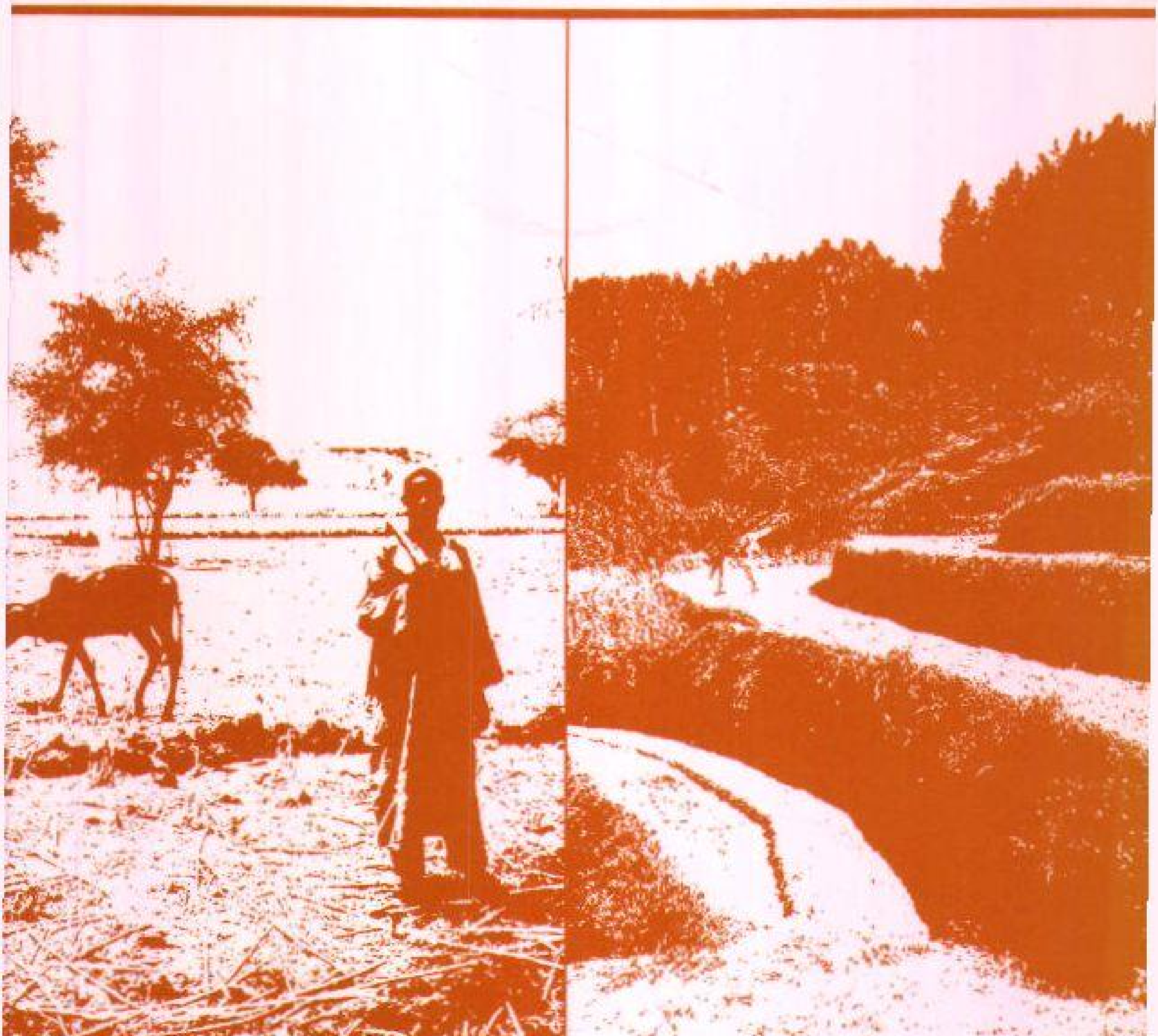
The Price of Soil Erosion

an economic evaluation of soil conservation and watershed development

Jan de Graaff



STELLINGEN

1. Ook al is het moeilijk 'de prijs van bodemerosie' te bepalen, het is zeker de moeite waard de waarde ervan te schatten.
   Dit proefschrift

2. In de voorbereidingsfase van bodem- en waterconserveringsprojecten dient op stroomgebiedsniveau zowel hydrologisch en erosie onderzoek als sociaal-economisch onderzoek uitgevoerd te worden om een totaal beeld te verkrijgen van de mogelijke effecten van projectactiviteiten.
   Dit proefschrift

3. Bij de beoordeling van bodemconserverings- en stroomgebiedontwikkelingsprojecten moet meer aandacht worden besteed aan het onderscheiden van diverse categorieën van actoren; niet alleen vanwege verschillen in hun doelstellingen, lokatie en gebruik van productiefactoren, maar ook met het oog op het relatieve belang van hun participatie voor nationale conserveringsdoelstellingen.
   Dit proefschrift

4. Gezien de toenemende schaarste aan water en de afnemende opties voor de aanleg van nieuwe dammen en reservoirs, zal onderzoek naar benedenstroomse effecten van bodem- en waterconservering steeds belangrijker worden.
   Dit proefschrift

5. De twee belangrijkste evaluatiemethoden kosten-baten analyse en multi-criteria analyse moeten niet worden gezien als tegenpolen. In de beoordeling van bodem- en waterconserveringsactiviteiten vullen zij elkaar zinvol aan.
   Dit proefschrift
   Van Pelt, M.J.F., 1993. Ecological sustainability and project appraisal: case studies in developing countries. Avebury, Aldershot.

6. Vooral in sub-humide, bergachtige gebieden met 'multi-storey' teeltsystemen, dient landbouwbedrijfsonderzoek een ondersteunende functie te vervullen bij luchtfoto-interpretatie voor landgebruiksplanning.

7. Bij ingewikkelde berekeningen met rekenbladen (spreadsheets) is het van belang een vorm van 'dubbele oftewel Italiaanse boekhouding' toe te passen.

8. In bedrijven en instellingen moeten computergebruikers niet continu overspoeld worden met nieuwe programma's en versies. Het nut van de vernieuwingen weegt vaak niet op tegen de kosten van omschakeling en verhoogde onrust.

9. Bij verkeersregulerende maatregelen zoals stoplichten zou vaker gebruik gemaakt moeten worden van kosten-baten of multi-criteria analyse. Het langdurig stilzetten van verkeer geeft wel veel veiligheid maar weinig vervoer. Een niet continu gebruik van stoplichten en diverse vormen van rotondes kunnen een goed alternatief bieden.

10. Bij sportprestaties moet men zo min mogelijk gebruik maken van oneigenlijke 'beslissingsregels', zoals strafschoppen (bij gelijkspel), 'tiebreaks' of finish-foto's. In exceptionele gevallen moet er in berust worden dat er meer dan één winnaar is.

11. Betaald parkeren in een deel van een stad leidt tot overlast en parkeerproblemen in andere delen van die stad.
    Deze lokatie

12. Het dozijn is een praktisch getal: niet alleen voor tijdsindeling, maar ook voor groepsindeling, zoals in het geval van enquêteurs in landbouwbedrijfsonderzoek en van studenten bij veldpractica.

Jan de Graaff

Stellingen bij het proefschrift:

The Price of Soil Erosion; an economic evaluation of soil conservation and watershed development

Wageningen, 18 september 1996

PROPOSITIONS

1. Even though it is difficult to determine 'the price of soil erosion', it is certainly worthwhile estimating its worth.
   This thesis

2. In the preparation phase of soil and water conservation projects, hydrological, erosion and socio-economic research should be undertaken at watershed level, in order to obtain a complete picture of the possible effects of project activities.
   This thesis

3. In the appraisal of soil conservation and watershed development projects, more attention should be given to distinguishing various categories of actors: not only according to the differences in their objectives, location and use of resources, but also according to the relative importance of their participation to national conservation objectives.
   This thesis

4. Given the increasing scarcity of water and the decreasing opportunities for the construction of new dams and reservoirs, research concerning downstream effects of soil and water conservation will become increasingly important.
   This thesis

5. The two major evaluation methods: cost-benefit and multi-criteria analysis should not be considered as antipoles. In the appraisal of soil and water conservation activities and projects they complement each other very well.
   This thesis
   Van Pelt, M.J.F., 1993. Ecological sustainability and project appraisal: case studies in developing countries. Avebury, Aldershot.

6. In particular in (sub-)humid mountainous areas with multi-storey cropping systems, farm economic research should play a supporting role in photo-interpretation for land use planning.

7. In complicated calculations with spreadsheets it is important to apply a kind of 'double or Italian bookkeeping system'.

8. In firms and institutions computer users should not be continuously snowed under with new programmes and versions. The benefits of the innovations often fail to offset the costs of switchover and of enhanced unrest.

9. Traffic regulating measures such as traffic lights require more use of cost-benefit and multi-criteria analysis. Stopping the traffic for long periods of time does provide improved road safety but little movement. An intermittent use of traffic lights and various forms of roundabouts offer good alternatives.

10. In sport events as little as possible use should be made of inappropriate decision rules, such as penalties (after a draw), tiebreaks or the photo-finish. In exceptional cases we should accept more than one winner.

11. Paid parking in part of a city leads to overcrowding and parking problems in other parts of that city.
    This location

12. A dozen is a practical number: not only for the division of time, but also for dividing groups, as in the case of enumerators in farm surveys and students in field practicals.

Jan de Graaff

Propositions with PhD thesis:

The Price of Soil Erosion; an economic evaluation of soil conservation and watershed development

Wageningen, 18 September 1996

THE PRICE OF SOIL EROSION

an economic evaluation of soil conservation

and watershed development

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Jan de Graaff

THE PRICE OF SOIL EROSION

an economic evaluation of soil conservation and watershed development

PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Landbouwuniversiteit Wageningen
op gezag van de rector magnificus,
dr. C.M. Karssen,
in het openbaar te verdedigen
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ABBREVIATIONS

ANSWERS	Areal Nonpoint Source Watershed Environment Response Simulation
CBA	Cost-Benefit Analysis
CEA	Cost-Effectiveness Analysis
CES	*Conservation des Eaux et des Sols*
ECBA	Economic Cost-Benefit Analysis
EPIC	Erosion/Productivity Impact Calculator
EUS	Environmental Utilisation Space
FAO	Food and Agriculture Organisation of the U.N.
FCBA	Financial Cost-Benefit Analysis
GAM	Goal Achievement Matrix
GATT	General Agreement on Tariffs and Trade (now WTO)
GLASOD	Global Assessment of Soil Degradation project
GDP	Gross Domestic Product
GNP	Gross National Product
IBSRAM	International Board for Soil Resources And Management
IFAD	International Fund for Agricultural Development
IIMI	International Irrigation Management Institute
IRR	Internal Rate of Return
ISRIC	International Soil Reference and Information Centre
KIT	Royal Tropical Institute
KRP	Konto River Project, Indonesia
LEI(S)A	Low External Input (Sustainable) Agriculture
LUST	Land Use System and Technology
LWUS	Land and Water Resources Utilisation Space
MCA	Multi-Criteria Analysis
NGO	Non-Government Organisation
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
OOPP	Objective Oriented Project Planning
PBS	Planning Balance Sheet method
RRA	Rapid Rural Appraisal
SCBA	Social Cost-Benefit Analysis
SCWD	Soil Conservation and Watershed Development
SWC	Soil and Water Conservation
UF	*Unité fourragère*; french term for feed supply unit (1 kg barley)
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNIDO	United Nations Industrial Development Organisation
WAU	Wageningen Agricultural University
WEPP	Water Erosion Prediction Project
WFP	World Food Programme
WOCAT	World Overview of Conservation Approaches and Technologies
WOTRO	Netherlands Foundation for the Advancement of Tropical Research
WTO	World Trade Organisation

PREFACE and ACKNOWLEDGEMENTS

This book is an account of research into evaluation approaches and techniques for soil conservation and watershed development projects. It draws from research I have undertaken for the Indonesian-Netherlands Konto River Project (1986-1990) and for the interuniversity research project on the Management of Natural Resources in the Sahel (1992-1995) and from work undertaken during earlier professional engagements with two FAO projects in Tunisia and Jamaica.

