the reasons why grassland should be reclaimed (percentages).

Increase grazing land	40
Stop erosion	20
Bare land is useless	14
Land looks unpleasant	7
Bare land causes lack of water in the area	8
Others, e.g., bare grassland leads to gullies	
	100
Total n	310

The majority of the respondents felt that grassland should be reclaimed in order to increase grazing. Whereas on the face of it this is a valid response, i.e., to increase carrying capacity, we found that the older respondents most often gave this reason. Their concern appeared to be with decreasing herd size and greater livestock mortality from drought and starvation. These people are unlikely to participate willingly in a long-term pasture reclamation programme which may include keeping livestock out of certain denuded areas for long periods, since such measures would entail keeping smaller herds. The need for 'dramatic improvement' in pastures under any programme or for sending livestock to 'holding farms' was expressed by the majority of the respondents. They seem to feel that farmers could be assisted to buy cooperative farms which they would use as holding farms while they reclaimed their own pastures without losing their subsistence supply of milk or the petty cash obtained from selling or butchering the odd cull. Farmers were not keen to relate overgrazing to erosion, or even to define the factors leading to overgrazing such as overstocking or poor establishment of grass. Yet as stated earlier, this was perhaps the most serious conservation problem observed in most areas except Masii.

Gullies are a serious problem on sloping land in Kalama and Kilungu. In these areas, people have had favourable experience with sub-surface dams. In areas where slopes are not very steep and the flow of water is likely to be slow, sisal was mentioned as a solution. In fact sisal

Table 4. Perceptions on how bare grassland should be reclaimed (percentages).

Cutoffs[a]	53
Plant grass	26
Dig cutoffs	10
Plough the land	7
Other, e.g., plant trees, stop grazing	4
	100

a. 'Cutoffs' was a term used by the respondents to refer to various types of conservation structures.

might be able to establish itself in a gully. Tables 5 and 6 present the respondents' attitudes concerning gully reclamation in more detail.

Table 5. Perceptions of why gullies should be reclaimed (percentages).

Stop erosion	52
They consume all the good land	17
So people and animals will not break their legs	10
Water drains into them	8
Others, e.g., land will have a more attractive appearance	13
	100
Total n	310

Table 6. Perceptions of how gullies should be reclaimed (percentages).

Plant sisal	28
Construct sub-surface dams	23
Construct terraces	13
Fill with soil	8
Plant grass	8
Plant trees	4
Fill with stones	6
Others, e.g., fill with logs	10
	100
Total n	310

The solution most frequently suggested to control gully erosion was the planting of sisal, which is not suitable for all types of gullies. Filling gullies with soil, grass, trees, etc. may be feasible for small gullies but is difficult with larger ones. An alternative solution, not mentioned by the people interviewed, may be to establish vegetation and build cutoffs on the areas above gullies to reduce the amount of water flowing into them. One factor not mentioned or implied in the responses is the relative merits of each method in relation to the resources available to local communities. We found that most communities do not have the resources to reclaim a gully of average size, about 10 feet wide by 5 feet deep, and most existing conservation structures are in areas without gullies. There is a need to assess the amount of land lost through gully erosion and to devise measures to reclaim it.

Table 7. Perceptions of why forests should be preserved (percentages).

Building materials for houses	40
Induces rain	26
Charcoal	7
Windbreak	7
Firewood	7
Others, e.g., trees hold soil, sale of trees brings money	13
	100

Last, we enquired about forest preservation. The preservation of forest growth was the only special conservation problem which none of the respondents seemed to recognise: 16 per cent said it was not necessary, and most of those who did support the protection of forests gave unsatisfactory reasons in terms of the aims of conservation. Rather than reasons relating to conservation, many people suggested saving forests merely as sources of charcoal and firewood.

We found evidence of a number of misconceptions about trees and rain, and some of them are propagated by government officers who encourage farmers to plant trees to increase the rainfall. It is generally believed that it rains less than it used to and this is sometimes attributed to cutting down trees. We can find no evidence for this. The history of Machakos District includes periods of drought and famine as well as periods of heavy rain, and there is no appreciable long-term trend. What has happened however is that cutting trees plus overgrazing has led to much faster runoff of water when it does rain, and this has been accentuated as the network of channels has proliferated. Some streams and springs dry up much more quickly than in the past, giving the impression that rainfall has decreased. Planting trees may not bring more rain, but it may slow down runoff and encourage infiltration. This coupled with deep seepage, raises the water table and consequently improve) the continous streamflows. However, much will depend on slope, soil depth, type of trees. etc.

ATTITUDES TO DESTOCKING

It was anticipated that respondents who have lost livestock might have different attitudes to destocking, and hence the zones and locations in the study area are compared in terms of the extent of livestock losses and the attitudes to destocking. Farmers were asked to indicate how many of their animals had died in the previous year. Tables 8 and 9 show the breakdown of these losses for large animals only, that is cows, oxen, heifers and bulls.

Table 8. Agricultural zones and cattle losses (percentages).

Zone	Mean Number of Live Animals[a]	Number of Deaths of Cows, Oxen, Heifers. Bulls							
		0	1	2-3	4-5	6-7	8-9	Totals N	%
Masii, Wamunyu, Muthetheni	7.87	19	10	16	11	9	35	178	100
Lower Kalama and foot hills	5.06	-	14	19	3	-	65	74	101
Hilly Kalama	4.74	2	7	11	5	-	75	56	100
Total n[b]		34	32	48	25	16	153	308	

a. This was the mean number of animals per herd for each zone at the time of the survey.

b.n= number of animals.

Table 9. Locations and cattle losses (percentages).

Locations	Number of Deaths of Cows, Oxen, Heifers and Bulls							
	None	One	2-3	4-5	6-7	8-9	Total N	%
Kalama	1	11	15	4	-	69	90	100
Mwala	10	2	18	8	4	57	49	99
Muthetheni	-	15	23	12	19	31	26	100
Wamunyu	12	12	20	16	14	26	50	100
Masii	42	13	6	9	4	26	53	100
Total n	34	32	48	25	16	153	308	

From both Tables 8 and 9, it is clear that losses differed depending upon zones and the locations. The hilly zone had the highest losses of livestock, and this can be compared with the low remaining number of live animals relative to other zones. For the locations, Kalama had the highest losses, closely followed by Mwala. Close to 70 per cent of the respondents in Kalama had lost 8 to 9 large animals over the previous dry season. Another area of relatively large losses was Kiliku in Kibauni Location.

Looking at the attitudes towards destocking as shown in Table 10, there is a significant variation according to location. The relationship between livestock losses and attitudes will be brought out more clearly in a later section of this paper.

Table 10. Locations and attitudes towards destocking (percentages).

Location	Would you Destock?		Total	
	Yes	No	N	%
Muthetheni	67	33	24	100
Masii	61	39	49	100
Kalama	60	40	108	100
Wamunyu	54	46	46	100
Mwala	52	48	42	100
Total n	158	111	269	

AN EVALUATION OF THE UTILITY OF LOCAL ATTITUDES AND PERCEPTIONS

It can be observed in the areas under study in Machakos District that soil erosion is a major problem and that particular practices and attitudes contribute to this problem. For one thing, certain widespread beliefs should be discouraged since they do not appear to support the most effective solutions to the soil erosion problem. For instance, 99 per cent of the people interviewed felt that sisal lines are useful in preventing erosion on grazing land. Yet in the areas studied, sisal does not seem to perform effectively in preventing soil erosion. After growing to a certain height the bottom leaves decay, leaving an empty space at the bottom. Soil is often eroded around and through the roots of the plant. People also use the dried leaves as firewood, and animals feed on sisal during time of drought. The base of the plant is in many areas from one-half to one-and a half feet above the surface of the soil. For land that is fairly level, planting sisal is not an adequate means of preventing erosion.

On the other hand, it would be useful to investigate further the potential usefulness of sisal in gully reclamation. It might be the case that if slopes are not very steep and water velocity is low, sisal can be established

Table 11. Solutions frequently suggested for various soil erosion problems.

Problem	Two of the Most Frequently[a] Suggested Solutions to the Problem	
Soil erosion	1. Terraces (44%)	2. Tools or machines (37%)
Bare grassland	1. 'Terraces'[b]	2. Plant grass (26%)
Gullies	1. Plant sisal (28%)	2. Sub-surface dams (23%)

a. This refers to the largest percentage.

b. Again, this refers to conservation structures in general such as cutoffs, etc. Cutoffs are basically the same as terraces, but with a much larger channel and ridge.

in gullies and will serve as an effection measure to prevent erosion. This practice is popular in all of the areas studied.

Digging cutoff drains entails another problem. People may perceive complementary soil conservation practices as mutually exclusive. In other words, if one practice is adopted, it may be believed that other practices are unnecessary. Half of the farmers who never dug cutoff drains gave as their reason for this the fact that they had constructed terraces. Having terraces, they felt that digging cutoff drains would be a duplication of effort. Farmers should be made to realise that many different strategies are needed to tackle the complex problem of erosion effectively.

Finally, there are potential difficulties when people give the desire for more firewood, or more wood for charcoal making or building, as the reason to conserve trees. If these are the main reasons for conserving trees, the people may merely be planning to cut down the trees at a later date.

Despite these few areas where it appears that people's attitudes should be changed, there are other areas where their attitudes are basically sound but need to be modified to some degree. Sub-surface dams made from stones and cement are one very effective method for reclaiming gully areas. They are much more practical than planting sisal, since they not only conserve soil but also store water.

One farmer in the Kikaso mwethya area has reclaimed a gully in a very unique way. He filled over 150 sacks with soil and put them in the gully until it was almost full. The remaining part was filled with soil, terraces were constructed and sisal was planted on the upper slope and banks and grass on the terraces. Another farmer near Kyangala has established a good plantation of bananas in a gully area.

