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SOIL DEGRADATION PROBLEMS AND SOIL CONSERVATION TECHNIQUES AND MANAGEMENT: USE AND IMPLEMENTATION IN AFRICA

Selected Bibliography, Annotated Bibliography,

Register of Relevant Institutions, with Introduction

and accompanying volume of selected reprints

62

RESOURCE HANDBOOK SERIES NO. 1

Volume 1
by
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Cooperative Agreement on Human Settlement
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...much of the technical knowledge required for erosion control has been available for fifty years. While there is scope for increased understanding, the major challenge is now the development of conservation measures and strategies which conform to the economic, social, and political realities of the countries where they are needed.

Rorke B. Bryan, 1979

Humans are out of perceived necessity destroying the basis of their own livelihood as they violate the limits of natural systems. Those most vulnerable to these trends are the poor of the world. Their search for the basic requirements of food and fuel often force them to hasten the destruction of their own environment.

World Bank Forestry Sector Paper, 1978

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PREFACE

This handbook is the first in a series designed to bring together social and technical information on one problem or subject. It fits into a context of appropriate technology transfer, that is the relation of new technology to user systems in developing countries. This also involves re-evaluation of existing local practices to find out which have been successfully used in the past and why? Information of this kind can be effective in the design of new management systems.

The purpose of the handbook is essentially practical, geared to utilization. It combines reports of state-of-the-art research with reports of field experience, including historical experience of physical problems and efforts to deal with these in the past. It is meant as a decision making aid, a resource for planners or those concerned with projects in AID missions. The essence of this endeavor is the selection and coordination of useful materials, directly focused rather than comprehensive. The present document is a first draft and suggestions for up-dating and improving it are welcome.

We should like to thank Karen Sabasteanski for careful editing and help in organization, and Joan McGrath for producing the document on the word processor. Thanks are also due to Larry Lewis and Len Berry for advice and suggestions, and to Marla Wallace, Kokab Arif and Mary Hartman of the Goddard Library.

Eileen Berry
Jim Levy

INTRODUCTION

Soil erosion is a widespread problem in Africa and there is evidence that it has increased substantially over the past two decades. This increase has been attributed to a number of factors which include the movement of farmers onto lands that are marginal for cultivation and which would be more productive if kept in grassland, the overgrazing of semi-arid natural rangelands by herders, especially in the Sahel, the decline of fallowing in many agricultural systems as a result of land shortages without sufficient compensating increase in the use of fertilizers to maintain soil fertility and stability, and the cutting down of forest and woodland to make way for farming or to provide fuelwood for towns and peasant families.

While soil erosion is a natural physical process taking place in the absence or presence of human activity, it is a process that can be accelerated by mismanagement. Thus it becomes an economic problem as well as a technical problem, and, like all economic problems, it ultimately goes back to questions of social organization and management.

There is no shortage of research on the technical aspects of soil conservation and a topical bibliography on this subject alone would be superfluous since a computer search could easily retrieve any required materials. However, and this brings us to the practical purpose of this handbook, it is a different matter when it comes to user orientation and implementation issues. While technical information has been generally available for over fifty years (Bryan 1979), there has been much less attention paid to making this knowledge available and applicable to farmers, particularly to smallholders in developing countries where it is critically needed.

Technology transfer poses particular problems in this respect, especially in tropical environments. First of all, the biophysical conditions of the tropics are different from those of the higher latitude lands where most of the technical research has been done, so that simply applying these conservation measures developed from this research to developing countries is not feasible. Secondly, the social conditions of Third World countries present special difficulties for the introduction of soil conservation techniques since mechanical means of protection raise questions of time and money costs. Shortage of labor in many areas adds to these difficulties. Another problem is a bias against such conservation measures in areas where coercive colonial extension officers once instituted them for using forced labor.

A key social science research issue is to try to understand the present nature of land use and farming systems in developing countries and to appreciate the rationale for certain agricultural techniques and crop choices. Understanding local attitudes to soil conservation is a vital part of such research. Any innovations in this field would have to be locally acceptable and economically feasible to be effective.

The purpose of this handbook and acccompanying volume of selected papers is to pull together materials on this socioeconomic aspect of soil conservation, as distinct from the purely technical aspect. A computer search designed

to retrieve data on the topic confirmed the value of a resource handbook of this type. It was difficult to assemble materials on the relevance of technical research to user systems.

The handbook is organized in four sections:

1) Current state-of-the-art research on soil management problems and conservation techniques;

2) Colonial experience with the introduction of soil conservation techniques;

3) Indigenous methods of soil conservation; and

4) Re-evaluation of indigenous techniques.

The logic of this organization is to combine in one volume references to technical materials on the problems of dealing with soil erosion in the field and at farm level, and on the value of indigenous methods of land management. The handbook will also address the current interest in making indigenous methods more effective through the application of scientific principles to these techniques rather than replacing them with new technologies, which are often more highly capital and energy intensive and less likely to be accepted.

The first section lists works that deal with modern soil conservation research as applied to both assessing erosion hazards and describing field techniques to reduce soil loss. The Universal Soil Loss Equation developed by Wischmeier and Smith is the basic instrument used to quantify the effects of reducing soil loss, and a modification of this technique has been developed at the Institute of Agricultural Engineering, Zimbabwe. The technique is known as the Soil Loss Estimation technique for Southern Africa, which takes tropical conditions more fully into account, though the work in fact is specific to certain types of modern crop cultivation in Zimbabwe. Being able to quantify the effects of reducing soil loss below the tolerance threshold enables costs and benefits to be estimated and early warning trends to be identified in time for remedial action to be taken. The effects of severe soil erosion are destruction of agricultural and grazing land and, in less extreme cases, lowered yields and productivity.