While working as an agricultural economist for soil conservation and watershed development projects in Tunisia, Jamaica and Indonesia, I wondered whether the benefits of such projects were given adequate weight in conventional cost-benefit analysis and hence in project selection. For an FAO project in Jamaica an analysis was made of the effects of agro-forestry and soil conservation measures on land productivity and on the domestic water supply to Kingston (de Graaff, 1981). During the subsequent assignment with the Department of Development Economics of the WAU from 1982-1984, I undertook a study on the economics of coffee (de Graaff, 1986), which confronted me again with soil conservation needs on steep mountainous land in Colombia, Costa Rica and Kenya, and with extensive 'soil mining' plantation systems in Brazil and Ivory Coast.

During my employment with the Royal Tropical Institute (KIT), from 1984 onwards, I further developed my interest in the economics of soil conservation projects, and I greatly welcomed the opportunity to join the Konto River Project in Indonesia. This project (1979-1991) was co-financed by the Netherlands Directorate-General for International Cooperation (DGIS), and from 1986 onwards was executed by a group of consultancy firms and institutes, with DHV Consulting Engineers as leading partner. During this assignment an attempt was made to calculate long term benefits of soil conservation measures, resulting in less sedimentation and in a better seasonal distribution of streamflow, which eventually would prolong the economic life of a downstream reservoir (de Graaff and Dwiwarsito, 1990).

At the end of this assignment a research proposal was written, which was discussed with Klaas Vink, Director of KIT, and Arie Kuyvenhoven of the Department of Development Economics at WAU and was submitted for financial support to the Netherlands Foundation for the Advancement of Tropical Research (WOTRO) of the Netherlands Organization of Scientific Research (NWO). Meanwhile I was encouraged at the KIT to write a book about the economic aspects of soil conservation and sustainable land use. That book (de Graaff, 1993) constituted in fact a first step towards this research. In January 1991 I joined the Department of Irrigation and Soil and Water Conservation, where I received support from Leo Stroosnijder to work on the research project, which was approved by WOTRO in 1992. The research was eventually undertaken in the period from 1993 to 1996, and I hereby express my gratitude for the financial support from WOTRO.

During the preparation of this thesis I benefited greatly from the support of my supervisors Arie Kuyvenhoven and Leo Stroosnijder, with whom I had numerous discussions about the approach of the research and about the contents of the successive chapters. Through their advice and encouragements they kept me going. I also acknowledge the generous support and comments on some chapters from Sampurno Bruijnzeel, hydrologist at the Free University of Amsterdam and Bram Filius, economist with the WAU Forestry Department.

I thank Watsien Valk-Brouwer for the enthusiastic way in which she took over most of my courses during the research period, and for the many discussions we had. I enjoyed the work with Emiel van Loon on the Konto spreadsheet model, and his swift incorporation of technical parameters in this model. José Janssen assisted with the design of a handy spreadsheet farm model.

The research allowed me to reflect upon the results of projects, in which I had participated in the past. A revisit to Indonesia was made possible by LIPI (Indonesian Research Institute) which granted me a research permit. I owe much thanks to several staff members of the Ministry of Forestry and in particular to Mr. Bambang Murdiono, former project manager of the Konto River Project, who made all the necessary contacts at national and regional level. I also thank my four former Indonesian colleagues and Jan Willem Nibbering and Leo Stroosnijder for their assistance during the field work.

In Tunisia I received much appreciated help from Mr. Ahmed Chennoufi, agricultural economist at INAT and Mr. Ahmed Rajah, Head of the Soil Conservation Service in Kasserine. In Jamaica assistance was obtained from Mrs. Dorothy Llewellyn of the Agricultural Credit Bank, Joseph Lindsay from CARDI and from Bas van Noordenne, Sector specialist at the Netherlands Embassy.

In 1992 I became involved in the interuniversity cooperation project on Natural Resource Management in the Sahel (SPS), and I undertook numerous missions to initiate and supervise agro-economic surveys in six villages in Burkina Faso. I like to thank Mrs. Rose Nikiéma and Jan Willem Nibbering and other staffmembers of the Antenne Sahélienne for supervising the students and enumerators involved in this research. I am also grateful for the assistance and comments of the teamleaders Dick van den Beld and Hans van Binsbergen and other staff of the integrated development projects PEDI (Kaya) and PDI/Z (Manga) in Burkina Faso.

Students in agricultural economics, tropical land use, rural development studies and forestry made important contributions in farm household surveys and studies on costs and benefits of SCWD activities, in particular for the research in Burkina Faso, but also for that in Tunisia and Jamaica. I thank all of them and the enumerators for the way in which they undertook these activities.

Although frequent travel restricted my participation, the discussions within the Production Ecology discussion group (No 2) and the SPS group have benefited this research.

I am thankful for the assistance from the staff of the Department of Development Economics, and for the excellent lunches they organised at regular intervals. Arie Kuyvenhoven and Henk Moll assisted me with the original research proposal, Rob Schipper kept me up-to-date with literature and Prakash Sital 'recruited' enthusiastic students to participate in the research. At the Department of Irrigation and Soil and Water Conservation I thank in particular Leo Stroosnijder, Leo Eppink, Wim Spaan, Dirk Meindertsma, Fred de Klerk, the AIO's and the secretaries for all technical, logistical and, above all, continuous moral support. During hectic times, a pleasant retreat was found at the 'Vlaamse Reus'.

I appreciated the help from our librarian Rob van Genderen. The maps and figures were drawn by Frans van Ernst and Piet Kostense. Michel Riksen and Sara van Otterloo-Butler provided editorial assistance.

Last but not least I thank my parents for their support during my education, and Françoise and Florence for putting up for so long with an often absent or absent-minded husband and father.

PART I

SOIL AND WATER CONSERVATION AND ECONOMIC EVALUATION:

a conceptual background

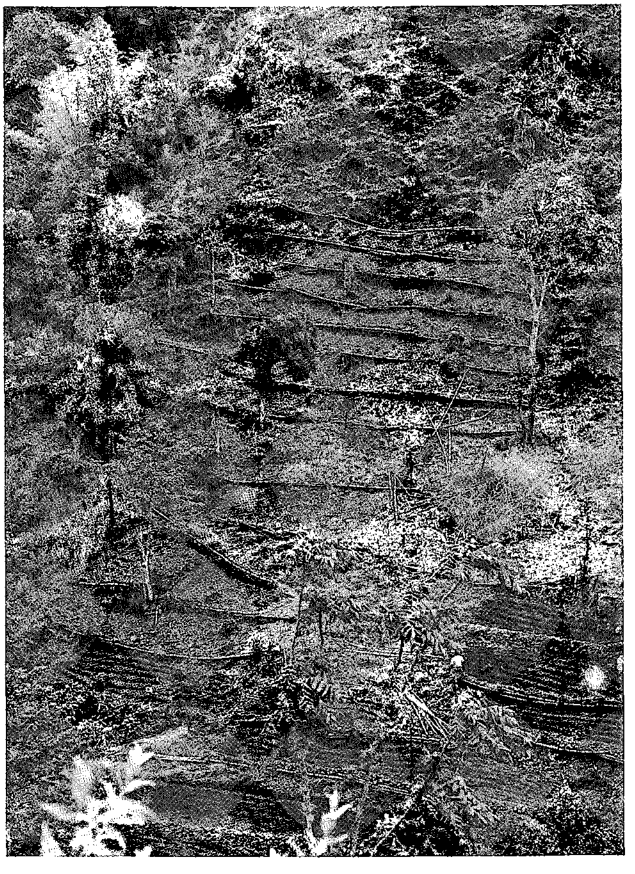


Plate 1 *Erosion and simple erosion control measures in Upper Yallahs watershed, Jamaica*

1 SCOPE AND AIM OF THE STUDY

Conservation is the greatest good for the greatest number over the longest time (Pinchot).
In: Page, 1977.

1.1 Land degradation and economic evaluation

Land degradation can be defined as a process that lowers the current and/or future capacity of the land to support human life (Oldeman et al., 1991). Land degradation is nowadays one of the most pressing problems of most developing countries and a major problem in many developed countries. Since most forms of land degradation take place gradually (except for landslides) and this gradual process is not clearly visible, insufficient attention is paid to it. To attract more attention to the problem, the European Union used the word desertification in the title of their research project on land degradation in Southern Europe: Mediterranean desertification and land use project (MEDALUS).

The problem of land degradation is not the same everywhere. In *semi-arid* zones, the increasing use of land which is only marginally suitable for agriculture and grazing often leads to soil erosion and declining soil fertility and soil structure, resulting in productive capacity loss and desertification hazard (Chapter 2). In *mountainous (sub-) humid* zones, deforestation and intensive cultivation of steep slopes lead to massive soil erosion, not only lowering productivity but also contributing to accelerated siltation of reservoirs that provide electricity, flood protection and irrigation water in downstream areas.

Avoiding such effects of land degradation constitutes the major benefit of soil and water conservation activities. Many developing countries have realized too late the seriousness of land degradation or depletion processes and now face severe ecological and economic problems (e.g. Ethiopia, Haiti).

In order to counteract on-site soil erosion processes, and to address the harmful effects on downstream areas, soil and water conservation projects and programmes are designed and implemented in the upstream areas. However, the promotion of such projects is hampered by the fact that neither their *effects* nor their *beneficiaries* can be easily detected (Part II). This makes it difficult to *evaluate* such activities.

Effects of interventions

Since interventions normally include such activities as reforestation, terrace construction, etc., they are generally characterised by high initial costs and by benefits that only become apparent in the long run. When applying conventional benefit-cost decision criteria, including discounting procedures, these activities tend to show low returns (Chapter 4). This may explain why governments and development agencies have been reluctant to finance such projects. There were, for example, no specific soil conservation and watershed development projects among the 87 World Bank agricultural projects for which an ex post evaluation was undertaken in 1993. And only few 'area development' and forestry projects had conservation components (World Bank, 1995).

The emphasis in project appraisal has been on the economic efficiency criterion of maximizing income or welfare through an optimal allocation of scarce resources. Externalities should be included in such an analysis, but less easily quantifiable effects such as downstream effects and the future benefits of preventing the irreversible loss of productive land are seldom adequately accounted for in such analyses. In soil and water conservation activities, a multitude of not immediately visible physical effects occur that need to be properly identified, quantified and valued in an evaluation process. To this end the technical relationships have to be established first between the various effects (inputs and outputs). This is seldom undertaken thoroughly, neither before nor after the implementation of soil and water conservation projects.

Although there is much debate about the relative importance of *on-site* and *downstream* costs of soil erosion (Crosson, 1986; Magrath and Arens, 1989; Pimentel et al., 1995), effects of erosion and sedimentation on the effective life and maintenance of reservoirs, irrigation canals and other downstream water infrastructure works are often neglected or underestimated. When these effects are likely to be important, soil and water conservation activities, and the evaluation of these, should preferably be undertaken within a *watershed* framework.