Soil conservation is rarely a once-for-all undertaking, but requires a continuing effort to maintain terrace banks, to raise the height of the lip (ridge) of terraces, to maintain the grass cover on the banks, and to remove silt from cutoff drains. Whatever assistance is given to farmers should encourage a continuing effort, rather than building a structure which is then neglected. People should be informed about the need for continued maintenance activities.

FACTORS INFLUENCING PERCEPTIONS

Perceptions can be influenced by the physical and social environment, by the individual's own experience, and by the opinions of other people who are important to him. In terms of the physical environment, the clearest example is the relationship between cattle losses and attitudes towards destocking. As shown in Table 12, more than half of those who had lost no cattle were against destocking, while even the loss of one animal alters the proportion to 71 per cent in favour of destocking. Of course those who have lost large numbers of animals often have so few left that they are unwilling to consider destocking as destocking is actually unnecessary. This shows that particular attitudes can be drastically affected by changes in the environment, such as severe animal losses in a drought-stricken area.

Table 12. Cattle losses and attitudes towards destocking (percentages).

Number of Deaths of Cows, Oxen, Heifers and Bulls	Would you Destock?		Total	
	Yes	No	N	%
0	47	53	30	100
1	71	29	31	100
2-3	69	39	44	100
4-5	55	45	23	100
6-7	74	26	15	100
8-9	58	42	124	100
Total n	157	110	267	

Those who have had the heaviest losses usually have the smallest number of stock at present. It is logical that they tend to be less in favour of destocking, as shown in Table 12. It would be sensible to push for destocking programmes in areas where losses have occurred but have not been extremely high.

In addition, certain ecological factors may have been in existence for a long time, and are not undergoing change at present. For instance, in one very rocky part of the country people joke that God created all the other parts of the land on the first six days and then on the seventh day threw down hi bag, which had only stones. People seem to feel that the land in such an area has been poor for a long time and hence the situation must be accepted. In general, long established ecological conditions are often the only major factors affecting an individual's idea of the usefulness of the soil and the relevance (or irrelevance) of his own efforts.

The social environment primarily refers to social groups, such as soil conservation groups, which attempt to fight soil erosion collectively. Although the groups are effective in convincing people that soil and water conservation is necessary, their influence on the perception of remedies is sometimes limited by the leaders' limited technical knowledge.

It is instructive to review the projects mentioned as high priority by key informants from these mwethya groups. After construction of terraces, the only other soil and water conservation activity mentioned is dam construction. This indicates that the perception of conservation is limited at the group level to a few activities. The perceptions of these groups will then influence individual farmers to perceive conservation in this limited way.

Table 13. Other projects of high priority (percentages mentioning).

1. Constructing dams	37
2. Building schools	29
3. Constructing cattle dips	6
4. Constructing health centres	8
5. Constructing roads	5
6. Starting marketing or production cooperatives	8
7. Building houses for members	8
Total	101
Number of key informants responding	60

As mentioned, the indivual's own experiences and personal characteristics can also affect his attitudes and practices. The most relevant experiences are those connected with general farm practices. Farmers who have adopted agricultural innovations are more likely to feel that the individual farmer can play a positive role in increasing farm productivity. To the extent that they see soil conservation as another way of ensuring this productivity, they will also adopt conservation practices.

Tables 14, 15 and 16 show how farm practises may relate to conservation practises. The first two tables are Guttman scales of general farm innovations and soil conservation practises. The percentages refer to the proportions of respondents engaged in particular practises. Scale steps are then simply the ranking of the practises according to these percentages.

Table 14. Farm innovations.

Scale Step	Innovation	Percentage of Sample Group Members Adopting
1	Began planting Katumani maize	99
2	Began planting crops in rows	97
3	Began ploughing land by tractor or ox plough	97
4	Began using farmyard manure	96
	Began crop spacing	-
5	Began early planting	93
6	Began seed selection	90
7	Began bush clearing	84
8	Began cattle dipping	80
9	Began crop rotation	76
10	Began frequent weeding	71
11	Planted fruit trees	60
12	Began seed dressing	48
13	Planted cassava as famine reserve	41
14	Farm surveyed	37
15	Began thinning and pruning	30
16	Began using compost manure	20
17	Began using casual labour	10
18	Began spraying and dusting crops	6
19	Planted cotton	4
20	Planted green grams	2
21	Opened savings account	0.6
	Keeps farm records	-
22	Installed water on farm	0.3
	Feeds cattle with purchased food	-
Number in sample		310
Coefficient of Reproducibility		0.88

Table 15. Farm conservation practices.

Scale Step	Practise	Percentage of Sample Group Members Adopting
1	Began terracing cultivated land	100
2	Began contour ploughing	99
3	Used grass cover on terraces	90
4	Began conserving trees	82
5	Began ridging before planting	70
6	Began fencing pasture	58
7	Began destocking	44
8	Began planting hedges as windbreak	30
9	Began improving grass pastures	24
10	Built contour straw heaps	15
11	Planted grass strips between crop areas	10
12	Dug cutoff on cultivated land	5
13	Began keeping river banks for pasture	4
14	Began mulching	2
15	Began constructing dams on farm	2
Number in Sample		306
Coefficient of Reproducibility		0.88

Table 16 shows the relationship between the ranking of individual respondents on the two scales. In this case, each respondent was ranked relative to the other respondents in terms of the number of practises adopted. This means that the lower ranks represent those individuals who had adopted very few practises, while the higher ranks (for instance, 25 - 30 for farm innovations) represent those who had adopted many of the practises. In this table, a respondent's rank on one scale is compared with her or his rank on the other scale.

Most of the respondents - 90 - rank in the middle of both scales. Smaller numbers rnak in the lowest group on both scales (12) or the highest group on both scales (2). The gramma statistic shows a positive relationship between the level of farm innovations and conservation practises, indicating that the respondents who are more innovative tend also to adopt more soil conservation techniques.

The positive correlation between group members who have adopted farming innovations and those who practise soil conservation suggests that there is a relationship between attitudes toward innovationand conservation efforts. Personal characteristics such as age, sex and level of education also influence

Table 16. The relationship between farm innovations and soil conservation practises.

Farm Innovation (Ranks)	Conservation Practices (Ranks) 0 - 6	7 - 12	13 - 20	Totals in Innovation Ranks
0 - 6	12	2	1	15
7 - 12	26	21	5	52
13 - 18	28	90	16	134
19 - 24	11	63	26	100
25 - 30	--	3	2	5
Totals in Conservation Ranks	77	179	50	306

Note: gamma statistic = 0.56

these attitudes. Table 17 illustrates a correlation between age and perceptions of why grassland should be reclaimed. In some cases, the older respondents tend to support conservation measures for reasons that would tend to increase erosion in the long run. Respondents over 30 years old are more likely to support the reclamation of grassland in order to increase grazing land which implies a long-term commitment to keeping large herds of livestock.

Table 17 Reasons for reclaiming grassland according to age groups.

Age Group	Reasons why Grassland Should be Reclaimed (%) To Increase Grazing Land	To Stop Erosion	Land looks Unpleasant	Other	Total (%)	N
Under 30	24	31	2	43	100	43
30-39	42	20	8	30	100	83
40-49	39	22	10	29	100	88
50+	35	13	4	48	100	93
						307

Finally farmers may acquire information and attitudes from other people who are influencial. The persons seen as having knowledge and experience and with whom the respondents feel they can communicate easily are likely to datermine their perceptions more strongly than all other factors combined. We were interested in determining the sources of information about conservation and began by investigating the level of contact with extension officers.

Table 18. Agricultural zones and extension visits (percentages).

Zone	Times Visited by Extension Agent in Previous Year				Total	
	Never	1-2	3-4	Over 4	N	%
Masii, Wamunyu, Muthetheni	76	14	6	3	174	99
Lower Kalama and Foothills	80	14	4	1	70	99
Hilly Kalama	91	7	2	-	57	100
Total N	241	39	15	6	301	
%	80	13	5	2	100	

Table 19. Agricultural zones and attendance at farmer training centre courses (percentages).

Zone	Ever Attended F.T.C.?		Total	
	Yes	No	N	%
Masii, Wamunyu, Muthetheni	21	79	178	100
Lower Kalama and Foothills	12	88	73	100
Hilly Kalama	5	95	57	100
Total N	49	259	308	
%	16	84	100	

From Tables 18 and 19 it is clear that roughly 80 per cent of the respondents had no exposure to formal agricultural advice or instruction. Some 36 per cent of all respondents said they learned about soil conservation from friends and relatives, 12 per cent from the mwethya group and 23 per cent said they have never learned from anyone. Friends and relatives seem to exercise the major influence on local conservation knowledge and practises.

Of those who were exposed to extension services, over half said they were told to construct terraces, only 2 per cent were told to plant grass and 4 per cent to construct dams. Of those who attended courses at Farmer Training Centres, 24 per cent reported receiving instruction on soil conservation, 5 per cent on tree conservation, 20 per cent on planting Katumani maize, and the rest reported courses on cattle keeping, the care of poultry, etc. These responses seem to indicate a need for broader education programmes in the area of soil conservation.

REASONS FOR PRACTISING SOIL CONSERVATION AND A TECHNICAL DISCUSSION OF CONSERVATION PRACTICES

Given these general trends, it is necessary to discuss the rationale behind people's adoption of conservation practices. In addition, we include a discussion of the technical aspects of soil conservation and related problems.

Table 20. Major reasons for practicing or not practicing specific soil conservation measures.