Field techniques to control soil loss involve either crop management or mechanical means of protection such as wind barriers, terraces, drainage ditches and bunds. These may also be combined. Crop management is particularly important in the tropics as it involves little disruption or extra cost to the farmer and can produce considerable benefits. It can also be adapted to annual or seasonal variation in erosion risk or hazard.

The second section is devoted to works that describe the types of soil conservation methods introduced by the various colonial agricultural extension services, and the often hostile reaction to these by small farmers. Much of this effort was coercive and therefore doubly resented, but hostility also arose because the focus on mechanical means of conservation involved arduous labor and low return for effort. This literature gives some valuable insights into socioeconomic issues.

The third section brings together some useful references on indigenous methods in different parts of the continent; methods which are geared to both local conditions of farming ecology and to labor constraints in local farming systems. The focus here is on local variations and the rationale for certain techniques. Many of these practices, such as long fallows, intercropping and multiple cropping, field preparation that involves the minimum disturbance of topsoil, and, in the case of rangeland, seasonal transhumance, have a long history of application in African farming and herding.

The last section provides references to work being done in re-evaluating these indigenous techniques. Some, like long fallows and seasonal transhumance, are no longer feasible in most places because of land shortage or political and economic changes which have curtailed movement. Others retain their role in land management and agricultural systems in some areas but have been replaced elsewhere by agronomic practices based on "western" models of farming that use monoculture, planting in rows, and the use of animal or even mechanical traction. These "modern" techniques are not always the most suitable either in terms of soil or slope conditions, nor in terms of farm economics. There has been as a consequence a renewed interest in practices such as intercropping where staggered plantings of different crops limit the exposure of fields and topsoil to wind, rain and sun by allowing maturing crops to shelter seedlings and to retain some cover over all parts of the field. Intercropping also provides a better mix of nutrients for the soil, limits the risk for farmers, and gives a better yield for labor. Scientific research has focused on how to exploit space, moisture, radiation, and nutrients, including pesticides and fertilizers, in the most effective ways by varying planting dates, row spacing, crop mixtures and other elements of the system.

A reconsideration by research workers of other agronomic methods such as low-tillage field preparation and the retention of some weed cover, together with the hoeing in of crop residue to retain moisture, is also evidence of the essential rationality of many indigenous farming methods. Deep ploughing and rigid devotion to linear rows of crops which are characteristic of extension programs in Africa, are seen to promote soil erosion in certain circumstances.

In the case of semi-arid areas, conversion of pasture to cultivation can actually increase soil erosion hazards since the grass provides a closer ground cover. Traditional use of these marginal lands by herders was basically sound from a management point of view, though the disruption of their management systems has led to overgrazing and deterioration in many areas now.

A better understanding of the indigenous practices and an acceptance of their value should improve relations between farmers and agricultural research stations where this work is in progress. Extension workers have often been negative towards indigenous farming methods, an attitude inherited from colonial days and supported by those who would like to sweep away small farming systems and create a modern agricultural system in their place. In Africa at present, this is not a feasible solution.

The re-investigation of customary forms of land management and the direction of scientific research is agronomy towards low-tillage methods is a promising approach to dealing with soil conservation problems in Africa.

References to work being done in this field, therefore, rounds out the bibliography by returning full circle to the current state-of-the-art research.

A general section in the selected bibliography has been included to cover works of a particularly comprehensive nature.

The selected papers have been chosen either because they are seminal, such as Wischmeier and Smith's work, or because they have a special relevance to Africa or to questions involving application in Africa. The list of institutions includes those which publish regular bulletins on these topics, enabling the reader to keep abreast of current research. While every effort has been made to include the most recent and the most useful references, the field is vast and it is possible that some have been overlooked. We therefore welcome any suggestions from readers of this handbook which will allow us to update and improve it.

Eileen Berry

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SECTION 1.

SOIL MANAGEMENT PROBLEMS AND CONSERVATION TECHNIQUES: CURRENT RESEARCH

SECTION 2.

COLONIAL EXPERIENCE WITH THE INTRODUCTION OF SOIL CONSERVATION TECHNIQUES

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SECTION I

CURRENT STATE-OF-THE-ART RESEARCH ON SOIL MANAGEMENT PROBLEMS AND CONSERVATION TECHNIQUES

The papers cited and annotated under this heading, together with the reprints selected for the accompanying volume, bring together pertinent information on the current state-of-the-art research on scientific methods of assessing soil degradation and techniques of measuring soil loss and sediment yield, plus evaluation of the various methods of soil conservation. The latter fall into two main categories: mechanical and biological. It is the biological techniques that appear to have the greater promise for successful introduction into African farming systems. This is because they are compatible with indigenous farming methods and also because they are low cost and, significantly, less labor intensive than mechanical methods; a factor which makes their application economically feasible in Africa where labor shortages in agriculture are being keenly felt and belatedly recognized.

The papers in this section also deal with the applicability of western research, largely conducted in temperate climates, to African tropical regions. The four critical controls on rainsplash erosion are: raindrop size and intensity, angle of slope, extent of ground cover and soil characteristics. Measurement of the first of these properties is difficult everywhere because few climatic stations record rainfall intensities while storms of high intensity are very localized, especially in Africa. Slope factors play a relatively larger part in values of erodibility for Africa where cultivation often takes place on very steep slopes. Besides suffering severely from water erosion, many tropical areas in Africa are especially vulnerable to wind erosion where overgrazing has reduced surface cover to critically low proportions. Ground cover is vitally important because wind cannot entrain soil which is protected by vegetation. The maintenance of ground cover is, therefore, a major factor in soil conservation.