Beneficiaries

Soil and water conservation activities are undertaken under various agro-ecological and socio-economic circumstances, in different parts of the world. However, for a multitude of reasons farmers do not generally engage on their own in investment in soil and water conservation. In the more advanced economies farmers may sometimes take the initiative, but in most cases they are stimulated to do so as a result of specific government policies, direct incentives or participation in specific programmes or projects. When the seriousness of the erosion problem was realized in developing countries in the 1950's, governments (initially colonial powers) took the initiative and for a long time they followed a top-down approach in the design and implementation of soil conservation projects and programmes. Many of these failed. Usually the priorities and capabilities of the land users were insufficiently considered in the preparation and execution of such projects or programmes.

Once the authorities had come to realize that the proper implementation of such activities would depend on the acceptance by and full participation of the population, soil conservation and reforestation activities became less dominated by regulations. There was a shift towards 'protect and produce' (FAO, 1983), including less direct soil conservation related activities (e.g. promoting tree crops) and the measures were accompanied by incentives (e.g. subsidies) or by rural development 'starter' activities (e.g. drinking water supply, access roads), to incite farmers to participate. In other words conservation gradually evolved into regional development activities using watershed boundaries. These are referred to as '*watershed development* activities', that could form part of a national programme. To illustrate that this study is concerned with activities that are primarily aimed at soil conservation and implicitly also at watershed development, the abbreviation *SCWD* (soil conservation and watershed development) is used throughout the book.

Important questions that arise are whether such projects are eventually able to contribute to both development and conservation goals, whether subsidies can be justified from a national economic point of view, and how these issues could be dealt with properly in the preparation and appraisal of such projects.

Since the various actors in SCWD activities all have a different stake in degradation and may consider different options for conservation, one should first properly identify these groups, with their respective objectives and resource endowments, and use that information as a starting point in the preparation and appraisal of such interventions. One of the main questions to be asked in this analysis is: who is paying '*the price of soil erosion*'.

Evaluation method

SCWD projects are sometimes undertaken by private non-governmental organisations, but because of their high initial costs and long gestation period they are usually implemented by public organisations, and financed from the regular government budget, through foreign aid or by loans from development banks or other financial institutions. Although only in the case of financing on the basis of loans a detailed project appraisal is undertaken, in all other cases there is an interest in knowing more about the costs and benefits of investment activities in soil conservation and watershed development.

Cost-benefit analysis (CBA) is normally applied, but given the fact that neither the multiple effects, nor the beneficiaries can be easily detected, quantified and valued, cost-benefit analysis may not be the most appropriate tool for the evaluation of such projects. Since many effects cannot be expressed in monetary terms and many different groups of actors are involved in these projects, each having different sets of objectives, multi-criteria analysis (MCA) may offer better possibilities for applying various evaluation criteria and different weight sets for these criteria. There is a need to compare the advantages and disadvantages of the two methods in the preparation and appraisal of SCWD activities and projects.

There is not yet much evidence of the appropriateness of actual project appraisal techniques for SCWD projects. Ex post evaluations of such projects, that focus not only on effectiveness and efficiency but also on the impact in the long run, or on sustainability criteria, have only become available in recent years. Development banks, that have gradually become more involved in financing such projects, have taken the lead in the further development of evaluation tools.

1.2 Subject and main concepts

Objectives

This research is aimed at improving the methodology for the preparation and appraisal of soil conservation and watershed development (SCWD) activities or projects. These projects have certain features that distinguish them from other agricultural or rural development projects, and that make their appraisal more difficult. To address the main issues raised in section 1.1, emphasis will be laid on the following three aspects of the preparation and appraisal of SCWD projects:

- To develop a method for distinguishing groups of actors likely to participate in or to be affected by soil and water conservation measures, and to use the analysis of impacts on these *groups of actors* as starting point for the overall project evaluation;
- To develop methods for incorporating in an impact assessment the analysis of *on-site* and *downstream* effects of erosion and soil and water conservation measures on the functions of land and water resources.
- To investigate which *economic evaluation methods* are most useful and appropriate for the ex ante and ex post evaluation of soil and water conservation activities or projects.

The concepts

Soil and water conservation

Since land degradation is a major threat for most developing countries, soil conservation is one of the major issues for sustainable development. In an economic sense Ciriacy-Wantrup consideres 'conservation' as a way of redistributing use in the direction of the future (van Kooten, 1993). A redistribution in the opposite direction, towards the present is then referred to as 'depletion'. In many developing countries, in particular in Sub-saharan Africa, agricultural development is nowadays to a large extent based on soil (fertility) depletion or soil mining (van der Pol, 1992; Stoorvogel and Smaling, 1990).

In order to include this feature of soil mining, Stocking et al., 1989 have defined soil conservation measures technically as: 'any set of measures intended to control or prevent soil erosion, or to maintain fertility'. In practice erosion control measures are not only aimed at preventing soil (and nutrient) losses but also at controlling and conserving water resources. In order to stress the importance of water retention, FAO (1995) states that adoption of improved water conservation technology in the Central Great Plains of the USA made the largest single contribution to the increase in average wheat yields from 750 kg/ha in 1936 to 1,800 kg/ha in 1977. Therefore it is more appropriate to use the term soil and water conservation measures, abbreviated as SWC.

Roose (1993) distinguishes two schools of soil and water conservationists. The first emphasizes 'the run-off with its increasing erosive energy that needs to be checked by mechanical measures' and the second is mainly preoccupied with 'the impact of raindrops that needs to be minimized through adequate vegetative cover'. Which approach should prevail largely depends on climate, soil and slope conditions, etc. In the planning and design of SWC measures one should pay attention to both, just as farmers generally do. While the first school dominated in the past, in recent times the focus is more on the provision of adequate soil cover, which is referred to by some as 'conservation farming'.

Soil and water conservation measures and maintaining soil fertility should be part of good (farm) management practices, but a distinction could be made between:

A. SWC measures on *public* land, that can be directly planned, executed and managed by government or parastatal agencies (e.g. reforestation; stream bank control);
B. SWC measures on *private* land, that are implemented and maintained by the farmers, with some government support.

The measures on private land can be further sub-divided into three major categories:

1. SWC measures that form an integral part of annual (recurrent) land husbandry practices (e.g. soil tillage, annual crop rotations, fertilization);
2. SWC measures (investment) on farmers' own land, that constitute either:
   a. *physical structures*, or line interventions, to check erosion (e.g. terracing, hedges, stone rows), or
   b. *land use changes*, leading to more permanent soil cover (e.g. reforestation, conversion to perennial cropping);
3. SWC measures that are taken along the edges of farmland, along paths, etc, that the farmer does not consider as exclusively his own responsibility (e.g. gully plugs, roadside drainage and planting).

The first type of measures on private land should indeed be considered part of regular, yearly crop and land management activities, the effectiveness and efficiency of which could be assessed by applying partial budget analysis. Farmers need first of all extension support for such activities. On the other hand, few farmers will take any action on their own with regard to the third category, which is generally seen as a public or government responsibility. There are on-site and downstream benefits, which are both hard to assess.

Here the emphasis is on the second category of interventions on private land, that constitute *long-term investment* to the farmer. Unfortunately, these measures do not bring immediate benefits as in the case of the purchase of oxen, the digging of a well, etc. Because of the long term or investment nature of such activities, a cash flow or cost-benefit analysis over at least 15 years is usually needed to determine their efficiency.

All the above types of interventions on public and private land contribute to a better utilization of the available land and water resources and to a decrease of the (net) detrimental effects of sedimentation downstream, but it is not always clear who will benefit from these interventions. Therefore methods should be developed for a detailed impact assessment (Part II). Although SWC measures are no longer imposed on farmers by regulations, attention should still be given to legal and institutional arrangements and policy-making in general to support the implementation and proper maintenance of the different measures.

Watershed development

Because of the importance of downstream effects, in particular in (sub-) humid mountainous zones, and in order to follow a logical implementation schedule, soil and water conservation activities should preferably be placed in the framework of watershed development. A *watershed* is defined as a 'topographically delineated area, drained by a stream system, i.e. the total land area that drains to some point on a stream or river'. Apart from a hydrological unit it has also been described and used as a physical-biological, socio-economic and political unit for the planning and management of natural resources (Gregersen et al., 1987). In steeply dissected areas watersheds may coincide with administrative and economic regions. The United States Department of Agriculture's Soil Conservation Service has long been the leading agency in watershed planning, and this explains why the expression '*watershed management*' is often used. This term has been defined in 'Forest Terminology', Society of American Foresters, in 1944, as follows: 'The management of the natural resources of a drainage basin primarily for the production and protection of water supplies and water-based resources, including the control of erosion and floods, and the protection of aesthetic values associated with water' (Hewlett, 1982). In the United States it mainly concerns the control of rivers and streams from state controlled mountainous areas that intersect the valleys, where farmers usually own large properties. The federal authorities can execute conservation works in upstream areas, and they can stimulate farmer participation in the lower areas by means of regulations, subsidies, tax privileges, etc.

In densely populated developing countries, the main organizational bottleneck is formed by the extensively subdivided and tremendously diverse land use by thousands or millions of small farmers or tenants, who often cannot look further than the next harvest. For governments it is almost impossible to approach all these farmers individually (e.g. farmers in central-south Tunisia could in the 1970's apply for subsidies for terracing, but the procedures were very long and the response was low). In such situations it is better to speak about '*watershed development*', which better indicates that it does not only concern the physical resources, land and water, but to a large extent also the human resources. Here watershed management refers to protective activities, aimed at the prevention of downstream adverse effects, such as protection forest, gully control etc., or activities which should be financed from public funds (classified above under A and B3). Watershed development is defined as 'the process of stimulating farmers within a watershed to carry out activities in order to provide resources that are desirable to and suitable for society, but under the condition that sustainable use is made of soil and water resources. Social, economic and institutional factors, operating within and outside the watershed must be considered' (adapted from Gregersen et al., 1987).

The actors that are encouraged to implement SCWD measures are not necessarily the major beneficiaries of these measures. Governments often promote and support these activities on behalf of downstream communities and/or future generations.

Projects

For reasons discussed above, farm households usually receive assistance in SCWD activities through government supported projects or programmes. A *project* is defined as: a discrete package of investment, policies and institutional and other actions designed to achieve a specific development objective (or set of objectives) within a designated period (Baum and Tolbert, 1985). A project is likely to comprise several or all of five elements: capital investment; provision of services; strengthening of local institutions; improvement in policies; and a plan for implementing these activities. Projects are considered as the building blocks of regional, sectoral and national plans. In developing countries a project is often conceived solely as donor assistance, but it is defined here as whatever self-contained activity initiated and/or funded by public or private agencies (e.g. factory, road construction, conservation activity). It differs from programmes mainly because of this self-contained nature.

The emphasis here is on *investment* activities of SCWD projects, although it is acknowledged that services, policies and the strengthening of local institutions often play an important role in such projects too.

Benjamin (1981) makes a functional classification between five groups of agricultural development projects, focusing respectively on: technological innovation (e.g. new varieties, mechanization); broadening the physical resource base (e.g. irrigation, settlement); improving the status of disadvantaged groups (e.g. land reform, credit); improved post-harvest handling and distribution (e.g. marketing and storage); and institution building (e.g. education and training, farmers' organisations). He included 'watershed-type projects, involving erosion control and reforestation,' under the second category but did not explain why. His remarks about the glamour and socially divisive features of this category of projects seem to refer to large settlement and irrigation schemes in the past. Since both irrigation and soil and water conservation projects nowadays focus heavily on the rehabilitation of land and water resources, this second category of projects should be referred to as: 'improving and conserving the physical resource base'. Soil conservation and watershed development (SCWD) projects would then clearly belong to this category, even though they often also involve institution building and are invariably directed at improving the status of disadvantaged hillside or upland farmers.