(1) Began Terracing Cultivated Land

Why doing?	Why discontinued	Why, if never?
a. To prevent erosion (91%)		
b. To stop water from running through the farm (5%)		
(N= 310)		

(2) Began Deep Ploughing

Why doing?	Why discontinued?	Why, if never?
a. To soften the soil (22%)		a. Lack of good tools (50%)
b. To trap water (17%)		b. No oxen (39%)
c. To get more moisture for crops (13%)		(N = 28)
(N= [illegible])		

(3) Used Cover on Terrace Banks

Why doing?	Why discontinued?	Why, if never?
a. To hold soil on terrace banks (58%)	a. Uprooted during road construction (100%)	a. Lack of grass seeds or money (48%)
b. To prevent erosion (20%)	(N = 2)	b. I intend to do so (13%)
c. To feed cattle (10%)		c. They grow Naturally (12%)
(N = 220)		(N = 75)

(4) Began Conserving Trees

Why doing?	Why discontinued?	Why, if never?
a. For building (33%)		a. Lack of trees to plant (25%)
(N = 220)		b. There are enough trees (20%)
		(N = 79)

(5) Began Ridging

Why doing?	Why discontinued?	Why, if never?
a. To trap water in the farm (73%)	a. No axes (100%)	a. Don't know the technique (32%)
b. To prevent soil erosion (11%)	(N = 4)	b. Lack of material (25%)
c. To lessen the speed of water (9%)		c. Never heard of it (12%)
(N = 186)		(N = 113)

(6) Began Fencing Pastures

Why doing?	Why discontinued?	Why, if never?
a. To protect grass from other cattle (63%)		a. Lack of material (25%)
b. To mark the boundary (18%)		b. Lack of time (15%)
c. To conserve feed for the cattle (12%)		c. Land is not adjudicated (10%)
(N = 165)		(N = 141)

(7) Began Destocking

Why doing?	Why discontinued?	Why, if never?
a. To have enough grass (18%)	a. They are few (60%)	a. The animals are few enough (60%)
b. To match the size of my land (16%)	b. The grass is enough (20%)	b. No cattle (33%)
c. To prevent erosion (15%)		
(N = 143)	(N = 5)	(N = 160)

( ) Planted Grass Strips Between Crop Areas

Why doing?	Why discontinued?	Why, if never?
a. For feeding cattle in the dry season (74%)	a. Because of drought (100%)	a. The land area is too small (34%)
b. To reduce erosion (12%)	(N = 4)	b. Lack of grass seeds (15%)
c. To increase soil fertility (9%)		c. All the land is cultivated (14%)
(N = 54)		(N = 213)

( ) Dug Furrows on Cultivated Land

Why doing?	Why discontinued?	Why, if never?
a. To direct water away from land (28%)	a. Lack of tools (100%)	a. I prefer terraces (30%)
b. To prevent erosion (22%)	(N = 6)	b. I intend to in the future (19%)
c. To trap water (20%)		c. The terraces are enough (17%)
(N = 200)		(N = 104)

(1) Began Keeping River Bank for Pasture

Why doing?	Why discontinued?	Why, if never?
a. To feed animals (96%)		a. Not near the river (67%)
b. To sell the grass (2%)		b. River is dry and stony (12%)
(N = 57)		(N = 243)

(11) Began Mulching

Why doing?	Why discontinued?	Why, if never?
a. To retain moisture (52%)	a. Lack of rainfall (100%)	a. Lack of plant material (68%)
b. to protect terraces (26%)	(N = 2)	b. Don't know the technique (13%)
(N = 19)		(N = 276)

(12) Began Constructing Dams on the Farm

Why doing?	Why discontinued?	Why, if never?
a. To get water for domestic use (48%)		a. Lack of tools (35%)
b. To increase amount of water (35%)		b. Lack of money (34%)
(N = 23)		c. No river nearby (13%)
		(N = 246)

(13) Planted Trees

Why doing?	Why discontinued?	Why, if never?
a. For wood to build houses (36%)	a. They dried up when planted (100%)	a. Lack of rain (44%)
b. To break strong winds (12%)		b. There are a lot of trees (14%)
c. To attract rainfall (12%)		c. Lack of money (10%)
(N = 138)		d. 'Ants' problem (90%)
		(N = 124)

(14) Dug furrows on Uncultivated Land

Why doing?	Why discontinued?	Why, if never?
a. To prevent erosion (47%)	a. Lack of tools (100%)	a. No tools or poor tools (21%)
b. To divert water to cultivate land (17%)	(N = 2)	b. I want to do the cultivated land first (13%)
c. Because water may carry grass (15%)		c. Lack of time (10%)
(N = 59)		(N = 245)

(15) Brought Water to the Land

Why doing?	Why discontinued?	Why, if never?
a. For domestic use (90%)		a. Lack of money (58%)
b. For irrigation (10%)		b. Lack of water (17%)
(N = 10)		c. Lack of water pipes (7%)
		(n = 298)

Note to Table 20.

The major reasons are those reasons which were given by the largest percentage of the respondents. These percentages will not equal 100% since not all reasons are included in the table. The N refers to the total number of respondents who said they were presently doing, or were not now doing, or had never done a certain practice. If some respondents did not reply to specific questions the total of all N's will not equal 310.

Several points emerge from Table 20. For one thing, the reasons stated for adopting specific conservation practises are often not actually related to conservation. For example, if trees are only preserved for later use as firewood or building material, they may not be allowed to remain long enough to achieve conservation goals. The terracing of cultivated land is the one exceptional practise where almost all the respondents mentioned prevention of erosion as the basis for adoption. From observations in the field, it seems that most cultivated land is protected against erosion by cutoffs and bench terraces with the exceptions of Kilungu and Mukaa Locations.

Of all the terraces examined, the majority can be classified as bench terraces. Most of these have been constructed by throwing soil uphill (the fanya juu method). In this way banks are formed which are often nearly vertical and between which the slope of the ground is reduced. The extent to which the original slope of the cultivated land is reduced by terracing varies greatly. On a number of farms the land between the banks is approximately level, but on the majority it is still sloping forward to varying degrees and runoff accumulates at the front edge of the bench. Where there is a substantial lip (ridge) along the front edge of the bench and where the bank and lip are stabilised with grass, any run-off accumulating at the front is retained and eventually infiltrates or evaporates. However, on a number of farms the lip is inadequate and the grass cover poor or even non-existent. In these circumstances, it is inevitable that runoff passes from one bench to the next and in so doing carries with it some of the soil which has been painstakingly thrown up to form the bank.

A second important point is that the reasons given for discontinuing a conservation practise or never adopting it may indicate to government planners what would be the most useful approaches for overcoming these constraints. For example, most respondents understood that deep contour ploughing is usefull because it loosens the soil. However, half of those who had never ploughed deeply did not have the necessary tools, and another 39 per cent lacked oxen. Similarly, the reasons given for not fencing pastures include a lack of material and the fact that the land has not yet been adjudicated. For planting vegetation strips between crop areas and for mulching, the lack of material is cited as the major reason for non-adoption. Lack of tools is given as the major reason for not constructing dams and not digging furrows on uncultivated land. These responses indicate that in many cases non-adoption is due to a lack of resources, rather than to attitudinal factors. In other cases, the major constraint seems to be a lack of technical knowledge of how to carry out certain practises.

The use of Makarikari grass on terrace banks has been widespread but is not always satisfactory. Alternatives need to be evaluated in different ecological zones. In this case then, the practice itself needs to be slightly modified in terms of the type of vegetative cover used. Lack of planting material is the major reason for never adopting this practice and this again is connected to the economic resources of the individual farmer.

Conserving trees is a critical issue for government planners. About 10 per cent of the people interviewed stated that trees attract rain. To what extent is this belief scientifically valid? Trees are often conserved so that they may later be used for firewood and building material, which indicates that they may only be preserved in the short run. The reasons given for planting trees are almost the same as those given for conserving them. However, in the case of tree planting, both non-adoption and discontinuation are related to lack of rain and the 'ants' problem, as well as to a lack of seedlings.

At this point, we should clarify the 'ants' problem, since it inhibits the adoption of several other soil conservation practises. When water is scarce in an area, these 'ants' - which are actually termites - eat all the grass and loose dry matter. At Kiatuni, they are reported to have swept through one mile on either side of the Syuuni River, creating a near desert. Then they tend to move on to greener areas.

Basically, terrace banks, crops and overgrazed land are threatened by these termites. The respondents complained that ants are a major threat to terrace banks as they build nests below the upturned soil and eat any grass that is planted. They kill young crops such as maize, and overgrazed land also appears susceptible to attack. This problem may have become more critical in recent years because of the removal of the termites' natural enemies such as ant bears and black and brown ants. From our field observations we concluded that most areas of bare land in Kalama and Kibauni are the result of this termite infestation, and they may be as serious a problem here as army worms in other areas.

Many people (44 per cent) did not ridge their fields because they do not know about this technique. A number of respondents also did not know about the benefits of planting hedges as windbreaks. Where hedges had been planted but the practise later discontinued, the termite problem was blamed. Of those who had never fenced their pastures, 10 per cent gave as their reason the fact that the land was not adjudicated. A larger proportion of the total sample - 25 per cent - in fact had not had their land adjudicated. While some saw non-adjudication as a barrier to conservation practises, others did not.

Most respondents have never made straw heaps (trash lines) on the contours of their fields because the straw is stored for cattle feed. River banks are kept for pasture and grass strips are planted between crop areas primarily for the purpose of feeding cattle. Respondents were also asked whether they had ever planted crop land in grass. Of those who had, 37 per cent planted star grass, 26 per cent Napier grass, 4 per cent Rhodes grass and the rest planted other types of grass.

Grazing land is poorly protected relative to cultivated land. After a period of heavy rain there are good crops on many farms, but the grazing land which might be expected to have a thick cover of grass is frequently bare or nearly bare. Recovery of grass after the recent prolonged dry spell has been relatively slow and erosion appears to be continuing rapidly. The only exceptions are where the owner has protected his grazing land and allowed it to recover. The combination of a long dry spell, heavy grazing and termite activity has undoubtedly been responsible for killing many of the grass plants. As the compacted surface of the ground provides a poor environment for seedlings to become established, some intervention is needed to re-establish a sward. Some of the effort at present devoted to digging cutoffs on grazing land might achieve results of greater value if it were devoted to restoring grass sward.