In farming areas the maintenance of ground cover is an important consideration in retaining no-tillage methods of agriculture and should be investigated critically wherever the introduction of plows or tractors are contemplated. In semi-arid areas the most efficient use of land, bearing in mind the cost of soil conservation methods, is production from grassland. Current scientific research on soil degradation and soil conservation techniques appears to be universally applicable, with the noted reservation that the significance of certain factors varies between tropical and temperate regions, and that there are particular problems associated with present day African farming and herding systems, the solution to which, from the point of view of soil conservation, must be geared to the capacity of local people to implement conservation measures as discussed particularly by Hudson, 1982.

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SECTION 2

COLONIAL EXPERIENCE WITH INTRODUCTION OF SOIL CONSERVATION TECHNIQUES

The purpose of drawing attention to the colonial experience is to point up the long history of soil degradation problems in Africa and attempts to deal with these. This historical background is an invaluable source of data, especially data on the socioeconomic constraints to the introduction of conservation methods. In the colonial period, schemes for better land management were often set up with little or no consideration of the local social systems which regulated the existing use and distribution of land. Coercion was the chief form of implementation and this history is a legacy that remains important in terms of effecting present day participation in soil conservation schemes. The fact that many of the methods which colonial authorities attempted to introduce involved much hard physical labor and frequently produced little in the way of economic return to the farmer, suggests pertinent lessons for those planning innovative methods of land management in Africa today. The emphasis in colonial times was on mechanical methods of soil conservation that were beyond the capacity of many indigenous agriculturalists to implement successfully. Disparagement of the indigenous biological methods of soil management often accompanied colonial efforts and approach. In retrospect, indigenous methods are seen to have much merit and though land management systems from the past cannot be reinstituted, some of the features of these earlier systems are receiving new attention.

The papers included in this section have been chosen on two counts, either because they point up the socioeconomic constraints and cultural issues that emerge when new soil conservation measures are introduced or they give in-depth and detailed descriptions of the physical problems of soil erosion, siltation and land degradation. The fact that many of these environmental problems persist to this day makes the historical evidence important in recognizing the long term nature of these processes and problems. For this reason, a number of references dating back to the 1930's have been included.

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SECTION 3

INDIGENOUS METHODS OF SOIL CONSERVATION

The papers in this section are largely confined to descriptions of indigenous farming systems and the land management techniques involved in them rather than to soil conservation techniques alone, for which few references appear to exist. Biological methods based on crop management have been the main methods of conservation outside the Mediterranean regions, and hand raised bunds or ridges are the main forms of construction used to control soil and water. Biological methods are low-level responses, in a technological sense, involving little extra cost to farmers, and they have been naturally appropriate in Africa where farms are typically small (five hectares or less) and where farming is still largely based on hand cultivation. Intercropping to retain ground cover, crop rotation and fallowing to maintain fertility, and, in some areas, mulching to protect soil in between harvests, are key elements of these systems. Mulching can lead to problems in areas which experience very hot and humid climatic conditions, leading to high rates of organic decomposition, but it is a useful method of combating erosion in other places.

The interest in these papers lies in their present relevance to the introduction of soil management techniques and better ways of combating soil erosion. These may well be more successful if they are based on crop management approaches, though this does not mean a return to traditional methods. Economic and political changes in Africa have led to the disruption of traditional systems in ways that make any such proposition untenable and it would be unproductive to ignore modern scientific research. Long fallows are no longer possible in regions of land shortage, crop mixtures have already been changed, and new agricultural methods already introduced in many places. What remains relevant is the low cost biological approach to land management wherever this is appropriate because it is more likely to be understood and adopted by local farmers than the commonly recommended practices of terracing and contour farming which require higher inputs of capital and labor.

Given this situation, and the increasing acceptance by planners of building upon local knowledge and experience, a consideration of indigenous farming methods can provide baseline data for the application of scientific methods of crop management relevant for Africa.

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SECTION 4

RE-EVALUATION OF INDIGENOUS TECHNIQUES

This section follows logically from the previous one and the papers included in it deal with the application of scientific principles and research to crop management. Multiple cropping, either intercropping or sequential cropping, involves growing two or more crops in the same field in a year, and is a common traditional technique of intensive garden scale and small farm cultivation in Africa. This is particularly the case in tropical regions where high all year round temperatures make such practices feasible and maximize land productivity per unit area per season. The purpose of scientific research is to find the most effective ways of exploiting space, moisture, radiation and nutrients by varying the elements of the system to improve yields. Crop mixtures, row spacing, crop densities and planting times and sequences are all subject to scientific evaluation and measurement. Technology transfer directed towards increasing the productivity of existing systems is now being recognized as an effective research strategy applicable to the maintenance of land quality as well as to improvement of yields.

A paper on no-tillage agriculture is included in this section to demonstrate how research on new agronomic methods in developed countries also points to renewed interest in crop management techniques for soil conservation. This means a move away from deep furrows, row cultivation, deep plowing and clean weeding. Weeds and other competing vegetation are controlled by chemical herbicides, thus eliminating the need for mouldboard plow and disk harrow. The modern no-tillage agriculture thus combines the use of modern herbicides with the oldest indigenous methods of seed planting, and there is less need for the use of mechanical control processes such as contour farming, contour strip cropping and terracing. It is claimed that soil erosion is virtually eliminated where no-tillage agriculture is practiced. It was the mechanical control methods, introduced into Africa as "modern," though many were of very ancient provenance, that sparked such hostility during the colonial period. Some of these practices are now seen to be ineffective in the context of African farming and in some cases are ineffective or too costly to employ in industrialized countries.