A problem with SCWD projects, and in which they differ from settlement and irrigation projects, is that a considerable part of the benefits does not accrue to the target groups but to future farmers and people downstream. When preparing such projects one should therefore take into account the great discrepancy between the public objectives and the private aspirations of farmers. Much attention must be given to reconciling conflicts of interest, through the provision of incentives and/or so-called 'starter' activities (Chapters 5 and 11).

SCWD projects are usually faced with a wide array of difficult issues, of diverse nature.

A choice has to be made between different technological options, responsibilities have to be defined for the many organisations involved and several socio-cultural constraints have to be dealt with.

Evaluation

While the word 'evaluation' is often used in a wider sense, here the definition of a UN committee is used: a process for determining systematically and objectively the relevance, efficiency, effectiveness and impact of activities in the light of their objectives (UN, 1984).

Evaluation can be undertaken prior to a project (ex ante evaluation), during the project (on-going evaluation) and after completion of the project (ex post evaluation). It therefore plays a role during almost all stages of the project cycle. While the term evaluation will be used here for all three cases, the term appraisal will be reserved for ex ante evaluation. For an effective on-going and ex post evaluation, objectives should be clearly defined and where possible quantified, and a continuous or periodic review or monitoring of project activities is required.

Following Imboden (1978), the object of project appraisal and evaluation could be either an activity (project), a set of inter-related activities (programme) or a decision (policy).

Whereas the research focuses on improving methods for the preparation and ex ante evaluation of SCWD activities and projects, the case studies in Chapter 9 and 10 concern ex post evaluations of SCWD activities in four developing countries. From these evaluation studies recommendations are derived for the preparation and appraisal of similar projects.

In developing countries, where capital and skills are scarce and increasing income has high priority, efficiency is still the major criterion and CBA the dominant evaluation method. But large inter-sectoral infrastructure projects in developed countries, with their different interest groups and multiple objectives, are increasingly appraised with the help of MCA methods. SCWD projects in developing countries have some features in common with the latter projects. Therefore either of the two methods could possibly be appropriate for the evaluation of these projects, or they could be used in combination, as proposed by van Pelt (1993) for sustainability-oriented projects in general.

1.3 Key elements and limitations of the approach

Key elements

In the past soil and water conservation programmes have been notorious for their top-down approaches, whereby a single drastic measure was imposed upon land users (e.g. terracing, tree planting), who were seldom consulted and therefore did not feel themselves responsible for maintaining the measures.

New soil and water conservation strategies emphasize the need to integrate such measures in the farming systems and to focus in the preparation and implementation of soil and water conservation or SCWD projects more on a bottom-up approach. Therefore much attention needs to be given in project preparation to the identification of farm types and potential *target groups* and to the analysis of farming systems. This analysis will, in combination with pilot implementation, lead to the selection of different measures for different target groups, and to more realistic estimates of participation rates.

Through base-line socio-economic surveys an impression can be obtained about the frequency distribution of the different farm types within a watershed or region. The impact assessment and financial analysis for each farm type that forms a target group for a certain SCWD activity, should constitute the starting point for the (SCWD) project analysis.

In project preparation and appraisal much use is nowadays made of *spreadsheets*, which offer numerous financial functions and can easily be transformed in cost-benefit calculus packages (e.g. COSTAB). Therefore use is also made of spreadsheet modules and multiple spreadsheet models for the impact assessment of the activities.

This *impact assessment* should, where possible, make use of system analysis and methodologies developed by technical disciplines in the field of land and water resources. The primary effects of soil and water conservation activities relate to the retention of soil, with its nutrients and organic matter, and the regulation of water. The yield response to these effects constitutes the major *on-site impact* of the measures. Here use is made of simple water balance and nutrient balance spreadsheet modules, to calculate this yield response.

Since data on erosion, sedimentation and changes in streamflow are generally lacking, little attention has so far been paid in the appraisal of SCWD projects to the *downstream effects*, although such projects are often primarily designed to improve these effects. It is quite evident that many reservoirs are faced with rapid siltation, that dredging is costly or not feasible at all and that the number of suitable sites for new reservoirs is rapidly diminishing. Therefore downstream effects can no longer be ignored. For the assessment of these effects a *watershed* (spreadsheet) *model* has been developed and used for an area for which detailed data on land use, erosion and water fluxes were available.

When downstream effects are of high importance, impact assessment of upland activities should cover a whole (sub-)watershed. Attempts should then be made to scale up the on-site effects on field and farm level to effects on watershed level. In this 'upscaling' use is made of the land use system and technology (*LUST*) concept, as applied in land evaluation studies (Alfaro et al., 1994).

After an assessment of the strengths and weaknesses of alternative *evaluation methods* in dealing with SCWD projects, the possibilities of using the two major evaluation methods CBA and MCA in such projects are explored. In the case studies both methods are applied in different situations and an assessment is made of the role these methods could play in the preparation and appraisal of similar projects.

Because of the divergent objectives of the main actors involved in these projects, different weights sets of criteria are applied in the evaluation of the case study projects, in order to present results from *different points of view*. Separate evaluation results for land users and government may reveal the potential conflicts of interest and the extent of incentives required to reconcile these different points of view.

Limitations

In this research the economic evaluation mainly concerns a partial equilibrium, *financial analysis* of SCWD activities and projects. Very little attention is given to the macro-economic framework and to major economic issues in project evaluation, such as shadow pricing and the use of conversion factors to arrive at the proper economic valuation of major inputs and outputs. However, reference is made to the various theoretical books and practitioner's guides, which deal with these issues. While focusing on the financial attractiveness of selected SCWD activities for major target groups, this study also pays some attention to the discrepancies between the financial results for major actors and the financial and economic results for the project or watershed at large.

Although mention is frequently made of sustainability as an important evaluation criterion, the expression here refers to environmental sustainability and is mainly applied in the narrow sense of *conservation of land and water* resources, which in many developing countries is the most important feature of environmental sustainability.

Farmers, particularly in semi-arid zones, face many *risks* and uncertainties, and the adoption of conservation activities is often constrained by these. Although this issue is raised, it admittedly receives no major attention in this book.

In the upscaling of on-site effects at field and farm level to downstream effects at watershed level, use has been made of simple aggregation rules and no attempt has been to use more advanced hydrological *modelling* techniques and Geographical Information Systems (de Roo, 1993). In project appraisal emphasis is on the comparison of discrete cases and not on optimization. Similarly no use has been made of farm household modelling in the selection or construction of farm types. And because of their rather extensive data requirements, no use has been made of sophisticated erosion prediction technology (e.g. WEPP, EPIC), although similar basic principles are applied. Only in the preparation of large projects or programmes may it be cost-effective to collect detailed data in order to apply these modelling techniques and advanced packages.

The study does not pretend to provide a comprehensive framework for the evaluation of SCWD projects, covering all stages of the *project cycle*. While it puts emphasis on the appraisal of SCWD projects, it also pays some attention to the other stages in the project cycle. The appraisal stage is closely linked to the preparation stage, during which most data are collected on which the appraisal is based. During these two stages attention should also be paid to the establishment of indicators for project monitoring and (ex post) evaluation.

1.4 Structure and outline

The study consists of three parts. Part 1 provides the conceptual background in soil and water conservation and economic evaluation. Part 2 discusses the newly proposed elements in the impact assessment phase of the evaluation of SCWD activities and projects, and provides in its last chapter a framework for the preparation and appraisal of such projects. Part 3 deals with the application of the proposed methodology in different circumstances, and with the general lessons that can be drawn from these case studies.

PART I Soil and water conservation and economic evaluation: a conceptual background

After outlining the scope, objectives, key elements, structure and contents of the research in this chapter, *Chapter 2* deals with the degradation of natural resources in (sub-)tropical areas and with the SCWD activities needed to eliminate or reduce the degradation of land and water resources. Firstly the functions of these resources are assessed, then there is an examination of how these functions are reduced through land degradation and how soil and water conservation measures (can) help to restore these functions. Since the use of a resource in one place and at one time may affect its use in another place at another moment, one needs to look at resource use in a wider framework, in which the concept of the land and water resource utilisation space could play a major role.

In *Chapter 3* attention is given to the different groups of actors that have a particular interest in the functions of land, water and vegetation resources in watershed areas, and who need to be considered in project planning and economic evaluation. To assess their role in the overall decision-making framework, one needs to analyze how they perceive the land degradation process and the SCWD activities and how they each make their own decisions with regard to the use of land, water and vegetation.

Chapter 4 focuses on the different economic evaluation methods and more particularly on the pros and cons of the two proposed methods (CBA and MCA) used in the evaluation of SCWD activities and projects. Special attention is given to the three main evaluation criteria: efficiency, equity and conservation, and to the extent attributes of these criteria can be quantified and expressed in monetary terms.

PART II Impact analysis of soil conservation and watershed development activities

After an introduction on impact assessment, *Chapter 5* is mainly concerned with the identification of actors, their participation in SCWD activities and the upscaling of effects from field and farm to watershed level. Thereafter attention is paid to the selection and construction of so-called farm patterns. The chapter also discusses conflicts of interest that occur in SCWD projects and provides a summary of economic incentives applied to reconcile these conflicts.

Chapter 6 focuses on simple methods of analysing on-site effects of soil and water conservation measures, on the level of fields or LUST's. In the appraisal of SCWD projects it is usually assumed that crop production in the 'without-case' gradually decreases as a result of soil erosion, while production in the 'with-case' remains stable or increases thanks to better use of water and nutrients. Impact assessment can be improved by using water and nutrient balances and crop response functions. For this purpose simple spreadsheet modules are developed.

Chapter 7 deals in a similar way as the previous chapter with downstream effects of SCWD activities. After a brief analysis of former methodologies, a spreadsheet model is developed, with which first on-site effects of measures are determined for different LUST's. These LUST's together form part of the hydrological units that make up a watershed. Subsequently an analysis is made of how the measures affect water flows and sediment transport within these units and the watershed. On the basis of the changes in streamflow and sedimentation, downstream benefits can be calculated.

Chapter 8 provides a framework for the preparation and appraisal of SCWD activities and projects. It focuses on the impact assessment in the appraisal stage, where use is made of the methods and spreadsheet models developed in the previous chapters. It also covers several steps that already need to be taken in the identification and preparation stages.

PART III Evaluating soil conservation and watershed development in practice

In order to test the respective parts of the methodology and to apply this framework, partial ex post evaluations have been undertaken of soil conservation and watershed development activities and projects undertaken in the period 1970 to 1990 in semi-arid and (sub-)humid mountainous areas in developing countries. In both case studies the advantages and disadvantages of the main evaluation methods (CBA and MCA) are explored.

Chapter 9 focuses on the assessment of on-site effects of soil conservation measures in semi-arid zones. It analyses first the costs and benefits of line interventions and fertilization measures on the Central Plateau in Burkina Faso, which constitutes a typical case of land degradation in semi-arid zones. To show that problems of and solutions for soil erosion may be different in other semi-arid zones, a comparison is made with the situation in an agro-ecologically similar area in Tunisia.

Chapter 10 discusses methods to incorporate downstream effects in the evaluation of SCWD activities in (sub-)humid mountainous zones. Thanks to the availability of much physical and socio-economic data, the Konto River Project area in Indonesia offers a good example. A detailed analysis is undertaken of costs and benefits of reforestation, perennial cropping and terracing activities in this upper watershed area in the period 1986-1990. For the assessment of the downstream effects use is made of the spreadsheet watershed model, discussed in Chapter 7. Finally a comparison is made with the evaluation of SCWD activities in a more or less similar agro-ecological zone in Jamaica.