POSITION PAPER ON SOIL CONSERVATION

by

Land and Farm Management Division[1]
Ministry of Agriculture

PREAMBLE

The soil of Kenya is a stock resource, irreplaceable once destroyed. It is an asset which should be maintained for future generations. The task of the agricultural sector in Kenya is therefore not only to feed the nation, to produce for export and to provide employment, but also to maintain the soil and water resources of the nation in a productive state.

There is reason for great concern in this respect. Soil erosion is reaching disquieting proportions and water catchment areas are increasingly disrupted due to uncontrolled cultivation and overgrazing.

The key to successful soil and water conservation is appropriate land use at the farm level, and government action is required to guide and support proper land-use intensification. This includes improving the extension service and creating an incentive system so that soil and water conservation becomes a profitable proposition from the farmer's point of view.

The promotion of soil and water conserving practices at the farm level, however, is not enough. Additional minor projects are required, such as construction and maintenance of cutoff drains, minor dams, and reafforestation of catchment areas. These small projects should be labour-intensive, thereby providing employment to the rural communities, and will require government subsidies.

Minor projects require some government provision of machinery. Several permanent substations of the Tractor Hire Service will be established for this purpose in smallholder areas. It is furthermore proposed to amalgamate as early as possible the Soil Conservation Service and the Tractor Hire Service into one statutory body, working as a contractor under the Ministry of Agriculture. This will clearly enhance the effectiveness of these services.

A growing proportion of the farming community has become aware of the need for better conservation of resources. Therefore the time is ripe for government action. It is essential to allocate adequate funds in the budget for resource conservation.

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1. This paper was presented at the Workshop by Mr. J.M. Muasya.

PAST EXPERIENCES

Before Independence

The government has always been concerned with the protection of Kenya's agricultural potential. During the colonial era both mechanised and labour-intensive soil conservation works were started. The mechanised operations were carried out only in the 'scheduled' areas, while the labour-intensive measures were concentrated in the non-scheduled areas. Mechanised soil conservation activities were partly carried out commercially and operated on large-scale individual farms. Since most of the large farm owners received government loans, this method of soil conservation could be easily enforced and proved to be effective.

Labour-intensive soil conservation in the small-farm areas encountered many problems. Where it succeeded, it was due to the following factors:-

1. Soil Conservation. Where soil conservation measures were a precondition for the establishment of a profitable land-use system (e.g. coffee growing) a significant proportion of the farmers maintained their terraces.

2. Water Conservation. Where dams were constructed, they supplied water to both humans and livestock. This provided an incentive to the local people so that the dams were maintained.

3. Land Tenure System. Where land was individually owned the owners were more inclined to maintain the resource conservation measures on their farms than were people using communal land.

4. Afforestation. Where forests were cut down, trees were replanted to safeguard the future firewood and timber supply.

The failures were attributed to the following problems:-

1. Organisation. The people were forced to carry out soil conservation measures without seeing any immediate benefits and they considered it a kind of punishment. The farming communities were not given enough education or explanation concerning soil conservation and often did not understand its importance.

2. Approach. The approach was mainly technical with little emphasis on transforming the entire land-use system. Little thought was given to the fact that in some cases land-use systems which conserved the soil were less profitable than destructive systems, and insufficient emphasis was given to profitable crop and animal husbandry practices.

3. Land Tenure System. Where the land tenure system led individual families to feel insecure about their property rights, conservation works were badly maintained.

4. Enforcement of the Law. The general enforcement of soil conservation by the agricultural staff made effective extension work difficult. The role of an extension officer was incompatible with the role of a law-enforcer.

After Independence

After independence mechanised soil conservation work continued in the large-scale farming areas and was extended to some of the marginal small-holder areas such as Machakos, Baringo and West Pokot. Machinery was mainly used for dam construction and terracing where topographic conditions permitted. However, labour-intensive soil conservation activities slowed down significantly as soon as independence was attained as most wananchi (people) believed that soil conservation was a colonialist activity.

The government's first priority after independence was self-sufficiency in food production, and the extension package was therefore focussed on the creation of a 'green revolution'. The government also concentrated on the resettlement of landless people. Moreover, a major land adjudication programme was started so that farmers could use title deeds as security to obtain loans for developing their farms. However, not all allocated plots were suitable for farming and some unsuitable areas such as steep hills and river banks were cleared for cultivation. In the marginal areas, land which was originally used for grazing was now partly cultivated, thus reducing the grazing land without reducing livestock numbers.

ONGOING ACTIVITIES

In 1975 a soil conservation pilot project was started in Kiambu, Murang'a, Machakos, Kitui, Elgeyo Marakwet, Nandi and Bungoma, to act as a demonstration for labour-intensive soil conservation work in high potential small-farm areas. This project was funded by the Kenya government with technical aid from the Swedish International Development Authority. It was expanded in 1976 to cover 22 districts. The project, which is presently being expanded to cover the whole country, aims among other things at preparing the Ministry of Agriculture for its task of guiding major soil conservation work in the future. This is achieved by:-

1. Training all Ministry of Agriculture field staff in soil conservation techniques,

2. Providing extension and motivation for soil conservation at the locational level,

3. Designating demonstration areas covering small catchments in which general soil conservation work, such as cut-off drains, are publicly subsidised using off-season manual labour and individual farmers are obliged to carry out soil conservation work on their farms, such as digging bench terraces and planting grass,

4. Establishing horticultural tree crop nurseries and grass multiplication centres in all districts involved in the project; subsequently distributing planting materials and hand tools to the farmers, and

5. Establishing a soil conservation unit at ministry headquarters, to guide, plan and monitor all soil conservation efforts in the country.

Furthermore, the Soil Conservation Service has been equipped with additional heavy machinery and the Tractor Hire Service has been expanded.

POLICY FRAMEWORK FOR RESOURCE CONSERVATION

The General Principle

Experience clearly indicates that the solution to the soil and water conservation problem lies with the expansion of resource conserving land-use systems which are profitable from the point of view of the farmers. Soil and water conserving husbandry practices will then become a permanent feature of the agricultural production process. This requires a comprehensive and long-term approach to rural policies. It is essential that the objective of maintaining the natural resources of Kenya in a productive state is embedded in all aspects of national decision-making, and this involves several major policy tasks.

Actions Required

Information and Education. Farmers, extension workers, administrators, politicians and the general public in Kenya have to be made conscious that erosion constitutes a threat to the future food production potential of the nation.

The purpose of an education and information effort is not only to inform the public concerning the various technical measures which contribute to the conservation of soil and water resources, but also to change the value system of the people of Kenya so that resource conservation becomes a national responsibility. All possible channels for influencing people have to be used for this purpose: barazas (meetings), agricultural field days, teaching in schools, political meetings and the mass media.

Motivating the Farmers. Farmers cannot be expected to apply conservation measures voluntarily unless they are profitable. The labour input is usually high, while the returns (or the prevention of losses) are not apparent for some time. It is therefore essential to provide a strong system of incentives, which entails five government contributions:-

1. Extension and research should concentrate on profitable and resource conserving crop and livestock activities. This includes, for instance, coffee and tea growing, intensive dairying with planted grasses, fruit and vegetables, bananas and plantains, as well as irrigation and valley bottom farming.

2. Intensive soil-conserving land use requires the provision of inputs such as high quality seeds, fertilisers, pesticides and planting materials for trees and grasses. It is essential that these inputs are generally available to the smallholders and that farmers have easy access to an effective system of small-farm credit. The success of public soil and water conservation efforts in smallholder areas is closely related to an effective rural service structure.

3. Soil and water conservation on steeply sloping land is closely related to the planting of trees and grasses on the contour. This requires the organisation of nurseries to supply planting material, which should be made available to farmers at a subsidised price.

4. The establishment of soil and water conservation structures at the farm level usually involves a high initial labour input. Loans covering the costs of materials and labour should be made available. The interest rate and recovery period for these loans should be adapted to the long gestation period of these types of investments.

5. Soil and water conservation is clearly a function of price relations for the farmers. Favourable price relationships between inputs and agricultural produce in general are of crucial importance. High fertiliser inputs are essential for a vigorous plant cover which reduces runoff. Moreover, price preferences might be considered for those commodities which involve soil conserving types of land use, such as milk, rice and permanent crops.

Minor Communal Projects. The expansion of soil and water conserving land-use practices at the farm level is not enough. In a great number of cases collective investment in the construction of cutoff drains, stoppage of gullies, drainage works, minor dams and afforestation is required. These projects should be chosen according to the following criteria:-

1. They should have a permanent impact on soil and water conservation.
2. The projects should have a directly productive element: prevention of soil loss, reduction of yield loss in dry years, provision of water for human consumption and for livestock, provision of firewood, etc.
3. They should correspond to the wishes of the people of the area and should be carried by the spirit of harambee (self-help).
4. The beneficiaries should declare that they are willing to form an obligatory farmers' association which is held responsible for the maintenance of the structures which have been established with public funds.
5. They should be carried out largely with hand labour. Most of the work should be done in the off-season to provide work for underemployed people in the rural areas.

Land Tenure Policy. Soil and water conservation can be greatly encouraged by appropriate land tenure policies. Erosion is often worst on communal pastures. Land adjudication establishes a direct relation between the individual farmer and the return from soil and water conservation measures, and it is therefore considered a useful element in a resource conservation strategy. Also private ownership makes it easier to identify the farmer who fails to prevent erosion and thus to enforce rules and regulations in specific cases. However, land not suitable for crop and livestock production (steep slopes, areas close to rivers, etc.) should not be adjudicated to individuals. Land of this type should be designated for government afforestation programmes. Land adjudication is also a precondition for the introduction of a land tax system. Soil and water conservation implies a long-term commitment of public funds and a land tax system would be the most reliable way to supply these funds.

Enforcement of the Agricultural Act. It is also suggested that the Agricultural Act should be amended according to the recommendations of the Ministry of Agriculture to suit present land-use patterns in the country. The amendments would include such measures as planting trees on specified areas, constructing terraces where there are certain soil and slope conditions, and other measures deemed necessary for resource conservation. Once the Act has been accepted, it should be firmly enforced.