In U.S. farming, the recommended avoidance of conversion of rangeland to cultivation in semi-arid regions where pasture provides a closer ground cover, and the decline observed in such conversion, is also highly relevant to the African situation.

The direction of research into crop management strategies for soil conservation combined with the re-evaluation of indigenous farming methods suggests a promising trend in dealing with land resource management in Africa.

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SECTION 1.

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Okigbo, B.N., and D.J. Greenland. 1976. Intercropping systems in tropical Africa. In Multiple cropping, ed. R.I. Papendick, et al., 63-99. American Society of Agriculture (ASA), Special Publication no. 27. Madison, WI: ASA.

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Bennema, J. and T. De Meester. 1981. The role of soil erosion and land degradation in the process of land evaluation. In Soil conservation: Problems and prospects, ed. R.P.C. Morgan, 77-85. Chichester: John Wiley and Sons.

A critical aspect of land management planning consists of determining the 'susceptibility of land to erosion' or what can better be described as the 'risk of soil degradation due to erosion'. Degradation in this case means the degradation of the ecological and management qualities and the decrease of possibilities for improvement of these qualities.

When compiling regional or national land degradation maps, it is essential to include some consideration of the ease with which erosion degradation risk can be controlled. For example, in soils without a long period of dryness, it is possible to manipulate the crop factor in such a way that the land is covered for most of the year and the erosion hazard is reduced. To determine the feasibility and effectiveness of alternative control measures, the interaction between soil, land cover, the farming operation and the cultural, social, economic and political environment must be analyzed. As it is suggested throughout this handbook, few researchers have attempted to develop a framework for assessing the social aspects of soil conservation practices or the interaction of these with the physical and biological environment. This does not mean that such an analysis is not practical, but rather, for the time being, it remains the responsibility of individual researchers to integrate the social, physical and biological aspects of soil conservation practices into their analysis.

Bennema and De Meester suggest an important distinction between the definition of permissible soil loss at the farm and regional levels. Permissible soil loss at a farm level is that loss which does not negatively affect the main ecological and management qualities of land associated with a specific utilization type. Permissible loss for a region or area is that loss of which the total net impact is not negative. Research to define qualitative or quantitative criteria which are socially and economically acceptable for measuring permissible soil loss levels have had little apparent success. According to Mannering (1981), this has impeded efforts to establish norms for national conservation policies and programs.

Dunne, T. 1977. Studying patterns of soil erosion in Kenya. FAO Soils Bulletin 33:109-22.

Dunne's paper describes a number of field methods for monitoring rates of soil erosion that can be grouped into two basic approaches: (1) Point measurement of sediment yields in river channels. The principal problem with this approach involves the difficulty of extrapolating the spatial pattern of soil loss from point measurements. Recent research (e.g., Dunne and Dietrich 1982) however has, led to the formulation of models which permit the extrapolation of qualitative and quantitative information from point measurements of sediments to basin wide studies of erosion. (2) Permanent experimental plots which are designed to measure rainfall and runoff soil loss, assess the individual and combined effects of factors influencing rainfall and runoff losses (e.g., hillslope gradients, soil type, and land use), and measure the conservation efficiency of vegetation cover, engineering structures, and local cultural practices.

There has been a growing effort in recent years to demonstrate the economical use of air photo and satellite imagery to assess and map existing and potential erosion hazards in tropical regions of developing countries.

Food and Agriculture Organization of the United Nations (FAO). 1979. Watershed development with special reference to soil and water conservation. FAO Soils Bulletin no. 44. Rome: FAO.

Chapter seven of this report presents a detailed summary of the technical considerations involved in the design and implementation of various biological and mechanical soil and water conservation methods on four types of land use and land cover. These are: conservation methods for croplands (including the design of interception and diversion ditches, broad base terraces, bench terraces with soil rivers and stone walls, and contour banks); pastures and rangelands; wastelands; and land under forest cover. FAO (1965, 1976b), Sheng (1981), Blaisdell (1981), Hudson (1981a), Sperrow and Keefer (1975) give a similar discussion of soil conservation methods. El-Swaify, Dangler and Armstrong (1979, chapters 4 and 5) summarize a wide range of research into the effectiveness of these soil conservation methods. Other relevant publications include: Okigbo and Greenland (1976) which reviews the agro-economic aspects of traditional multiple cropping systems in Africa; Kunkle and Harcharik (1977) which discusses alternative soil conservation methods for non-agricultural upper basin land uses (i.e., upland windlands) and describes the relationship between erosion in these areas and downstream cultivated lands. In addition Okigbo and Lal (1977); Aina, Lal, Taylor (1977); and Stocking and Elwell (1976) assess the effects of cover crops on erosion and Lal (1974b, 1976d) examines the effectiveness of cultural versus mechanical alternative systems of soil conservation practices in the African tropics.

Fournier, F. 1967. Research on soil erosion and soil conservation in Africa. Sols Africains 12:53-96.

This paper reviews the results of research which examines (1) the causal factors of soil erosion by water (storm intensity, frequency, total rainfall); (2) the factors controlling the rate of soil erosion by water (soil type, steepness and length of slope, vegetation cover, land use); (3) the application of on-site and empirical measurements of soil erosion (i.e. the Universal Soil Loss Equation); (4) the effectiveness of various mechanical and biological soil conservation methods.