Chapter 11 deals with incentives needed to stimulate farmers to undertake SCWD activities, when only part of the benefits accrue to them. The effectiveness of the different incentives applied in the case study projects is analyzed, and suggestions are made about the appropriate use of various types of incentives under different circumstances.

Chapter 12 provides some major conclusions and recommendations for the preparation and appraisal of SCWD activities. Attention is also given to the monitoring during project implementation, from which lessons can be drawn for future projects.

The case studies

Although the application of the proposed evaluation methodology is only discussed in the third part, some details of the case study areas and projects are already presented in earlier chapters to illustrate certain points of discussion. Background information on the four case study countries is provided below and in Annexe 1.

With a per capita annual income (GNP) in 1990 of less than US$ 600, Burkina Faso (US$ 330) and Indonesia (US$ 570) belong to the category of low-income countries. Tunisia and Jamaica with a 1990 GNP per capita of about US$ 1,500 are classified as lower-middle income countries (World Bank, 1992). Most other general development indicators confirm these welfare differences (Annexe 1). Burkina Faso is the only landlocked country, and together with Jamaica it does not belong to the oil-producing nations.

The four countries also differ in many other respects (e.g. size, population, urbanization, role of agriculture, natural resource use). However, they have also some features in common. In many areas in the four countries population density is close to or exceeds the carrying capacity (under the present technology), and this severe population pressure has led to emigration and other migration patterns.

In all four countries *migration* has been or still is a common answer to land degradation. In Burkina Faso, Tunisia and Jamaica a large part of the population (between 20% and 40%) has left the country more or less permanently in the past 50 years. In Burkina Faso people also migrate to the southern part of the country. In Indonesia the discrepancy in population density between Java and the other islands has led to large scale transmigration to other islands. Seasonal migration is also important. As the scope for (e)migration has declined, all the more emphasis is now needed on the conservation of land and water resources.

2 DEGRADATION AND CONSERVATION OF LAND AND WATER

Old land dies, dying land has wrinkles (A Tunisian farmer's perception of erosion processes). In: Loedeman, 1975.

2.1 Renewable and non-renewable natural resources

For the evaluation of interventions in the field of soil and water conservation, a good understanding is required of the functions of land and water resources, of the forms and processes of degradation of these resources, and of the variety of SCWD activities which could be applied to halt this degradation. This chapter provides a concise survey of these.

Natural resources have for long been seen as providing a basis for national prosperity, power and wealth, and there was little concern about the danger of their depletion. Minerals, like gold and silver formed the basis for our monetary system, while fossil fuels, like coal, oil and gas played a major role in the industrial revolution. Since these two categories of natural resources were formed over an extremely long period of time, they could be considered under their present forms of exploitation as non-renewable or exhaustible resources. For their optimal utilization (depletion) and pricing specific theories have been developed in the past few decades.

As early as 1913, Gray classified resources according to their relative scarcity in three groups: 1: in abundance; 2: probably scarce in the future; and 3: at present scarce. He divided the latter group into four sub-categories: a. not exhaustible through normal use (water power); b. exhaustible and non-restorable (mineral deposits); c. exhausted by use but restorable (forests, fish); d. exhaustible in a given locality but restorable through the employment of other resources of a different kind or of similar resources in different locations (farm land). Figure 2.1 gives a present-day classification (based on Heijman, 1991 and de Graaff, 1993).

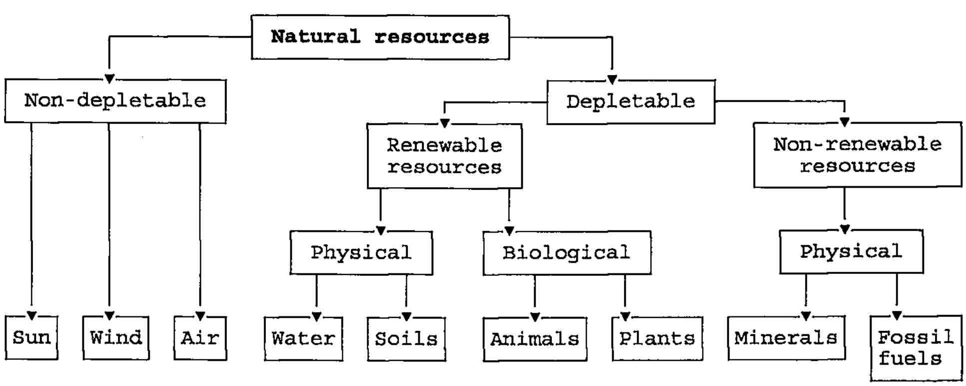


Figure 2.1 *Categories of natural resources*

The natural resources that play a major role in the agricultural sector, like agricultural land, forest and fisheries are generally described as renewable resources. It should be realized however, that these resources are self-renewing at a limited rate only. It may depend upon the size of the stock in existence at any given time and upon the extent and nature of human intervention into the stock dynamics (Kneese and Sweeney, 1985). De Groot (1992) defines non-renewable environmental functions as those which cannot be restored within a reasonable period of time, arbitrarily put at 100 years.

Only in the last decade have the environmental resources - air, water and open space - received more attention. Along with sun and wind, these resources have long been thought of as non-depletable resources. Now they are often considered as renewable resources, and in some cases they could even constitute non-renewable resources.

The *plant and animal* species are in principal renewable resources, as long as their regeneration systems are not endangered. The loss of genetic resources and the reduced bio-diversity are however one of the present major ecological problems. Much emphasis is therefore nowadays given to the preservation of wildlife systems and to natural forest areas. Because of the long rotation periods and in some cases delicate multiplication systems of forest trees (Veevers-Carter, 1984), in particular for hardwood, one could question whether (natural) forest can really be considered as a renewable resource. According to the definition of de Groot (see above) certain types of tropical timber should be considered non-renewable. In the eighteenth century German foresters already recognized this problem, and introduced the term 'sustained yield'. They defined so-called 'allowable cuts' in the exploitation of forests in order not to exceed the sustainability. The present levels of exploitation of tropical natural forests seem to be far in excess of their sustainability level.

Nature has been defined as the total of biotic (organisms that are preserved by reproduction) and abiotic (not living) components on earth. All life is based on photosynthesis and respiration. Since only plant life is capable of photosynthesis, humans and animals should, strictly speaking, be regarded as parasites of plants. Therefore bio-mass production should form the basis of carrying capacity studies.

The *soil*, as the principal growth medium for plants, shows both features of a (more or less) renewable resource and of an exhaustible resource. Its pool of nutrients and its organic material can be replenished, but when the (top-)soil depth is reduced through erosion the soil will eventually be lost, irreversibly. A similar situation emerges when the soil is continuously used without replenishing its nutrients (referred to as soil mining). The latter may soemtimes lead to desertification in arid and semi-arid zones. The process of desertification has been defined by Nelson (1988) as follows: 'Desertification is a process of sustained land (soil and vegetation) degradation in arid, semi-arid and dry sub-humid areas, caused at least partly by mankind. It reduces productive potential to an extent which can neither be readily reversed by removing the cause nor easily reclaimed without substantial investment'.

Through the hydrological cycle, the earth's inventory of *water resources* is continually transformed among the three states: solid, liquid and gas (Young and Haveman, 1985). While enormous quantities of water are available, only a tiny fraction is available at the right time and at the appropriate place to be used by humans. Fresh water for human use may be found in surface water, which is usually considered a renewable or flow resource, or in ground water, which in some cases could better be considered as a semi-renewable or even non-renewable or stock resource. This is certainly the case for such underground water sources as the foggaras and artesian layers in, for example, North Africa (Furon, 1967) that have been formed over centuries.

The distinction between renewable and non-renewable resources is of importance for sustainable development. To maintain the services and quality of natural resources, the use of renewable resources should not exceed the natural rate of regeneration, while the use of exhaustible resources should be governed by optimal efficiency and/or should not exceed the rate at which renewable substitutes are made available (Pearce and Turner, 1990).

With regard to use and disposal of such basic elements as water, nitrogen and carbon-dioxide, one refers to *cycles*, which in itself suggests that these elements are renewable, at least at global level. The problem is, however, that these elements are extracted at one place, where they may become deficient and may reduce production, and are deposited elsewhere, where they may become excessive and form a threat to production and health (e.g. flooding, pollution). Renewability should thus be defined in terms of time and space.

2.2 The functions and use of land and water resources

Land

The production factor land is only available in a fixed amount on earth. On the basis of this fixed availability of land, the (exponential) population growth and the law of diminishing returns, Malthus (1958) predicted in 1798 that per-capita food supply would be brought down continuously to subsistence level. That would then put a stop to population growth. In his economic theories Ricardo (1817) made a distinction between different qualities of land, and an increased use of land would then mean that one would generally cultivate more 'marginal' or 'less suitable' land. However, neither of these economists foresaw that technological advances would be able to 'outpace' the law of diminishing returns. Important factors in agriculture in this regard were the introduction of inorganic fertilizers and mechanization. Common (1988) adds that in effect West European economies in the nineteenth century were not (any more) operating with fixed amounts of land (Malthus), nor with successive increments of inferior land (Ricardo). New land had become available in the colonies and the fossil-fuel exploitation in shipping made these lands effectively available to Western Europe, by means of production of food, fodder, fibres, etc. Some land in Europe could even be released for other uses. One could also state that the originally limited 'carrying capacity' of the land in Western Europe was firstly enhanced by technological advances and secondly by the opening up of new lands.

The situation in many developing countries is now quite different. New lands are hardly available any more (or only at the expense of forest), the population is increasing at a much faster pace and technological means are not available (yet) at a sufficiently low price. In some areas Malthus' pessimistic views emerge again. Quality of land is also rapidly deteriorating in many developing countries. In (sub-)humid mountainous zones much land is gradually turned into waste land and in semi-arid zones desertification may take place.

Land is not a clear resource in itself. Thinking in terms of environmental functions, as defined by de Groot (1992), land can be closely associated with regulation, carrier and production functions (Table 2.1). It offers plants a medium for their roots, animals the space for grazing and people the options to build houses, roads etc. Its soil provides the various elements for plant growth: nutrients, water and oxygen in various combinations, but not always in the right proportions for optimal plant growth.

Although land is often judged on the basis of its potential or attainable productivity, its value is determined by location, relative scarcity and other factors (van Kooten, 1993).

Table 2.1 *Some main functions of land, forest and water in watershed development*

Functions	Land	Protection Forest	Water
Production & carrier functions	- Living space - Crop production - Grazing land	- Wood, fuel, fodder - Genetic resources - Recreation	- Drinking water - (Irr.) crop prod. - Hydro-electricity
Regulation functions	- Soil-water balance - Nutrient cycling [1] - Waste assimilation	- Watershed protec. - Climate regulation - Bio-diversity	- Hydrolog. cycle - Flood control - Groundw. supply
Information functions	- History - Science	- Aesthetic - Spiritual	- Ethical (life) - Science

1) And organic matter cycling.
Source: derived from de Groot, 1992 and Bouwhuis, 1993.

Natural forests and woodlands

The emphasis in this study is on activities aimed at conserving land and water resources. Easily renewable biotic resources can play a role in this, as agents of conservation (e.g. plant cover can reduce the impact of erosion, micro-organisms can improve soil structure, etc).

However, there may be a good reason to expand the conservation aim to include some categories of natural vegetation. Certain types of natural forest and woodlands, of which regeneration is extremely slow and complicated and should thus be classified as non-renewable, may fulfil important regulating functions in watersheds, at least in (sub-)humid zones. Since this function is inseparably linked to their location in the most upper parts of these watersheds, it could almost be seen as a special category of land. These (semi-)natural mountain forests (referred to as protection forest, in Dutch *schermbossen*) provide the best protection against erosion and mass movements. Although forests normally use more water than most other forms of land use, they play an important role in the hydrology of watershed areas, by retaining water in wet seasons and gradually releasing it in dry seasons. At high altitudes so-called 'cloud' forests can also capture cloud moisture by condensation, which increases effective precipitation (Hamilton, 1986). In the past these natural mountain forests were abundant, but now they are scarce or becoming scarce. Paired watershed experiments in tropical Africa have demonstrated that with skilled development both tea estates and pine plantations could be hydrologically almost equivalent to natural forests (Pereira, 1986). The discussion nowadays centres around the question, whether these are exceptional cases or not.