Benefits of Soil and Water Conservation

It must be realised in this context that several kinds of benefits can be expected from major public efforts in the field of soil and water conservation.-

1. The reduction of erosion and runoff not only reduces the loss of productive resources but also contributes to the maintenance of yields in relatively dry years. Yield variation will be less.

2. Soil and water conservation requires a high labour input and can have a significant impact on the rural employment situation. Most of the work can be carried out in the off-season so that the availability of labour for crop and livestock production will normally not be affected.

3. Minor communal works will provide income in the off-season for the underemployed in the rural areas. Such employment will contribute to the incomes of poorer rural families.

4. Soil and water conservation projects lend themselves to local participation in the identification and decision making process.

ORGANISATIONAL SETUP

Establishment of the Soil Conservation Unit

The Ministry of Agriculture established a special unit within the Farm Management Branch to be responsible for resource conservation. The functions of this Soil Conservation Unit are as follows:-

1. Preparation of training, extension and documentary materials,
2. Preparation of policy guideline papers on resource conservation,
3. Initiation of a soil conservation master plan,
4. In liaison with provincial and district authorities, preparation of concise district resource conservation programmes and co-ordination of activities,
5. Instigation of farm-management and agronomic research as required, and
6. Co-ordination with other Ministry of Agriculture programmes, as well as with other ministries and with the general public.

Implicitly it will also be the task of the Soil Conservation Unit to propose and implement clear guidelines concerning government subsidies for mechanised conservation work, taking into account such factors as the profitability of the work, the source of funds (no subsidies required for projects already financed by the government), and the promotion of rural mechanisation (subsidies to private contractors). Moreover, the Unit should also advise farmers and organisations on when and where to use machinery for resource conservation.

Provincial and District Activities

The Land and Farm Management Officers at the provincial and district levels will take the following actions:-

1. Incorporation of resource conservation into all aspects of agricultural extension,
2. Organisation of courses on soil and water conservation for agricultural assistants,
3. Establishment and maintenance of soil and water conservation demonstration areas and organisation of field days,
4. Organisation of nurseries, supplying planting material for permanent crops (fruit trees, fodder trees, bananas, grasses) at a subsidised price to farmers, and
5. Programming and implementation of minor communal projects; formation and supervision of 'maintenance associations'.

The regular field staff of the Ministry of Agriculture should, given proper directives and supervision, be able to implement this programme. To strengthen supervision it is proposed to designate provincial, and possibly district, Soil Conservation Officers. Their tasks would also include liaising with District Development Committees concerning minor projects and formulating concise district resource conservation programmes. These programmes should include afforestation, small irrigation schemes, valley bottom development and reseeding programmes.

Inputs by the Soil Conservation Service and the Tractor Hire Service

Minor communal soil and water conservation projects require supplementary mechanised inputs. In the past, the Soil Conservation Service (which operates the Ministry of Agriculture's heavy machinery pool) and the Tractor Hire Service provided mechanised services to farmers and government organisations. The soil conservation service operated mainly in the former 'scheduled' areas and the Tractor Hire Service mainly in high- and medium-potential smallholder areas. Private enterprise in this field is limited and government participation will be required for some time.

In order to increase the government's capacity to implement resource conservation measures in smallholder areas, it is proposed that Tractor Hire Service Units be transformed into sub-stations of the Soil Conservation Service, to be situated permanently in Meru, Embu, Machakos, Kitui, Nyeri, Bukura, Baringo and Kisumu. Mechanised services could then be offered for minor communal soil and water conservation projects during the off-ploughing season.

The efficiency and cost-effectiveness of the present services need to be improved considerably by, among other things, increased flexibility in operation (e.g., an incentive system for the staff, double shifts and enough funds for fuel and repairs), better accounting procedures and strengthened supervision and planning. Therefore, it is proposed that the combined Soil Conservation Service and Tractor Hire Service should be transformed as early as possible into a statutory board which would act as a contractor to provide services to the government and to individuals at commercial rates. In the case of subsidies, the government should reimburse the board directly.

For the time being, the heavy machinery pool should only be enlarged in connection with specific development programmes, such as in Machakos and Baringo. The provision of medium-size and small tractors will require considerable expansion so that the proposed sub-stations in high- and medium-potential smallholder areas can be adequately equipped.

Research

The present research facilities offer a whole array of services which are applicable to soil conservation, including crop and animal husbandry research, seed certification, soil surveys and irrigation and drainage research. New initiatives include dryland farming research and the Marginal Lands Pre-Investment Study.

Research on resource conservation topics will continue to be carried out within the existing research framework. Consideration should be given to the establishment of an integrated land-use department at the National Agricultural Laboratories, bringing together the additional research required, such as on mixed cropping, contour cropping and fodder crops as well as on the technical, economic and human side of land-use patterns.

Activities of Other Ministries

Interministerial Committee. In order to make this important programme succeed, an interministerial committee should be set up, bringing together the major institutions closely involved with resource conservation. The institutions to be represented on this committee would be the Ministry of Agriculture, Ministry of Water Development, Ministry of Lands and Settlement, Ministry of Natural Resources, Ministry of Tourism and Wild Life, Ministry of Education, the Agricultural Finance Corporation and the Ministry of Finance and Planning.

The Ministry of Agriculture. This ministry will be responsible for the overall planning, implementation and co-ordination of the soil and water conservation programme. The details of these functions have already been explained.

The Ministry of Water Development. This ministry is responsible for conserving water and providing water for human and livestock consumption. At present a large part of the development budget is allocated to this ministry. This ministry will therefore work hand in hand with the Ministry of Agriculture in soil and water conservation.

The Ministry of Lands and Settlement. As mentioned earlier, land tenure policy is very important in determining the success of a soil conservation programme. This ministry will assist by submitting proposals for adjustment in land adjudication policy so that priority can be given to the project areas. The same ministry will assist by setting aside land within the settlement areas which is not suitable for cultivation so that it can be left for afforestation, etc.

The Ministry of Natural Resources. This ministry will assist the programme through afforestation of catchment areas, provision of tree seedlings to farmers, and bulking the various species of trees which will be needed in different parts of the country.

The Ministry of Tourism and Wild Life. Game reserves and game parks are known to be seriously eroded. This ministry will be required to submit proposals for effective soil conservation in these areas.

The Ministry of Education. This ministry will play an important role in educating the younger generation in schools concerning soil conservation. Most of the school population lives in the rural areas and the young people can help train their parents concerning soil conservation.

The Ministry of Finance and Planning. This ministry is responsible for approving the soil conservation budget and should therefore be well informed about the progress of the programme.

The Agricultural Finance Corporation. The Agricultural Finance Corporation should be asked to establish a soil conservation loan programme with soft lending terms, to encourage farmers to invest in soil conservation measures.

The Ministry of Co-operative Development. This ministry will be responsible for organising credit to small farmers and the marketing of produce through co-operative societies.

PERMANENT SERVICES WITHIN THE MINISTRY OF AGRICULTURE

It will be necessary to institute a resource conservation approach in all the Ministry of Agriculture's services.

The Soil Conservation Unit and Related Activities

The activities to be funded have been described in this paper and a more detailed description was given in October 1976 in another document, "Application to the Government of Sweden for Participation in the Soil Conservation Programme for the High-Potential Areas, Phase II". However, instead of the 30 districts and 350 locations mentioned in the 1976 request, it is now proposed to extend the programme to 32 districts (Lamu and Samburu to be included) and 500 locations.

The costs involved are £350,900 in 1977/78, £540,000 in 1978/79, £625,000 in 1979/80 and £700,000 in 1980/81.

<u>Soil Conservation Service Sub-stations (Tractor Hire Service).</u> We have proposed the establishment of Soil Conservation Service sub-stations in eight areas. The sub-stations should be incorporated into the existing field facilities of the Ministry of Agriculture, e.g. attached to such institutions as Farmers Training Centres or Institutes of Agriculture. The capital costs of this programme would be 40 new tractors (100–120 h.p.), additional equipment such as dozer blades, V-ditchers, etc., and buildings. The total cost would be approximately £750,000.

In the 1977/78 development estimates an amount of £155,000 was designated for this purpose with the remainder to be allocated in equal portions during the next two financial years.

<u>Working Capital Fund for the Soil Conservation Service Statutory Board.</u> If it is decided to establish a statutory board, this body should have ample working capital to enable it to meet local needs flexibly (repairs, incentives to drivers, maintenance of stocks) and to overcome the delay periods between the start of an actual job and payment. An appropriate amount would be approximately 50 per cent of the recurrent costs (K£400,000) for the combined Soil Conservation Service and Tractor Hire Service. Additional costs can be expected for upgrading Soil Conservation Service facilities.

<u>Expanded Credit Facilities and Subsidies.</u> As stated before, the interest rate and recovery period for resource conservation loans should be adapted to the long gestation period and profitability of these types of investment. The government should therefore make available soft loans to be distributed through the Agricultural Finance Corporation or other organisations.

In addition, the government budgets should earmark funds required for direct subsidies to soil conservation works, for example the reduced rate for mechanical operations.

<u>Minor Projects in the Districts</u>

The demand in the districts for these projects will be very great. For example the E.E.C. Machakos Project proposes that over K£5.5 million of donor funds will be spent on resource conservation, including small dams, over an area of 93,000 ha. in the coming four years. This amount excludes either government or farmers' contributions.

It therefore seems logical to allocate initially some amount for resource conservation projects in each district (e.g., on average £30,000 per district in 1978/79, £50,000 in 1979/80 and £80,000 in 1980/81). These funds should be channelled through the Ministry of Agriculture.

Special Regional and District Programmes

Under the guidance of the Ministry of Agriculture the districts should prepare as soon as possible concise resource conservation programmes. These should be submitted to the treasury, which in turn should invite donors to sponsor certain components or districts(such as the present approach to the Rural Access Roads Programme and the Rural Development Fund). Responsibility for overall implementation should be centralised within the Soil Conservation Unit. Where heavy machinery is provided for these programmes, its operation should be handed over to the Soil Conservation Service.