In a similar effort, El-Swaify, Dangler, and Armstrong (forthcoming) present a detailed summary of published research on the regional processes and extent of rainfall erosion in Africa. (A bibliography of the research cited by these authors is also reproduced in this handbook.) In addition FAO (1965) provides a brief discussion of the principal types of erosion damage caused by rainfall and runoff (sheet and microchannel erosion, gullying, and sedimentation). Skidmore (1977) presents a brief discussion of criteria for assessing wind erosion and of the application of the wind erosion equation developed by Chepil and Woodruff (1965) and Woodruff and Siddoway (1965). Only a small number of available publications discuss the effectiveness of alternative wind erosion control measures. These include Woodruff and Chepil (1965), World Meteorological Organization (1964), Hagan, Skidmore and Dickerson (1972), Radke and Hangstrom (1976), and Siddoway and Barnett (1976).

Kussow, W., S.A. El-Swaify and J. Mannering, eds. 1982. Soil erosion and conservation in the tropics. American Society of Agronomy (ASA), Special Publication no. 43. Madison, WI: ASA.

Two papers published in this volume discuss the implications of transferring knowledge, techniques and models of analysis from research centers in the United States to tropical regions of developing countries. A paper by Foster, Moldenhauer, and Wischmeier (1982) limits itself to considering the transfer of techniques for examining the physical processes of erosion, and more specifically, to the application of the Universal Soil Loss Equation (USLE), derived primarily from examination of erosion processes in the American midwest, to tropical regions of developing countries. The paper concludes: "Basic erosion prediction and control principles apply universally. Erosion is related to the effective erosivity of raindrop impact and runoff outing on the soil, and the susceptibility of the soil to erosion. Erosion is controlled by reducing rainfall erosivity, soil erodibility or both. With appropriate adaptations, the USLE or a similar simple and easily used equation can be a useful planning tool for the tropics."

The second paper, by N.W. Hudson (1982) entitled "Soil conservation research and training requirements in developing tropical countries," examines

the transfer of the USLE in the broader context of the cultural, social, economic, political and physical conditions of developing tropical countries. Hudson argues that "we are operating so far outside the range of our experiments (i.e., to derive the USLE in the United States) that we cannot extrapolate (i.e., to conditions existing in tropical regions of developing countries)." Research into alternative methods of soil conservation in tropical regions of developing countries must consider the socioeconomic constraints on farming operations, e.g. the fractionalization of land which impedes the implementation of regional land management policies, but also the particular agroecological context of production in these regions, such as the frequent cultivation of steep (20 percent or steeper) slopes.

Wischmeier (1976) presents a brief but comprehensive discussion of the variables in the USLE, the uses for which the equation was designed, and the potential misuse and misinterpretation of the equation and its results. For a further review of the development and application of the Wischmeier-Smith USLE to evaluate soil loss from sheet and rill erosion, refer to Wischmeier, Smith and Uhland (1958), Wischmeier and Smith (1978), Wischmeier (1973), and other publications by these authors cited in the bibliography. For a discussion of the application of the USLE to conditions of the African tropics, refer to Fournier (1967), Roose (1977b), Hudson (1981a), El-Swaify, Dangler and Armstrong (1979), Sperrow and Keefer (1975), and Jones and Wild (1975).

Lal, R. 1979. Physical characteristics of soils in the tropics: Determination and management. In Soil physical properties and crop production in the tropics, ed. R. Lal and D.J. Greenland, 7-44. Chichester: John Wiley and Sons.

Soils textbooks and assessments of soil management and conservation alternatives are generally the product of research on temperate soils and agriculture. Results are often misleading or irrelevant to students unfamiliar with temperate climates. A growing number of publications do however present a comprehensive review of soil science as applied to tropical regions of Africa. In this particular paper, Lal defines those physical characteristics of tropical soils which must be analyzed in order to formulate appropriate soil management strategies (such as soil structure and its relation to infiltration rates and water retention capacity), and describes the principal methods in use for such analysis. For a broader and more detailed discussion of the characteristics of tropical soils, including the chemical properties of soils, soil fertility, and soil organic matter, refer to Hudson (1981), Moss (1968), Young (1976), Buringh (1970); Sperrow and Keefer (1975) who present an introduction to soil science applied to East Africa; Charreau (1974), Kowal and Kassam (1978), Jones and Wild (1975), and Ahn (1968, 1970) who focus on the analysis of soils in West Africa; and Thompson and Purves (1978) and Thompson (1965) who describe a soil classification system for Zimbabwe.

Okigbo, B.N., and R. Lal. 1977. Role of cover crops in soil and water conservation. FAO Soils Bulletin 33:97-107.

The majority of farms in tropical Africa are five hectares or less. The authors argue that the commonly recommended practices of terracing and contour farming are not feasible given the limited capital and labor resources available to small farmers. Alternative methods of soil and water conservation, therefore, need to be considered for tropical farming systems. Okigbo and Lal describe the effectiveness of cover crops and mulch farming techniques for soil and water management. Although very small quantities of mulch have pronounced effects on reducing surface runoff and erosion, the production of large amounts of organic residue on the soil surface (i.e., as a result of hot and humid conditions which cause high rates of organic decomposition) constitutes a major constraint for the successful use of mulch in the humid tropics. Leguminous cover crops which are killed by herbicides one or two years after establishment for mulch in zero tillage cultivation of maize, cassava, cowpea, soybeans, and pigeon peas, have proved successful in reducing erosion, conserving moisture and maintaining adequate levels of organic matter, which produce as good or better yields than conventional tillage.