The non- or semi-renewable natural forest resources also perform an important function in safeguarding bio-diversity and/or in nature conservation. This is largely outside the scope of this study, however.

Water

Water is of great importance to mankind, and performs multiple functions in many different forms. Through the hydrological cycle it plays an important function in regulating the local and global climate. The sea, rivers and canals allow for many transport activities, and another important carrier function is the use of water for recreational activities. The main production functions of water concern its use in rainfed agriculture, irrigation, in industry, at household level, and for generation of electricity. Most countries have heavily invested in water resources infrastructure, for multiple use.

In agriculture consumptive use is made of water. Almost every process in plants is affected by water availability. The total weight of living plants consists for more than 90 %

of water and most agricultural produce also contain a considerable amount of water, ranging from about 12 % for grains to 70 % for tubers and 90 % for many fruits. Water is absorbed by the plant roots and lost through transpiration. About 95 % of water taken in by plants is transpired with 5 % being used in metabolism or growth (Jackson, 1989).

Agriculture depends as much on water as on land, and the problems of land degradation and the measures to prevent it, can not be discussed without also taking into account the peculiarities of the natural resource 'water'. As shown in paragraph 2.3, soil erosion by water is the most serious form of land degradation, and harnessing the water resources is a major objective of erosion control. In humid mountainous zones emphasis is on safely evacuating the surplus water and storing it for irrigated agriculture in drier periods of the year, or for other purposes. The same is undertaken in hilly semi-arid zones. But in these areas and in arid zones emphasis is also on measures to retain the water and to increase infiltration, in order to increase vegetation which in turn may help to reduce degradation.

Attention has to be paid to the meaning of *water 'use'*. One distinguishes offstream-, instream- and consumptive uses (Solley et al., 1983). Offstream uses are those requiring withdrawal or diversion from a groundwater or surface water source. Examples include crop irrigation, industrial water use for cooling or cleaning and municipal water supply for consumption, cleaning or waste removal. Non-withdrawal (instream) uses do not require diversions from ground water or surface water: examples include hydroelectric power, maintenance of streamflow or water supplies to support fish and wildlife habitats or aesthetic values, dilution of waste waters, freshwater dilution of saline water bodies and right-of-way provision for inland waterways navigation.

In the case of use for consumption, the water is no longer available, due to evaporation, transpiration, incorporation in products or another form of removal from the environment.

In principle the same water can be used more than once in different ways: first instream for transport and fisheries, then offstream after withdrawal from the surface water, for irrigation water. Part of the latter will be consumed by the plants, while some will be released and form a return flow to ground or surface water, to be 'used' again. When one refers to water use, one should specify whether it concerns withdrawal and/or consumption.

Resource allocation in an economically efficient way presupposes certain conditions for a smoothly functioning *market system*. In the case of water these conditions seldom prevail. Markets in water are rudimentary and unorganized. This relates to the problem of properly defining water use (Young and Haveman, 1985), and to various attributes of water, such as its mobility, its variability in supply, its potential for sequential and multipurpose use, the economics of scale in its storage and distribution and its bulkiness (low value per unit weight). Because of the absence of clear markets, and since water has public goods characteristics, public intervention may allocate resources more efficiently. This may either be achieved through regulations, through public investment in structures (e.g. dams and reservoirs for water supply and/or flood control) or even by public ownership and operation (e.g. in the case of hydroelectric power and municipal water supply). In practice governments often make water available (e.g. for irrigation) at rates that are far below cost price, contributing to excessive use while sometimes further disturbing income distribution.

According to WRI (1990) the total amount of available renewable fresh water resources is about 7,690 m3 per capita per year, while the actual average consumption amounts to about 660 m3 per capita per year (of which 69 % is used for agriculture). Since precipitation and water storage are unevenly distributed, water availability varies widely by country, and in many parts of the world over-use of water resources has lowered ground water tables, reduced surface water reservoirs and caused salinization problems.

2.3 Land and soil degradation

Although the degradation of land resources is a complex process, in which natural, geological and climatic factors play a certain role, human interference has become of overriding importance. Soil erosion is firstly a natural, geological process with a speed of about 0.1 - 1.0 mm/year. The influence of man, mainly by removing the protective vegetation cover, leads to an acceleration of the soil erosion process with intensities of up to 40 mm/year or more (Stroosnijder and Eppink, 1992). Through this process of accelerated or man-made erosion, the land gradually loses its production, regulation and information functions. At the same time it may also lead to a decrease in some functions of the water resources concerned.

Apart from detrimental effects, land degradation may occasionally also have beneficial effects. Mixtec cultivators in Mexico promoted gully erosion on the side slopes to double the width of the main valley floor (Spooner and Mann, 1982). Soil erosion in the uplands may also create additional land in river deltas. Napoleon seems to have supported his claim to the Netherlands in 1806 with the argument that it was originally created by sediment derived from France and elsewhere. In defining the issue and in measuring its extent one therefore has to focus on the net detrimental effects of land degradation. The loss of functions of land and water in one place at one moment may be compensated by the gain of functions in another place and/or at another moment.

Of the total land area of the earth (approx. 13,000 million ha), 12 % is used as arable land, against 24 % as pasture land, 31 % as forest and wood land and 33 % as other, waste and desert land (WRI, 1990). The overall loss of arable land due to land degradation is currently about 0.5 % per year, which is more or less equal to the amount of land that is annually added to the stock of arable land. However, the latter process takes place mostly at the expense of forest and pasture land, and concerns land that is relatively less suitable or more marginal for arable purposes. The world average deforestation rate is about 0.3 % per year. But deforestation is largely confined to developing countries and there the deforestation rate amounts to at least 0.6 % per year (Repetto and Gillis, 1988). Deforestation in these countries is mostly followed by inappropriate land use and leads in many cases to severe erosion and irreversible damage to soils.

Deforestation and land degradation are particularly severe on so-called common property, open access or non-exclusive resources, or on land for which property rights are not well defined or ignored by all or major categories of actors. Since Hardin (1968) used the term 'Tragedy of the Commons', this issue has been much debated.

The GLASOD-Project has made an assessment of the extent of various forms of soil degradation in the world (Oldeman et al., 1991). It distinguishes first seven categories of land that either by natural or historic man-made processes have no agricultural productivity whatsoever: wastelands, rock outcrops, salt flats, active dunes, deserts, arid mountain regions and ice caps. Together this non-used waste land amounts to 11 % of the land area of the earth (Table 2.2). A relatively large amount of non-used waste land is found in Africa (e.g.

desert land).

On the other hand they consider three forms of stable terrain: Stable terrain under natural conditions (rainforests, tundra, etc.); stable terrain with permanent agriculture (well managed with no degradation); and terrain stabilized by human interventions (e.g. reforestation, terracing, gully control, water management). These forms of stable land constitute 28 % of the total land area.

Table 2.2 *The extent of human-induced soil degradation by continent*

Continents	Total land surface (million ha)	Stable land	High degrad. hazard	Human-induced degraded	Non-used waste land
Africa	2,966	15 %	43 %	17 %	25 %
Asia	4,256	33 %	38 %	18 %	11 %
S.& C. America	2,074	19 %	62 %	15 %	4 %
N. America, Europe & Australia	3,717	38 %	46 %	11 %	5 %
Total world	13,013	28 %	46 %	15 % (1,964 mill. ha)	11 %

Source: Oldeman et al., 1991.

According to this study about 15 % of the total land surface, or 1,964 million ha, is clearly subject to human-induced land degradation. The problem is slightly more serious in Africa and in Asia, although the amount of stable land is also relatively high in Asia. There remains a fourth category of land that can neither be considered as stable land nor as waste land and that is not yet degraded (i.e. not yet losing its functions). However, it may already be affected by degradation and has a high degradation hazard.

The GLASOD project distinguished the following major forms of human-induced soil degradation, leading to a loss of soil productivity (Oldeman et al., 1991):

- *Water erosion*
  - Loss of topsoil and subsoil
  - Terrain deformation or mass movement
- *Wind erosion*
  - Loss of topsoil
  - Terrain deformation (hollows and dunes)
- *Chemical deterioration*
  - Loss of nutrients and/or organic matter
  - Salinization
  - Acidification
  - Pollution (urban and agricultural)
- *Physical deterioration*
  - Compaction, surface sealing and crusting
  - Waterlogging (excluding paddy fields)
  - Subsidence of organic soils

They admit that *biological deterioration* could be added as a category of its own. Since they focus on soil resources and generally refer to soil degradation, the deterioration of vegetation (e.g. deforestation, weed infestation) is not seen as a form of degradation in itself.

Table 2.3 *Extent of land degradation types by continent*

Form of degradation	Africa	Asia	S. & C. America	N.America, Europe/Austr.	World
	(extent		in	percentages	)
Water erosion	46	59	55	62	56
Wind erosion	38	29	15	22	28
Chemical degr.	12	10	26	7	12
Physical degr.	4	2	4	9	4
Total	100	100	100	100	100
Area (million ha)	494	747	306	417	1,964

Source: Oldeman et al., 1991.

Table 2.3 shows that soil erosion by water is clearly the most important form of land degradation. It is followed by wind erosion, which is of significant importance in Africa. According to Oldeman et al. (1991) soil nutrient losses are particularly important in South and Central America. In practice it is not easy to indicate the major form of degradation. Water erosion always causes nutrient losses, and often contributes to physical degradation.

This research is particularly concerned with soil erosion by water. Water erosion is most commonly divided into three (instead of the above two) categories: surface (sheet and rill) erosion, gully erosion and mass movements (landslides). Surface erosion is caused by the impact of raindrops on the soil and the subsequent transport of soil particles down the slope. Surface erosion can still be amended by the farmer, through land use changes and land management. If surface erosion is ignored, larger water masses may concentrate and result in the formation of gullies that cannot be easily amended. Mass movements are geological processes that are indirectly accelerated by human actions, and cannot easily be prevented.

2.4 Soil and water conservation

Soil and water conservation is aimed at eliminating or at least reducing the effects of land degradation. Through measures one tries to conserve or restore the multiple functions of the land and water resources concerned. The relative importance of these functions and the danger of losing these functions through land degradation, vary by region.

Soil erosion by water is in the first place caused by rainfall, and is much influenced by the topography of the terrain. For soil conservation purposes the agricultural areas in the tropics and sub-tropics could therefore first be divided into relatively dry or (semi-)arid and relatively wet or (sub-)humid zones. These zones could then be further divided into relatively flat areas and hilly or mountainous areas.

Semi-arid (sub-)tropical zones

Although there are mountainous semi-arid zones (e.g. in the Middle-East, parts of the Andes) these zones play only a minor role in agriculture, and most of the semi-arid zones in the world have gentle slopes. An important distinction in semi-arid zones is that between zones with winter rainfall (e.g. Mediterranean areas) and that with summer rainfall (e.g. African Sahel, India, Northeast Brazil). Summer rainfall is much affected by high levels of evapotranspiration or high crop water requirements, reducing water use efficiency.

While erosion features and conservation measures in semi-arid zones show similarities with those in (sub-)humid zones, there are also large differences and there are some important additional constraints to consider in semi-arid zones.