This approach is already being partially adopted in the Machakos (E.E.C.) programme and in Baringo (USAID). Furthermore the F.A.O. might become involved in horticultural tree crop planting programmes and a development project in Kitui.

The funds requested for resource conservation components in these programmes are as follows (K£'000):-

		1977/78	1978/79	1979/80	1980/81
Machakos:	Soil Conservation	105	190	250	280
Machakos:	Water Conservation	330	986	1,719	1,447
Baringo:	Rehabilitation	-	82	72	n.a.
Kitui		53	103	95	114
	Total	488	1,261	2,136	n.a.

With further plans to be formulated on an urgent basis, expenditures in 1978/79 should rise to £1.5 million, in 1979/80 to £3.0 million and in 1980/81 to £5.0 million.

Summary of Expenditures (£'000)

Ministry of Agriculture Permanent Services	1977/78	78/79	79/80	80/81	Donor
Soil Conservation Unit	350	540	625	700	SIDA
S.C.S. Sub-stations	155	295	300	-	GoK
Working Capital Fund of S.C.S. Board	-	400	-	-	GoK
Credit and Subsidies	n.a.	n.a.	n.a.	n.a.	
Total	505	1,235	925	700	
Minor Projects in the Districts	100[a]	960	1,600	2,560	GoK
Special Programmes	488	1,500	3,000	5,000	Various
Grand Total	933	3,695	5,525	8,260	

a. USAID reflow funds.

APPENDIX: THE SOIL CONSERVATION PROGRAMME FOR 1977/78

A detailed description of the Programme is given here as presented in the 'Application to the Government of Sweden for Participation in the Soil Conservation Programme, Phase II' of October 1976.

1. Training of Ministry of Agriculture Staff

Senior Staff. Two one-week courses at the Kenya Institute of Administration have been organised for the weeks starting 29 August and 5 September 1977. Each course will have 30 participants and the cost per participant will be approximately £100.

Junior Staff. Twelve two-week courses (two per province) are scheduled between 12 September and 26 November 1977. Each course will have 30 participants at a cost of £50 per person.

In additional to one Soil Conservation Co-ordinator (Dr. Wenner), there will be three lecturers appointed so that the courses can be given simultaneously in four different places.

2. District and Locational Activities

The activities at the locational level will decide the success of the soil conservation programme. This implies that the role and position of the Agricultural Assistants and Junior Agricultural Assistants at the locational level should be considerably strengthened by providing each staff member who successfully finishes the conservation course with:-

1. Sufficient technical equipment (i.e., clinometre, spirit levels, line levels, etc.),
2. Sufficient hand tools to encourage community projects (e.g., 25 pick axes, 25 spades, 15 hoes, etc.), and
3. Sufficient extension material and inputs such as grass seed, horticultural tree seedlings, etc.

Targets will be set for each trained member of staff.

Moreover, at the district level additional and enlarged pilot/demonstration areas will be developed. Further activities at the district level include:-

1. Soil conservation lectures in the regular courses of the Farmer Training Centres,
2. Special two-day courses for chiefs, sub-chiefs, teachers, etc., to be held at the Farmer Training Centres,
3. Organisation of field days,

4. Promotion of soil conservation projects within the District Development Committees,
5. Supervision of projects, and
6. Preparation of annual soil conservation programmes.

These activities will require approximately £180,000 in 1977/78 and will cover 33 districts with 350 locations. The districts involved, with the number of locations, are given below:-

Central Province

Kiambu	10 Locations
Kirinyaga	10 Locations
Murang'a	15 Locations
Nyeri	10 Locations
Nyandarua	5 Locations

Coast Province

Kilifi	8 Locations
Lamu	5 Locations
Kwale	10 Locations
Taita	10 Locations
Mombasa	2 Locations

Eastern Province

Embu	15 Locations
Kitui	10 Locations
Machakos	20 Locations
Meru	15 Locations

Nyanza Province

Kisii	15 Locations
Kisumu	10 Locations
Siaya	15 Locations
South Nyanza	15 Locations

Rift Valley Province

Baringo	10 Locations
Elgeyo Marakwet	8 Locations
Kericho	7 Locations
Nakuru	10 Locations

Rift Valley Province Cont'd

Nandi	10 Locations
Tans Nzoia	12 Locations
Uasin Gishu	15 Locations
West Pokot	5 Locations
Kajiado	5 Locations
Samburu	10 Locations
Laikipia	5 Locations

Western Province

Bungoma	20 Locations
Busia	15 Locations
Kakamega	15 Locations

3. The Establishment of Horticultural Tree Crop Nurseries

Initially only 12 horticultural tree crop nurseries were to be established in 1977/78, but given the importance of this activity, the total number has been increased to 26. Additional funds will be available through the USAID reflow funds.

The nurseries will be established at the following locations:-

Central Province

Kirinyaga	Kamweti Farmer Training Centre
	Mwea Irrigation Settlement Scheme
Nyandarua	Ol Joro Orok
Murang'a	Horticultural Research Station, Thika

Coast Province

Taita Taveta	Wundanyi
	Kitobo
Lamu	Mpeketoni
Kwale	Matuga District Development Committee

Eastern Province

Embu	Ishiara Irrigation Scheme
	Kiambere Irrigation Scheme
Kitui	Yatta B2
Machakos	Kyai Irrigation Scheme
Meru	Mitunguu

Nyanza Province

Kisii	Kisii Farmer Training Centre
Kisumu	Maseno Farmer Training Centre
South Nyanza	Homa Bay
Siaya	Siaya Farmer Training Centre.

Rift Valley Province

Baringo	Baringo Farmer Training Centre
	Perkerra Irrigation Scheme
Uasin Gishu	Eldoret Large-Scale Farmer Training Centre
Nakuru	Molo Research Station
Nandi	Kaimosi Farmer Training Centre
Marakwet	Chebororwa Farmer Training Centre

Western Province

Bungoma	Bungoma Farmer Training Centre
Busia	Busia Farmer Training Centre
Kakamega	Bukura Farmer Training Centre

Provincial Activities

A Provincial Soil Conservation Officer will be designated in each of the participating provinces, with salary costs, vehicle, accomodation, travelling and miscellaneous costs amounting to £8500 per province. Notice that the posts of Provincial Soil Conservation Officer are the only additional ones required at the field or provincial level.

Soil Conservation Unit

Apart from establishing this unit at the headquarters level, the main expenditures will be involved in preparing extension and documentation materials such as a soil conservation film.

VISIT TO MACHAKOS DISTRICT, 22 SEPTEMBER

On arriving at district headquarters in Machakos, the workshop participants were introduced by Mr. S.M.A. Wambua, the District Agricultural Officer, to members of the field staff. Mr. Wambua pointed out that Machakos is a district with serious soil conservation problems. He proposed to show the group successful conservation efforts, as well as failures, and welcomed constructive criticism.

The group first visited a concrete dam recently constructed on the Potha River at the Dryland Farming Research Station (Katumani) to provide water for the station's nurseries. Mr. Eliud Omolo, the Director of the Station, explained that the dam had cost half a million shillings[1] to build, and that it contained approximately 80 million litres of water which had been collected from only one night's rainfall. The participants were concerned about siltation in this stream, especially since some of the surrounding slopes were completely denuded due to overgrazing. Mr. Omolo asked the group to consider the difficulty of enforcing conservation measures on land which is privately owned, or even land owned by government agencies which permit overgrazing.

Next the group visited a field which had been under tomatoes, where both vegetation strips and a forward sloping bench terrace had been constructed to prevent erosion. Both measures had proven ineffective where water had concentrated in one place. The vegetation may have filtered out the sediment, but the water had passed through and caused erosion at the next level. This illustrated the fact that vegetation strips are only effective if water does not concentrate excessively.

According to the proposed amendments to the Agriculture (Basic Land Usage) Rules, vegetation strips would be compulsory on all sloping land, while terraces would only be made compulsory at the discretion of authorised agricultural officers. However, concern was expressed that officers in the field would be making decisions concerning which conservation measures to require although they themselves may have only a limited understanding of conservation structures and needs.

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1. 8.00 Kenya shillings = 1 U.S.$.

After eating a picnic lunch in Professor Mbithi's garden, the group continued to the farm of Mr. Kimondiu Mulinge near Makaveti market centre. Mr. Mulinge is a retired agricultural extension worker who has invested around KShs 18,000 in reclaiming an eroded gully which runs through the centre of his farm. He has built a series of stone washstops across the gully, ending with an earth dam which he constructed using an ox-drawn dam scoop. A pipe runs under the dam and provides irrigation water for a fruit and vegetable plot. Mr. Mulinge has also planted Napier grass extensively through the gully, which he uses for stall feeding his livestock. It is anticipated that his washstops will silt up over time, but when this happens he will increase the height of the stone walls, and eventually the land behind the walls should become level. Although this was a very interesting example of complex conservation measures which are technically feasible at the farm level, members of the group felt that very few farmers would be able to make such a substantial investment. Even if government loans were available for such amounts, repayment would be difficult since this is an investment which may yield large returns only in the long run.

The workshop participants next visited a large sloping field near Kiatuni market centre where a number of mwethya self-help groups were demonstrating the construction of terraces with hand labour and very simple tools. Several groups had come together from around the location for this demonstration, coming to 500 or more participants. Most of the participants were women, and Dr. Kayongo-Male pointed out that the small number of men involved limits the conservation activities of these groups, since the women cannot physically carry out all types of conservation work. Many women did not have shovels at all, and many of the shovels which were available were badly damaged. This lack of even the simplest tools is a serious constraint. Finally, this opportunity to observe how much labour is involved in carrying out conservation work underlined the importance of effective research and planning to make sure that such efforts are not misdirected.