Roose, E.J. 1977. Use of the Universal Soil Loss Equation to predict erosion in West Africa. In Soil erosion: Prediction and control. Soil Conservation Society of America (SCSA), Special Publication no. 21. Ankeny, Iowa.

Roose compares the results of the Universal Soil Loss Equation (USLE) to field measurements of sheet and rill erosion obtained in West Africa. The paper concludes that although the USLE "appears to be well adapted to the majority of cultivated soils in West Africa (clay soils which are predominately kaolinitic) and moderate slopes on ferralitic and ferruginous tropical soils (utisols and alfisols) in particular, data is needed to modify the equation for soils of swelling clays; for mountainous regions of recent origin, where gully erosion predominates; and for Saharan and Mediterranean zones where unusually intense rains are important."

Two other papers published by Roose (1977a, 1977b) review the same information. For a further discussion of the application of the USLE to African tropical conditions, refer to El-Swaify, Dangler and Armstrong (1979), Sperrow and Keefer (1975), Hudson (1981a), and Jones and Wild (1975); Cormory and Masson (1964) and Goujon (1968) which present case studies of USLE application to Tunisia; Hudson (1980) and Moldenhauer (1980), which discuss methods for measuring the factors of the USLE in regions where data is limited; Fournier (1967), and Armstrong, Mitchell and Walter (1980) which reviews erosion research in tropical Africa concerned with defining and measuring parameters important to soil loss prediction.

Elwell (1977, 1981) discusses the current development and application of regional soil loss estimation models, and more particularly the Soil Loss

Estimation Model for Southern Africa (SLEMSA), which serves to synthesize information related to soil erosion hazards (as in the use of SLEMSA, sheet erosion hazard on contour ridged land) and guides local soil conservation initiatives. From an assessment of local climate, soil, topography and land use, the SLEMSA user draws up an acceptable crop rotational system by selecting a combination of tillage, crop and management practices (i.e. control variables) which will reduce soil erosion to predetermined target levels. Elwell maintains that because of their low costs, models can be developed to suit local conditions.

SECTION TWO

Sudan Government of. 1944. The report of the Soil Conservation Committee, Sudan Government. Khartoum: McCorquodale and Co. (Sudan) Ltd. Khartoum, 1945.

One of the interesting facts concerning this report of almost forty years ago is that problems identified by the Commission are the same problems that are still recognized today. This does not mean that nothing has been done in the interim, nor that the findings of the Committee were not acted upon, but that the scale of the physical problems of soil erosion and degradation are such that continuous effort is needed to combat them, and human management continues to be hampered by increased demands on the environment by a growing population. The findings of the Soil Conservation Committee are echoed recently in the reports on the Sahelian drought of the seventies when human agency rather than climatic change was recognized as the major cause of resource degradation and remedies that emphasized better management were urged. In 1944, the Sudan Soil Conservation Committee had stated that:

> The soil deterioration that has occurred and which is still occurring may therefore safely be attributed to the work of mankind and to his domesticated animals rather than to any change in basic climate and the problem of control resolves itself into bringing about change in the ways of Sudanese peoples sufficient to restore the damage done and to prevent further deterioration of soils and rural water supplies.

They also stated that:

> This objective is one that has a reasonable chance of being achieved by making careful long term plans and by remorselessly carrying them out step by step over an indefinitely long term of years.

The list of problems identified included sheet erosion, gully erosion; soil deterioration due to overcropping and overgrazing in thickly populated areas even where slopes are minimal; deterioration of forest watersheds due to grazing and fire in the Red Sea Hills, the Nuba Mountains and the hills of Southern Fung and eastern Upper Nile Province and in the hills and mountains of Equatoria Province; and deterioration of forest watersheds by agricultural development of the heads of valleys in Equatoria Province. Spoilation of

agricultural land by dune formation in the Tokar Delta, and spoilation of harig (rainfed) lands by out of season fires on the clay plains of Kassala, Blue Nile, Upper Nile and Kordofan were also observed. A special note was made of the town and village peripheries generally which were deteriorating rapidly due to over cultivation, overgrazing, cutting trees for firewood or to combinations of these activities. Particular mention was made of Tokar town, Khartoum, Omdurman, Khartoum North, El Obeid and Nahud.

A series of very detailed recommendations were drawn up for each Province ranging from specific proposals for the control of badly eroded town perimeters to proposals for terracing and bunding on sloping agricultural lands. Many of these proposals are still valid today, and are also of interest for other arid and semi-arid areas.

Young, R., and H. Fosbrooke. 1960. Smoke in the hills: Land and politics among the Luguru of Tanganyika. London: Routledge and Kegan Paul.

This is an interesting account of conflict between traditional socio-economic systems and British colonial government efforts to control the physical environment, notably to introduce a program of soil conservation with emphasis on the construction of bench terraces, in the Uluguru mountain area of what used to be called Tanganyika and is now known as Tanzania. The interest in this conflict extends beyond the specific area and time because such problems are common to many parts of Africa and because the introduction of new agricultural methods and labor-intensive work in terrace building still raises issues of power and support for indigenous authority versus interventionists, now in the modern form of national government agencies or project personnel. Likewise, the questions concerning the implementation of new technology in actual field situations and the practical reasons for resistance on the part of local farmers remain relevant today.