- Production systems
In semi-arid zones there are not many production systems that are both quite productive and sustainable (form of stable land, according to GLASOD), such as multi-storey tree crop systems in the (sub-) humid zones. Because of the long dry seasons, annual cropping systems with fallow periods dominate. Production levels are limited by a lack of water and/or nutrients. While long rotation shifting cultivation methods in the past left enough time for a regrowth of natural vegetation and for the soil to replenish its nutrient and humus content, the shorter rotations, resulting from population growth, have gradually lead to exhaustion, declining productivity and less resistance to both water and/or wind erosion.

The role of livestock in dry zones is generally of more importance than in humid zones. Much of the land less suitable for arable cropping, either because of shallow soils (after erosion), stoniness, low inherent fertility, distance from village or other reasons, is used for grazing purposes. Livestock generally thrives better in dry than in humid tropical conditions. Just as the shorter rotations on arable land, the increasing number of livestock units per area of land used for grazing and fodder production has contributed to a gradual deterioration of grazing land.

Another very urgent problem in dry land farming systems is the gradually diminishing number of trees used for firewood, shade, micro-climate creation and many other purposes. More land is brought under annual foodcrop and cash crop cultivation. Trees and shrubs are usually not spared, and certainly not on common property land. In some countries farmers now use dried cattle dung instead of firewood for cooking and heating purposes, indirectly contributing to higher nutrient losses on the land and hence further degradation.

On land used for annual crops a high percentage of biomass (with its nutrients) is extracted, through harvesting of produce and grazing of the stubble. This so-called 'soil mining' also occurs in sub-humid zones, but is generally much more serious in semi-arid zones. In the latter areas the emphasis in soil and water conservation should therefore be laid on the *on-site effects* of soil erosion and soil and water conservation.

- Erosion factors
The low total annual precipitation in semi-arid zones is subject to large fluctuations, and can be largely concentrated in a few heavy showers. Much of this rain falls at the beginning of the cropping season, when the land is still fairly bare. Due to the scanty vegetation the soils have a relatively low organic matter content and thus a rather high erodibility.

Although semi-arid zones normally have gently sloping terrain, the slopes are long and often uninterrupted, allowing the overland flow to reach quite high velocities.

This combination of high rainfall intensity, vulnerable soils, long slopes and scarce vegetative cover ensures that the few showers contribute considerably to run-off, erosion and to physical degradation (compaction) of the soil, which further reduces vegetation.

In the analysis of these processes and of the effects of proposed measures emphasis should be laid on both the soil-water balance and the soil-nutrient balances (Chapter 6).

- SWC measures
Implementation programmes should be aimed at reducing the impact of rainfall by covering the soil, at slowing down the overland flow to increase infiltration and at various ways and

means of restoring soil fertility.

Since production levels are rather low in semi-arid zones, and hence the production value also, measures should be kept simple. A distinction is made between 'line interventions' such as earth bunds and stone bunds to check run-off and 'area interventions' to cover the soil and improve soil fertility (Stroosnijder and Hien, 1992). Simple area interventions such as appropriate crop rotations, supplemented with fertilizers, manuring and/or mulching can contribute to both maintaining soil fertility and controlling erosion. In situations where much land can still be left fallow, proper rotation schedules could also be considered with or without exceptional use of fertilizers in order to restore each time the natural soil fertility and to control erosion. The production level might be rather low in the latter case, but returns to labour might be attractive enough to induce farmers to follow such a system (Low external input agricultural or LEIA systems). However, because of the relatively high rural population density in semi-arid zones, not much room is available for this latter option.

Many efforts are being made to integrate crop and livestock farming systems, focusing both on fodder supply and on soil fertility maintenance. Many different actions are also being undertaken to restore the firewood balance. On the supply side village nurseries, woodlots etc. are being established, and on the demand side efforts are being made to introduce firewood-saving stoves and bio-gas installations, and to increase the use of kerosene.

There are several specific soil and water conservation issues in semi-arid zones. For physical soil conservation works that involve earth movement, the timing is problematic: farmers have enough time available in the dry season, but it is then very difficult to dig the soil. If the soil is disturbed while it is still bare, it may easily be removed by the first rains. The alternative of vegetative measures such as grass strips leads to both competition for water and nutrients with the crop, and to competition for labour during planting.

In semi-arid and in particular in arid zones the emphasis is often on water conservation. Although most physical soil conservation measures (e.g. terracing, stone rows) and some soil tillage methods, contribute to water conservation, there are also specific water conservation measures including the construction of dams and the preparation of specific water catchment zones (water harvesting). Dams can also be established for refilling ground water reservoirs.

- *Case studies*

In the past ten years many efforts have been undertaken in the Sahel and in particular in Burkina Faso (Chapter 9) to construct stone rows, that require little maintenance and can be built in the dry season. Since these stone rows only reduce water and nutrient losses and do not restore water and nutrient balances to sustainable levels, emphasis is now also on area interventions in order to restore fertility. To attack this problem together with that of overgrazing, (small) ruminants are kept part of the year in enclosures, while their manure is added to compost piles for fertilizing nearby fields.

In the Central part of Tunisia, where crops grow with only 300 mm (winter) rainfall, various attempts at terracing have been undertaken in the past. Among others the trend towards more large-scale mechanized wheat growing has frustrated these activities. The planting of tree crops such as olives, almonds etc., combined with eye-brow terraces may have contributed somewhat to erosion control. The problem of overgrazing has been attacked by planting perennial feed reserves along the contour (Chapter 9).

(Sub-)humid tropical zones

Humid and sub-humid tropical zones can be clearly divided into relatively flat lowland zones, located along the coasts or in plains and valleys, and hilly and mountainous zones. At higher altitudes the latter may have a temperate climate. Since the relatively flat (sub-)humid areas are not much affected by soil erosion by water (subject to flooding instead), this study focuses on hilly and mountainous zones. Such zones are in particular found in the Andes mountains in Latin America, along the mountain range in Central America, on some Caribbean islands, in East Africa, parts of South Asia and in many countries of South East Asia.

- *Production systems*

In sub-humid and humid zones one finds several production systems, that certainly at the lower scale, can be considered as both quite productive, stable and sustainable, not being adversely affected by water or wind erosion and not subject to net losses of soil nutrients (stable land). One such system is wet rice cultivation, which is often combined with fish culture or pig husbandry and often practised on well-built terraces, even on steep slopes. Another clear example are multi-storey cropping systems of tree crops, such as oil palm, rubber and coconut, underplanted with coffee or cocoa shrubs and an undergrowth of annual crops or grasses for fodder. Conservation measures are not very important for such systems.

Although in many Asian countries a combination of factors (e.g. rainfall, topography allowing for reservoirs) has made it possible to supply irrigation water to large areas, including the hilly and mountainous zones, these latter zones are more often characterised by rainfed farming systems.

- *Erosion factors*

In most (sub-)humid zones both total rainfall and rainfall intensity are quite high. If annual crops such as maize and cassava are grown on steep slopes, soil erosion can be considerable (over 100 ton/ha/year, or more than 7 mm/year). To assess the effects of such erosion, a distinction has to be made between soils that are relatively fertile to great depth and can sustain such erosion for a long time (e.g. volcanic soils), and relatively poor and thin soils (e.g. on limestone). In the latter case the productivity may be affected immediately, while in the former situation no major on-site effect (on production) can be observed as yet and only downstream effects may be observed (sedimentation).

Much has been written about the role of forests in soil conservation and watershed protection (Hamilton and King, 1983). Although vegetation can reduce both the impact of rainfall and the speed of overland flow, this is not always the case for tall trees. Raindrops can accumulate on the tree leaves and when there is little undergrowth the impact can even become higher (Wiersum, 1984). That a forest cover does not guarantee a good protection against erosion is illustrated in Table 2.4. Teak forests without undergrowth can show much erosion.

Since trees use more water (evapo-transpiration) than most other vegetation and bare land, reforestation in general leads to a reduction of the annual stream flow. However, the forest system releases water more slowly and in this way contributes to a better distribution of the stream flow over the year. This feature of forests is of importance when rainfall is seasonal and reservoirs have been established downstream.

Table 2.4 *Soil erosion in two watersheds on Java, with different geological formation and forest cover*

Description	Unit	Geological formation Volcanic	Tertiary
Total watershed area	(km^2)	45	79
Main vegetation type		Rain forest	Teak forest
Annual precipitation	(mm)	3,621	2,419
Sedimentation	(tons/km^2)	532	6,605
Denudation	(mm/year)	0.36	4.40

Source: de Haan, 1964.

- *SWC measures*

In (sub-) humid mountainous zones the same principles hold for soil and water conservation as in semi-arid zones, but the emphasis is different. It is often also important to increase infiltration, but it may be more important to safely evacuate surplus water (through waterways). Farmers with only steep sloping land must take ingenious measures to make any type of agriculture possible (Kloosterboer and Eppink, 1989).

The relatively high production value in these areas could make expensive structures cost-effective. The physical measures can in some cases (not too steep land, labour shortage) be undertaken mechanically, using heavy equipment. But for both technical and employment reasons, use is often still made of manual labour. The most common type of physical soil conservation measures in humid climates are level or reverse sloped terraces, hillside ditches, individual basins for tree crops, level ridging and gully plugs. Waterways are generally an indispensable complement to physical barriers, certainly in areas with occasional high intensity rainfall.

The soil management practices consist in particular of contour ploughing and no-tillage, minimum tillage and 'residue tillage' practices. Vegetative or biological conservation methods consist of contour planting, strip cropping, tree planting, grass-, trash- or fallow strips, mulching, etc.. Vegetative measures have the advantage of also contributing to other objectives (e.g. fodder and firewood supply, and marking boundaries). Certain agro-forestry systems (e.g. alley-cropping) contribute both to a reduction in erosion and to an increase in soil fertility (leguminous species). Vegetative measures can also be combined with physical measures (e.g. hillside ditches and grass barriers).

While the abundant rainfall and the topography in mountainous zones belong to the major factors causing massive erosion, these same factors favour the establishment of dams and water reservoirs for multiple purposes. Suitable sites are (were) often available for establishing such dams and because of the relatively high storage capacities behind such dams, the relationship between catchment area and benefit area is usually quite favourable.

These dams and reservoirs can be of major importance for irrigation in the lowlands, hydroelectricity for both rural and urban areas and for flood control. However, these dams and reservoirs are usually very costly, and in order to retain their important functions, the government and the public and private organisations involved in the management of them, will have a keen interest in upstream measures to reduce sedimentation.

It is in fact often these *off-site or downstream effects* of soil erosion in upper watersheds, that trigger off investment proposals for soil conservation and watershed management activities. Because of such downstream interest, emphasis is shifted from reducing erosion on agricultural fields to all different sources of erosion. Much attention will then be paid to checkdams, gullyplugs, structures and measures to control landslides or mass wasting and roadside and stream bank erosion. These types of erosion control measures are seldom undertaken by individuals, nor by local community groups and need to be financed and executed by public agencies.

However, efforts also need to be undertaken to reduce erosion on farmers' fields, even when they do not care about erosion. This requires (watershed) development strategies, involving actors at various levels, and demands much communication and coordination. It should eventually result in technical assistance to farmers in order to design and construct measures, and in financial assistance to them so that they can acquire the necessary inputs. Since part of the costs incurred by the upland farmers will benefit downstream land users and consumers, the use of generous incentives may well constitute an efficient use of resources from the national or regional (watershed) point of view. In particular, when soil conservation activities have important downstream effects, it is necessary to consider the whole watershed in the economic evaluation of these activities.