The last stop was a visit to Mr. Paul Nzivu's farm. Mr. Nzivu had constructed a large earth dam using a dam scoop. He had not put in a spillway as a precaution against flooding, but he planned to do so. Mr. Nzivu had also planted Napier grass which he used for stall feeding his livestock. His farm stood out from the surrounding area because his fields were well covered with grass. This is because Mr. Nzivu keeps only a small number of grade cows on a relatively large holding, so his fields are not overgrazed.

VISIT TO MURANG'A DISTRICT, 23 SEPTEMBER

Participants in the Soil and Water Conservation Workshop were welcomed to Murang'a District by the District Agricultural Officer, Mr. E.O Wanga, and introduced to other staff members. Mr. Wanga explained that Murang'a District varies in altitude from 4,500 to 8,000 feet towards the Abedares, and about 75 per cent of the farmland in the district is sloping. There are two types of soil conservation projects in the district: Soil Conservation Pilot Schemes funded by the Ministry of Agriculture and projects funded by the District Development Committee. Specific conservation projects are suggested to the District Development Committee for funding, and Committee members make the final selections after visiting the various sites.

The participants first visited Mr. Kiarie's farm where a cutoff had recently been dug across a sloping field just below the road. It was pointed out that roads are often a serious erosion problem in the district. The government pays farmers for conservation work on their own land at a rate of KShs 7/90 per day, calculating that a farmer can reasonably be expected to dig an 8-meter stretch of cutoff in one day. In this case, however, insufficient thought had been given to the safe disposal of water which would collect in the cutoff; no proper waterway had been built into which the water could be discharged. This example illustrated that the design of conservation structures is a highly complex task which requires well qualified government staff.

From across a slope, the participants viewed Mr. Gitau's farm, where there was a very large cutoff which again did not empty into any waterway. A closed cutoff such as this could overflow during a heavy rain and cause more erosion damage than if nothing had been built at all. Farmers in a catchment area should agree on the location of waterways before any cutoffs are constructed. If they cannot agree, then no construction work should be started. It was also observed at this site that government officers should advise farmers on where to build their houses whenever this is possible, so that houses will not be built in the path of a future waterway.

On the way to the next farm, the participants saw a cutoff constructed to carry runoff water from a road to a deep, narrow, grassed waterway. The waterway had been a small gully, but was well vegetated and appeared to be stable, although the slope was relatively steep.

On the farm of Wambui Richard the participants saw *fanya ju* terraces and a cutoff leading to a large gully which served as a waterway. Terraces in high rainfall areas such as Murang'a tend to be graded towards waterways, but rainfall intensity might be higher and infiltration rates lower in dryer areas such as Machakos, so that it might be even more advisable to grade terraces there. Rainfall intensity, soil factors and infiltration rates should be taken into account when deciding whether or not to grade terraces, rather than merely considering the average annual rainfall. For instance, the soils in Murang'a are derived from volcanic rock and do not cap easily, in contrast to the soils in Machakos which are derived from basement complex rocks and do cap.

The waterway at this farm had been planted in maize, rather than in a permanent grass or tree crop, and this could create serious erosion problems. Waterways are sometimes cultivated in a district such as Murang'a due to the extreme shortage of arable land. For the same reason, the cultivation of river banks is a common problem, and near the Abedares farmers have been issued titles to land which exceeds the maximum slope allowed for cultivation. Because of this pressure on land, and the problem of landlessness, it may be necessary to reconsider some of the stipulations in the amended Agriculture (Basic Land Usage) Rules. For example, if land cannot be found for waterways which will be planted in grass or a perennial crop such as bananas, then it makes more sense to plant vegetation strips, rather than building inadequate structures which will concentrate water in one place.

The group next visited a forest project at Kahumbu where cyprus, gum and pine trees had been planted in 1974 on a small sloping area owned by the County Council, both to stop erosion and to serve as a demonstration to local farmers. Mr. Macharia, the District Forestry Officer, explained that funds for this project had been provided by the District Development Committee. It was observed that the optimum spacing of trees to control erosion is 2.5 metres. The Forestry Department provides seedlings of fast-growing exotic varieties free of charge to local farmers, but cannot provide enough seedlings to keep up with demand. Forestry officers also encourage farmers to plant fruit trees and indigenous varieties, but they cannot provide seedlings of indigenous trees because they lack planting materials. They have encouraged farmers to plant small woodlots on their holdings.

Finally, the participants visited the 39-acre farm of Mr. Njuguna Mugo, who had constructed a pond and bought a pump and irrigation pipes in 1973 with a loan from the Agricultural Finance Corporation. The pond is stocked with fish and provides water for dairying and home consumption as well as for irrigation. Mr. Mugo produces citrus seedlings by grafting and he sells them to other farmers in the district. He also grows bananas, avocado pears and a variety of horticultural crops and coffee - all under irrigation. Although the productivity of this farm was very impressive, the group noted that the farm was unusually large for the area and wondered whether the majority of small farmers would be able to start similar projects.

RECOMMENDATIONS OF THE WORKSHOP

National Conservation Policy and Implementation Through the Extension Service

Policy

1. A National Soil and Water Conservation Committee should be formed in Kenya on a permanent basis, to include representatives of the appropriate government ministries and non-government organisations such as the University of Nairobi, Egerton College and the National Christian Council of Kenya. There appears to be little co-ordination among the various agencies and ministries concerned with conservation issues in Kenya, and we recommend that a meeting be arranged of all the groups involved with a view to setting up a National Resource Conservation Council under the umbrella of the National Environmental Secretariat. The Soil and Water Conservation Committee proposed here should be set up under this National Resource Conservation Council.

2. Soil and water conservation work at the district level should be co-ordinated with the activities of the District Development Committees.

3. The workshop participants support the basic principles contained in the 'Position Paper on Soil Conservation' presented by the Ministry of Agriculture's Land and Farm Management Division, but feel that these recommendations should be scrutinised in more detail by the proposed National Soil and Water Conservation Committee. We urge that sufficient technical and financial resources be made available by the Kenya government to carry out the recommended programmes. We also feel that the proposals for conservation research put forth in the position paper need to be enlarged and strengthened.

4. According to the proposed amendment to the Agriculture (Integrated Basic Land and Water Usage) Rules, the planting of vegetation strips will be obligatory on all cultivated land between 5 and 55 per cent slope, while terraces will only be made obligatory at the discretion of the authorised agricultural officers. However, these stipulations may not prove adequate to ensure the effectiveness of soil and water conservation throughout Kenya, as this effectiveness depends on the correct choice of methods and structures for each particular site, based on such variables as soil characteristics, climatic factors and successful conservation measures already practised by the farmer.

5. According to the new legislation it will be an offence to cultivate any land of more than 55 per cent slope. However, it was unclear to some workshop participants just what constitutes a 55 per cent slope. The generally

accepted way of measuring slope will be described in an appendix to this report. In view of observations in the field, it is also not clear whether a limit on cultivation of 55 per cent slope is suitable for all areas, and this issue merits further consideration.

6. The draft amendment to the Agriculture (Integrated Basic Land and Water Usage) Rules does not give sufficient attention to the reclamation of denuded or severely eroded land. The proposed National Soil and Water Conservation Committee should investigate the problem of land reclamation in Kenya.

7. The discussions which took place during the workshop dealt mainly with the problems of soil and water conservation in agricultural areas. Attention also needs to be paid to conservation problems in pastoral areas, where the main cause of erosion is overstocking. Paragraph 6 of the proposed legislation, which states that the Director of Agriculture '... may enforce the optimum stocking rates', does not deal with this problem adequately. Enforced destocking carries with it many social, economic and political implications: consideration must be given to such factors as land tenure systems in pastoral areas and the minimum herd size necessary to meet the subsistence needs of the existing human population. Consideration must also be given to development incentives which will encourage the pastoralists to limit their herd sizes voluntarily and marketing structures which will enable them to sell off stock without suffering financial loss.

Extension

1. The responsibility for soil and water conservation measures at the local level should be shared by the individual farmers, the local community, the agricultural extension service and the administration. The agricultural extension service, in co-operation with the soil conservation service, is responsible for designing appropriate conservation structures, on the basis of the entire catchment area, and advising farmers on the correct layout of these structures. The individual farmers have the primary responsibility for carrying out conservation measures and building and maintaining structures on their own land. The farmers of a small catchment area will have to form soil conservation associations which will be held responsible for the maintenance of soil conservation structures. These associations will also be responsible for the construction of conservation measures which extend beyond the boundaries of individual farms and should assist farmers with conservation work which requires a substantial financial or labour input. The administration is ultimately responsible for the enforcement of conservation measures and should provide financial assistance where necessary.

2. In addition to providing sound technical information and advice, the extension service has the task of motivating farmers to practise soil and water conservation and involving them actively in conservation work. The problem of motivation is a serious one which should be considered in detail by the proposed National Soil and Water Conservation Committee. Particularly in the marginal farming areas, the intrinsic rewards of conservation may not be immediately obvious, as farmers who build terraces and other structures on their land may not realise significant gains in productivity due to poor rainfall and other factors beyond their control. Such efforts in these areas should be encouraged with government support. This support could be allocated by dividing the country into zones based on the degree of erosion hazard, and providing substantial support in the most seriously threatened areas. Consideration should be given to rewarding communities, rather than individual farmers, so that group pressure and group assistance may be applied to individuals who are not practising an adequate level of conservation.

3. Extension agents should not be involved in policing farmers or enforcing conservation regulations. As far as possible, soil and water conservation should be enforced by the local community in the same way that co-operatives enforce the repayment of loans by individual members. Where this form of community enforcement proves inadequate, government enforcement should be carried out by the administration or a specially appointed body, rather than by the extension agents.

Research and Training

Research

1. Research on soil and water conservation in Kenya is urgently needed. Local research should include the analysis and monitoring of past and present conservation projects.