An understanding of this particular crisis, which led to the abandonment of the terracing program, provides insights for present-day environmental development planners, and supplies an historical perspective so necessary in trying to comprehend the full range of reasons for non-adoption of what seem to the planning authorities to be rationally sound agricultural techniques for soil conservation and land management. The authors describe very fully the complex factors behind the crisis, which included technical weakness in the conservation scheme itself resulting from inadequate scientific field testing, poor attempts at explaining the techniques and the reasons for them to local people, confusion of goals in respect of new agricultural methods and erosion control measures, inflexible and authoritarian management which was out of sympathy with local customs and local feelings about the land, and a total lack of appreciation on the part of the administrative staff that land management could not be divorced from social systems of land use.

Soil conservation became associated for the Luguru people with loss of control and fears that this could also lead to loss of the land itself, from

which they drew their subsistence, through forced migration to the plains and penalties for non-compliance in using the new prescribed methods of agriculture and land use. The failure of the Uluguru Scheme, particularly of the phase concerned with terracing and soil conservation, has lessons for all those working on similar conservation schemes in Africa today. The authoritarian way in which land usage rules were laid down and the punitive sanctions for non-compliance in 1952 (See Appendix V, pp. 192-194), were characteristic of the colonial approach to land management and were not confined to British colonial territories. This background of coercion and hostility still affects local attitudes today and underlies problems in achieving participation in new schemes for soil conservation in Africa.

Other works which deal with these problems include Hailey (1945); Tothill (1948); Stockdale (1937); Hellen (1969); and the Government of Sudan (1945).

SECTION THREE

Lal, R., ed. 1975. Soil tillage and crop production. International Institute of Tropical Agriculture (IITA). Monograph no. 2. Ibadan, Nigeria.

Research information on alternative tillage systems for different agro-ecological regions of the tropics is reviewed by Lal with particular reference to the effectiveness of minimum tillage (or zero tillage) systems. Whereas minimum tillage systems with crop residue mulches are advantageous for soil and water conservation and management in the humid tropics, such residue tillage systems are generally not possible in semi-arid regions. It is difficult to provide adequate mulching material in semi-arid regions with long dry seasons and often with heavy pressure from cattle populations. In addition, loess soils, when heavily grazed and periodically burned, are easily compacted and need mechanical soil manipulations for adequate seedbed preparation. Nevertheless, the high costs of fuel and the time required for seedbed preparations have forced most farming operations to maintain minimum tillage practices for economic crop production.

Research papers in this monograph are organized under four principal headings: (1) Tillage systems for upland crops on alfisols; (2) Tillage systems for utisols; (3) Tillage systems for semi-arid regions; (4) Tillage systems for rice. The introductory section consists of three papers which outline a set of general criteria for assessing the practicability of particular soil tillage systems in different climates and economies.

The first monograph published in this series by Lal (1979c) presents the results of a number of field experiments designed to assess various aspects of the relationship between food crop production and soil erosion, including consideration of soil and water losses for different slopes and soil management practices; mulching effects on runoff and soil loss; changes in soil physical characteristics and crop yields as a result of erosion. Again the results indicate the superiority of no tillage mulching-farming techniques and intercropping, which are the tillage systems most widely used by indigenous farmers in the areas studied.

Other publications which discuss the effectiveness of minimum tillage and intercropping farming systems include: Lal (1974a); Osuji and Babalola (1982); Aina, Lal and Taylor (1979); Marimi (1978).

Mbithi, P.M. and D. Kayongo-Male. 1978. Local environmental perceptions and soil and water conservation activities. In Soil and water conservation in Kenya, Occasional Paper no. 27, 102-24. Nairobi, Kenya: Institute for Development Studies and the Faculty of Agriculture, University of Nairobi.

There are only a few publications which attempt to develop a framework for analyzing the institutional, financial, social, cultural, and political aspects of land management or soil conservation methods. The complex interactions and dynamics of these factors make any attempt to synthesize their significance very difficult. Nevertheless, it can be argued that the failure of regional or national land management and soil conservation policies is often the result of the inability of planners and decision makers to adequately consider the human or social implications of policies.

In this paper, Mbithi and Kayongo-Male describe the design and results of a survey undertaken to examine the opposition to the introduction of various soil conservation methods by local peoples, the local perception of soil erosion hazards and the feasibility and effectiveness of soil conservation alternatives. This research clearly underlines the need for planners and decision makers to become aware of how particular soil conservation issues and policies are perceived by farmers and, conversely, the need for authorities to present to farmers their own assumptions and expectations in order to inform them clearly of the intent of proposed policies. For instance, it was clear to the authors that serious erosion factors in the study area (six locations in Machakos) were: overstocking, lack of conservation structures and lack of vegetation cover; yet most local farmers studied did not relate overstocking and overgrazing to erosion. Several believed that grass should be reestablished primarily to provide pasture and forests preserved for building materials to produce rain rather than for their part in soil conservation. Further, many farmers lacked the labor and capital resources to implement soil conservation practices, such as deep contour plowing, which were deemed feasible by researchers. This discordance between the perception of researchers and farmers can only be restored through mutual understanding of objectives and expectations.

Christy (1971) presents a framework for developing a comparative analysis of soil conservation legislation and institutions. There are three principal components to this framework. Firstly, the economic implications of particular policies or legislations which include consideration of economic benefits over time to individual farming operations and to the community as a whole and the farmers perception of economic risk and financial incentives (e.g., insurance) necessary to encourage their compliance with policies. Secondly, alternative strategies for implementing soil conservation policies on croplands, grasslands, and other types of land must respond to multiple objectives which emerge

in the context of the country's general resource policy. That is, it is necessary to identify resources and their uses and to establish priorities which will accomplish the greatest level of conservation within the financial and administrative capacity of the nation. Finally, the structure and task of institutions must be determined in order to minimize costs and effectively direct policies towards specific farming operations.

Other contributions to the analysis of the social aspects of soil conservation policies include: Douglas (1981) who discusses the practical socio-economic problems and consequences of promising future benefits at the cost of present production sacrifices; Hudson (1981b) who summarizes the principal themes of political, economic and social constraints on carrying out soil conservation policies; and Heusch (1981) who presents a case study of sociological constraints associated with soil conservation programs in the Rif Mountains of Morocco.

Okigbo, B.N. 1977. Farming systems and soil erosion in West Africa. In Soil conservation and management in the humid tropics, ed. D.J. Greenland and R. Lal, 151-63. Chichester: John Wiley and Sons.

This paper briefly lists the erosion hazards associated with different traditional farm practices and operations (bush clearing, burning of vegetation, etc.) and, more generally, with the characteristics of various farming systems in West Africa (shifting cultivation, compound farming, terrace farming and floodplain agriculture). As reported by many other researchers, Okigbo states that traditional systems of soil management do not involve serious erosion hazards provided periods of fallow are reasonably long, vegetation cover is maintained, and population pressure is low. The introduction of mechanized clearing and cultivation practices and the growth of human and animal populations generally result in drastic increases of erosion hazards.

Jones and Wild (1975, chapter 9) presents a similar assessment of the relation between West African traditional farming practices and erosion hazards. Ahn (1977) summarizes current research on farming systems in relation to erosion hazards for three East African countries, Kenya, Uganda and Tanzania. Although Ahn demonstrates the significant effect of local climate and soil characteristics on erosion hazards, land management strategies are again identified as the principal factors affecting erosion. Stocking (1972, 1973, 1978), Stocking and Elwell (1973, 1976a, 1987b) develop similar conclusions for southern Africa. Finally, Nye and Greenland (1960), Allan (1965), and Lal (1974b) examine the effects of shifting cultivation practices on erosion hazards throughout Africa.

Ruthenberg, H. 1980. Farming systems of the tropics. Oxford: Clarendon Press.

Ruthenberg's book contributes to an expanding base of research on the organization of tropical African farming systems and a historical analysis of transformations in these systems. The objective of this research is to provide qualitative and empirical information from which soil conservation and land use policy alternatives can be formulated and their impacts assessed. Ruthenberg devotes a chapter to describing the organization of six broad classifications of farming systems: shifting cultivation, fallow, livestock and dairy systems, systems of permanent upland cultivation, systems of arable irrigation farming, and systems of perennial crops and grazing. Ruthenberg's classification of farming systems involved crops, livestock and processing activities only. Two chapters, written by H.G. Zandstra (chapter 10) and M.P. Collins (chapter 11) present a comprehensive review of the methodology being developed for farming systems research.

A second publication edited by Ruthenberg (1968) similarly describes the organization of smallholder farming operations in Tanzania. Ten case studies are presented which describe the land use, crop and animal husbandry practices, and processing activities of small farming operations (see "Land use in Kilombero valley: From shifting cultivation towards permanent farming"; "Cotton farming in Sukuma land"; and "Cash cropping and its implications.") Other publications which provide important contributions to the analysis of African farming systems include: de Schlippe (1956) whose analysis of the Zande system of agriculture in Tanzania is a basic framework for later research in this area; Norman (1978, 1980); Norman, Simmons and Hays (1982); Knight (1974); Tempany and Gist (1958); Tempany and Mann (1930); Trapnell and Clothier (1957); Trapnell (1953); and Tothill (1948).

SECTION FOUR

Okigbo, B.N., and D.J. Greenland. 1976. Intercropping systems in cropical Africa. In Multiple Cropping, ed. R.I. Papendick, et al., 63-99. American Society of Agronomy (ASA), Special Publication no. 27. Madison, WI: ASA.

This paper presents a summary of the research undertaken to examine the particular regional characteristics of multiple cropping systems in tropical Africa. The authors conclude that, in general, mixed cropping patch intercropping and relay cropping systems (1) produce a greater output to input ratio than sole crop systems; (2) reduce the risk and minimize losses resulting from pest and disease and from drought or other adverse environmental conditions; (3) enhance spatial utilization of environmental factors (that is, certain crops require large space between plants while different species have different water and nutrient requirements and different rooting habits, and therefore growing crops in mixtures can maximize the use of light, water and nutrients

available in an area); (4) enhance the temporal utilization of nutrients (for instance, labor and harvesting are spread out more evenly during the cropping season and storage problems are minimized); (5) increase erosion protection, since because of the overlap of crops in terms of time, crop mixtures extend the period of the year during which the soil is protected by leaf cover and root systems. The paper provides a comprehensive bibliography of research relating to traditional cropping systems in tropical Africa.

Referring to similar research findings, Norman (1974) challenges the view that sole cropping systems are necessarily more productive then multiple cropping systems (even where improved technology is available), and uses this evidence to explain the resistance of small land holders to adopting sole cropping systems. A number of other publications present productivity assessments of multiple cropping systems based on particular case studies, including Charreau (1974), Norman (1974, 1978, 1980), Ruthenberg (1971), Dalrymple (1970), and Lal (1976, 1979c). Siddoway and Barnett (1976) review research data from the United States, Africa, and other areas which demonstrates the effectiveness of multiple cropping systems for reducing wind and water erosion, essentially as a result of maintaining extended vegetative cover.

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