2. The farming systems approach to conservation research should be emphasised, based on individual farm units or a small number of experimental catchment areas. Without suggesting any order of priority, such research should include the investigation of land-use patterns and crops for both high and medium-potential areas, research on water utilisation and the integrated study of water silt levels in connection with research on soil conservation, the study of permanent crops suitable for planting on the banks of terraces and on steep slopes, research on plants which can be used for the reclamation of denuded land, and on special cultivation methods such as minimum tillage and

tied-ridging. Studies have already been initiated in some of these areas, but better communication and co-ordination of research efforts are called for. A research programme stressing integrated land use which will be carried out at the National Agricultural Laboratories is fully supported by the workshop participants.

3. Additional hydrological data are needed to improve the design of conservation structures such as cutoffs and waterways. Prototypes of structures and tools should be developed which are appropriate for different levels of mechanisation.

4. Economic analysis should be carried out of the labour and input costs of establishing and maintaining different types of conservation structures under different conditions and the returns which can be expected in terms of agricultural output.

5. Social research is needed to determine which types of institutions, associations or groups at the local level will best assure the high degree of community co-operation necessary to build conservation structures and maintain them properly on a permanent basis.

6. Finally, a concerted effort should be made to generate financial support for local research on soil and water conservation.

Training

1. More course work on soil and water conservation should be included in the two-year training programme for the Ministry of Agriculture's Technical Assistants. In addition, a number of Technical Assistants in the field should be given specialised instruction in soil and water conservation through inservice training and courses offered at Farmer Training Centres. These specialised Technical Assistants can form mobile teams in areas where conservation problems are particularly acute to oversee the laying out of new conservation structures, while the general Technical Assistants can supervise the maintenance of these structures after they are built.

2. Egerton College already plans to increase course work in soil and water conservation for all students at the diploma level from 50 to 80 hours. In addition, specialised courses should be offered to all agricultural engineering students, with an increased emphasis on conservation measures suitable for small farms. The World Bank is now carrying out a manpower study in Kenya which should reveal whether more students should be trained in agriculture at the diploma level.

3. Basic training in soil and water conservation is already included in existing courses of the University of Nairobi's Faculty of Agriculture. Training in conservation should also be introduced into the curricula of other University departments where appropriate. The Faculty of Agriculture is to be commended for introducing a one-year postgraduate course in soil and water conservation.

4. The proposed National Soil and Water Conservation Committee should look into conservation curricula and teaching methods at all levels of the formal education system and make appropriate detailed proposals. Workshops should be organised bringing together lecturers in institutions of higher learning and curriculum development specialists in order to co-ordinate teaching methods and course content at all levels and reach agreement on the terminology to be used for conservation education.

5. Appropriate teaching materials on conservation are urgently needed at all levels. Groups such as the Kenya Institute of Education and the Educational Media Service of the Ministry of Education should be encouraged to prepare and distribute suitable materials.

WORKSHOP PROGRAMME

Wednesday, 21 September 1977 — Faculty of Agriculture, Kabete

8.45 a.m. Participants arrive

9.00 Opening Session

Chairman, Prof. C.N. Karue, Dean, Faculty of Agriculture, University of Nairobi

Preliminary Remarks, Prof. Karue

Welcome to the Participants, Dr. P.A.M. Misiko, Chairman, Workshop Steering Committee

Opening Address, Mr. P.K. Gota, Director of Agriculture

9.30 Technical Aspects of Soil Conservation

Chairman, Mr. M.N. Maina, Head, Land and Farm Management Division, Ministry of Agriculture

'The Kenya Soil Survey and Soil Conservation' by H.M.H. Braun and F.N. Muchena, Kenya Soil Survey

'Some Observations on Soil Conservation in Machakos District, Kenya, With Special Reference to Terracing' by D.B. Thomas, Department of Agricultural Engineering, University of Nairobi

'Specification, Construction and Use of the Metric Line Level' by A.M.W. Wanjama, Embu Institute of Agriculture

'Soil and Water Conservation on Subdivided Large-Scale Farms in Uasin Gishu' by J.F. Ogola, Soil Conservation Service, Eldoret

'Work Done by the Soil Conservation Station at Mariakani, Coast Province' by G.G. Mwangi, Soil Conservation Service, Mariakani

Discussion

11.00 Agronomic Aspects of Soil Conservation

Chairman, Dr. D.N. Ngugi, Department of Crop Science, University of Nairobi

'Cropping Systems for Soil Conservation in Kenya' by N.M. Fisher, Department of Crop Science, University of Nairobi

'Some Promising Native Legumes for Rehabilitating Degraded, Subhumid Kenya Highland Soils' by K.K. Wachiira, Department of Geography, Kenyatta University College

'An Assessment of Soil Erosion on a Field of Young Tea Under Different Soil Management Practises' by C.O. Othieno, Tea Research Institute of East Africa

'The Effects of Certain Tillage Methods and Cropping Systems for Conserving Rainfall in a Semi-arid Area of Eastern Kenya' by A.P.M. Marimi, Dryland Farming Research Station (Katumani), Machakos

Discussion

2.30 p.m. Water Conservation

Chairman, Dr. P.A.M. Misiko, Head, Department of Agricultural Engineering, Egerton College

'Problems of Soil and Water Conservation within the Upper Tana Catchment' by G.S. Ongweny, Department of Geography, University of Nairobi

'Representative and Experimental Basin Programme' by K.A. Edwards, Ministry of Water Development

'Natural Resources Conservation in Nyanza Province' by J.J. Gichuki, Acting Provincial Director of Agriculture, Nyanza Province (presented by J. Mbuguah)

Discussion

Tuesday 22 September 1977 Education Building, Main Campus

8.30 a.m. Socio-economic and Policy Aspects of Soil and Water Conservation

Chairman, Mr. G. Muchuri, Department of Agricultural Engineering, University of Nairobi

'Local Environmental Perceptions and Soil and Water Conservation Activities' by P.M. Mbithi and D. Kayongo-Male, Department of Sociology, University of Nairobi

'Position Paper on Soil Conservation' by the Land and Farm Management Division, Ministry of Agriculture (presented by J.M. Muasya)

'Proposed Amendment to the Agriculture (Basic Land Usage) Rules' presented by M.N. Maina, Head, Land and Farm Management Divison, Ministry of Agriculture (not included in the workshop report)

10.00 a.m. Visit to Machakos District, organised by Mr. S.M.A. Wambua, Prof. P.M. Mbithi and Dr. D. Kayongo-Male

Friday 23 September 1977 Education Building, Main Campus

8.00 a.m. Visit to Murang'a District, organised by Mr. E.O. Wanga

2.30 p.m. Group Discussions

Group A: Research and Teaching

Chairman, Prof. H. Ruthenberg, Planning Division, Ministry of Agriculture

Secretary, Dr. J.W. Kijne, Department of Agricultural Engineering, University of Nairobi

Group B: Extension and Policy

Chairman, Prof. P.M. Mbithi, Head, Department of Sociology, University of Nairobi

Secretary, Mr. C.R.J. Nyagah, Head, Land Development Branch, Ministry of Agriculture

4.30 p.m. Final Session

Chairman, Dr. P.A.M. Misiko,Head, Department of Agricultural Engineering, Egerton College

Secretary, Mr. D.B. Thomas, Department of Agricultural Engineering, University of Nairobi

Reports on conclusions and recommendations from the discussion groups

Approval of recommendations

Closing remarks

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APPENDIX: A NOTE ON THE DEFINITION OF SLOPE

by

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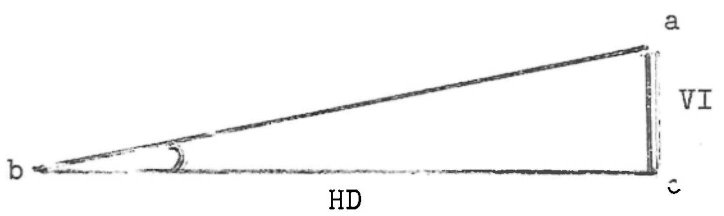
Slope, which is sometimes referred to as gradient or grade, can be defined in several ways which can be explained by reference to the following diagram:-



slope shown is:-
11° or
20% or
1 : 5 or
0.2m/m

1. Angle in degrees: This is the angle that the slope makes with the horizontal, i.e., angle abc in the diagram. This method of denoting slope is preferred by soil scientists, geographers and geologists who may be interested in describing land ranging from flat to nearly vertical.

2. Percentage slope: $\%\ \text{slope} = \frac{VI}{HD} \times 100$, where VI = vertical interval between two points, and HD = horizontal distance between the same points.

This method is often preferred by agriculturalists because (a) it is sometimes easier to measure with simple equipment, e.g., a line level and measuring sticks; (b) significant differences in slope can usually be expressed in whole numbers, whereas when using degrees decimals may be needed as half a degree is roughly the same as 1 per cent slope; and (c) the percentage slope is a more useful figure when marking out graded channels, etc. with the aid of a level.

3. Ratio: This is the ratio of the vertical interval VI to the horizontal distance HD and is shown simply as 1:5, 1:12, 1:20, etc. This method is more popular with road and railway engineers. Road signs sometimes show steep gradients in this way as a warning to motorists.

4. Metres per metre (or feet per foot): This is the vertical interval divided by the horizontal distance. This approach is used by irrigation engineers when designing channels with very slight gradients.

All these methods are different ways of saying the same thing and conversion from one to the other is straightfoward. The tangent of the angle abc is the same as VI/HD. If an angle is given, the percentage slope can be found by multiplying the tangent by 100. In the same way the percentage slope can be converted to degrees using tables of tangents.

It should be noted that if the angle is 45°, VI = HD and the slope is 100 per cent. As the angle approaches 90°, the percentage slope approaches infinity. The fact that percentage slope can exceed 100 per cent is sometimes not realised by agriculturalists for whom 65 per cent (33°) is already too steep for cultivation. A slope of 16 per cent (9°) is usually the limit for tractor operation and slopes over 20 per cent (11°) present serious problems for soil conservation.