- *Case studies*

In the densely populated island of Java, Indonesia, the last natural protection forest zones are threatened and the increasing cultivation of rainfed mountainous and hilly land leads to soil erosion and sedimentation in reservoirs. Over the period 1979 - 1990 the Konto River Project in East Java, investigated these issues and several organisations have implemented reforestation, coffee rejuvenation, terracing and other programmes. In Chapter 10 emphasis is given to the analysis of the downstream effects of these activities. A similar situation exists in the Kingston watershed areas in Jamaica which supply most of the drinking water to the capital. Deforestation and inappropriate cultivation methods have led to downstream sedimentation and changes in the stream flow. In the period 1988 - 1993 a tree crop project and a small watershed management project were undertaken, but it remains unclear whether these activities have had much effect on land degradation (Chapter 10).

2.5 The land and water resources utilisation space

The economic cost-benefit analysis of project activities, aimed at the efficiency criterion, should theoretically be based on a macro-economic model, which would allow the correct estimation of shadow or accounting prices. In a similar manner a national land capability and land use model (possibly linked to a hydrological and water use model) could form the basis for estimating parameters to be used in decision-making with regard to soil and water conservation activities. The FAO and UNEP assist Indonesia and Jamaica in establishing 'National soils policies'. These could possibly form the basis for such models.

In the western world diminishing returns, over-capitalization and over-exploitation (at and above sustainable rates) of resources and excessive imports of raw materials have led to environmental degradation (i.e. pollution). In developing countries the population pressure and declining 'carrying capacity' (at low, maximum affordable levels of technology), poverty, inequality and export of raw materials have brought about the degradation of their natural resources.

In developing countries there is a closer relation between ecology and economy. There is a direct link between natural and environmental resources and people's consumption patterns, while their waste is mostly of a biological nature (Kadekodi, 1992). However, many developing countries now find themselves in a vicious circle: population pressure and low income contribute to natural resource degradation, and the declining productivity of these resources further reduces income.

Within a watershed area a differentiation can be made with regard to various potential uses, defined here as the most intensive, whilst still sustainable use. The concepts that have traditionally been used to define potential or most desirable use, are land capability and land suitability. Land capability is in the first place based on topographical criteria and land suitability on soil characteristics. In both classifications a hierarchy of maximum 'permissible' use is applied. In land capability studies one refers to overuse, when a piece of land is used in a more 'intensive' way than is permissible according to the classification. Since the slope and the soil depth criteria used in the land capability classification are not the only factors determining sustainability (i.e. erosion), one should expand this hierarchical classification to including water and nutrient balance criteria.

Environmental Utilisation Space

Following Siebert (1982), Opschoor (1992) has elaborated the concept of environmental utilisation space (EUS). The EUS shows to what extent new activities can still make use of some resource, taking into account a certain level of sustainable resource use. In other words EUS is defined as the distance between actual and normative resource use (Kruseman et al., 1993). The concept is less relevant in the case of a weak sustainability policy, since environmental losses can then be compensated for by an increase in the man-made capital stock. The EUS for renewable resources can be presented by a logistic growth function for environmentally constrained regeneration.

In formula: $dN/dt = r(0) * (K-N)/K * N - U$

where:

N = actual stock level of renewable resource; dN/dt = net periodic addition to N;
R = periodical addition on basis natural regeneration; r(0) = natural rate of regeneration; K = maximum allowable (sustainable) stock of renewable resource;
U = societal extraction.

On intergenerational equity grounds: society wishes to maintain a steady state as:

$dN/dt = 0$, or $dR/dt = U$

The EUS concept is scale-independent, and can be defined in terms of a plot, a farm, a region, a nation or the world. Table 2.5 shows an example with regard to soil conservation.

The availability of soil nutrients, water and oxygen to the plants is greatly diminished through soil erosion by water. In the economic evaluation of soil and water conservation measures on a particular field of a certain farm(type), the situation without measures should be defined as one with continuing on-site losses of soil and nutrients and a sub-optimal use of water, which could also have further effects downstream. To what extent a measure is effective depends on the degree to which it contributes to its objective of reducing soil, nutrient and water losses. To what extent a measure is efficient depends on the response to (crop)yields or to the increased utility that is brought about by the amount of soil, water and nutrients retained by the measure. This must be seen in relation to the costs of the measure.

Table 2.5 *The concept of environmental utilisation space applied for soil conservation*

		At field level	At regional level
dN/dt	= net periodic addition to N	soil gain/loss	land (amount and quality) gain/loss
r(0)	= natural rate of regeneration	soil formation	rate at which productivity is regained naturally
N	= actual stock of renewable resource	rooting depth for activity A	land of certain quality in use
K	= maximum sust. stock of renewable resource	total soil depth	total land of this quality available
U	= extraction by society	soil loss due to activity	loss of land productivity due to activity

Land: Sustainability indicators and threshold values

Important attributes of land that determine its vulnerability to land degradation and in particular soil erosion by water are soil type (texture and structure), steepness and the length of its slope and the vegetation cover. These factors appear in the Universal Soil Loss Equation, which is used, among others, for predicting levels of soil erosion.

Important attributes that could be used to indicate whether and to what extent sustainable use could be made of the land for agricultural purposes, are:

- soil depth as an indicator of rooting space;
- organic matter content as a proxy for nutrient availability;
- soil structure (porosity) indicating the degree of infiltration of water and penetration of air, and
- water holding and water release capacity.

One way to take the increasing scarcity of certain categories of land into account in the economic evaluation of soil conservation activities in a certain watershed or nation, would be to consider that the price or value of good or prime agricultural land will increase in comparison with degraded or marginal categories of land. The price difference may constitute both a differential and a scarcity rent. In order to assess this land rent, due attention should be paid to costs of soil depletion (van Kooten, 1993).

Another way would be to focus on the 'carrying capacity' of the land. Assume, for example, that 0.2 ha of crop land is required per person for subsistence. Technology is such that the land should be fallow in two out of three years in order to maintain soil fertility. If the population increases, and the carrying capacity (0.6 ha per person) is exceeded, subsistence can only be maintained by improving technology (including fertilization and erosion control) to shorten rotations, or by increasing off-farm earnings. In the economic evaluation use can be made of the notion of 'Environmental Utilisation Space' (EUS), whereby the carrying capacities of the watersheds or areas concerned are indicated under various assumptions regarding technology, population increases, etc. In an area like the Sahel the 'carrying capacity' should cover the human and the livestock population and be based on the bio-mass or plant production required for this population. Much attention needs to be given to the crop-livestock interactions.

Water: Sustainability and threshold values

This study addresses remedies to land degradation and in particular to ways of reducing soil erosion by water. The water is both the agent responsible for the erosive forces, as well as a potentially important factor in plant production. The water supply is subject to unpredictable large fluctuations, in particular when it depends totally on precipitation. Surface water reservoirs and the pumping of groundwater can somehow assist in bringing water supply more in balance with the water consumption needs of plant, animal and human populations.

Important attributes for assessing the extent to which the population makes sustainable use of water resources are: 1: streamflow and its variability in rivers; 2: groundwater levels and its fluctuations; and 3: water quality from different sources.

In most countries in sub-humid zones only a small percentage of the renewable water resources (riverflow and groundwater) are drawn upon annually, but in countries with large semi-arid zones this is considerable (e.g. 53 % in Tunisia, 97 % in Egypt; World Bank, 1992). Since water demand sharply increases with development, water scarcity has become a major world problem.

In an economic evaluation one could deal with an increasing relative scarcity of water, by realizing that the marginal costs of providing water will increase, thus leading to a price rise. It is therefore necessary to make projections about the various sources of water supply and their actual and future procurement costs.

Crop water requirements vary throughout the cropping season. One possible way to assess the value of water under rainfed cropping conditions, is to draw up a crop-soil-water balance, and to determine what the effect would be of a little more or less water on production at certain periods during the year. Where the same crop is grown under both rainfed and irrigated conditions in one region, the production increase through irrigation may be a yardstick for the value of water, as long as all costs of the irrigation infrastructure and operations and the effects upon the surface or ground water are duly accounted for.

If through large scale reforestation or irrigation schemes the water balance in a whole watershed is changed, it will affect the often careful balance between the water supply and demand for domestic and agricultural purposes.

In Jamaica's Water Resources Development Masterplan water balances were drawn up for the whole island, subdivided into ten watershed areas (GOJ, 1989). Subsequently the national water supply and demand situation was analyzed up to the year 2015 (Appendix 10.2). It showed that the exploitable water resources from the areas surrounding the capital Kingston will not suffice for both domestic and agricultural water needs, and that further measures are required to increase water supply. Such regionalised water resources studies could, in combination with 'national soils policies', form the basis of an assessment for the need for soil conservation and watershed development activities.

Conclusion

In this chapter attention has been paid to the functions and use of the natural resources land and water, to land degradation and to ways and means of soil and water conservation in two major agro-ecological zones. In order not to exceed the land and water utilisation space, coordinated conservation efforts must now be made in many countries by the main actors involved. The decision-making process of these actors is the subject of the next chapter.

3 DECISION MAKING IN LAND AND WATER USE

My dear Sir, what you say sound good but me a woman and me can't worry to do more than what me doing now. Me just going to carry on as usual. Me can't manage to do more and me have no money to help me (Edwards, 1961; Jamaica).

3.1 Historical, spatial and institutional background

Many different actors are involved in soil conservation and watershed development projects and programmes. In developing countries, the main participants are usually those smallholders, peasants or farm households, that through their *land use* (or land use systems) and *land management* practices (or technology) contribute to land degradation.

These farm households form part of a *larger rural system* (e.g. village, region, watershed area) which has been shaped by past developments and the institutional setting. This rural system is nowadays almost everywhere linked up in various ways to the urban, national and international communities.

In many developing countries dryland and rainfed hillside agriculture consisted for a long time of shifting cultivation practices, whereby property rights were not well defined (Box 3.1). As long as the uplands (or valley-bottoms) near the villages were still under relatively undisturbed forest or woodland, shifting cultivation systems for the staple food crops thrived. Livestock rearing was partly undertaken separately by nomadic groups on more marginal lands, and was partly a complementary activity to cropping (draught animals, grazing on fallow land for manure, etc).

More intensive farming systems, with more clearly defined property or users' rights were mainly found on irrigated fields and on house plots (home-gardens). On these relatively small plots of land, farm households in many countries established a long time ago measures to conserve soil (e.g. terraces) and to maintain soil fertility (e.g. compost). But these measures were not primarily initiated out of a conviction to contribute to sustainability, but out of necessity and short term goals (e.g. wet rice on sloping land is impossible without terraces; home refuse can be easily disposed of in home gardens).

This does not imply that soil erosion was absent under these systems and only appeared after land use intensification in the last century. Human-induced soil erosion has been a problem since the domestication of animals and the invention of the plough. It has played a role in the disappearance of ancient cultures in among others Mesopotamia, the Middle East (Hillel, 1991), Mexico and India. These civilizations often expanded their territories to satisfy consumption needs and which sometimes resulted in highly degraded land (e.g. Roman Empire). Did the Western world's colonialism follow suit?

Colonial period

Colonial governments often had a high sense of responsibility for maintaining protection forest in upper watersheds, in particular for regulating the hydrological situation in the lowlands. In the then Dutch Indies a Forest Service Act was passed in 1865, which was followed in 1876 by an Act that dealt with protection forest. For similar purposes the Punjab Land Utilization Act was established in India in 1900 (de Haan, 1964). In the French colonies and protectorates, the Forest services were generally invested with considerable powers to protect forest reserves. After independence the forestry services continued to emphasize their protective tasks, but became gradually less effective in preventing deforestation.

On the other hand the colonial period had both directly and indirectly various negative repercussions for the local, indigenous farm households. Their access to land (for growing food crops, herding animals and cutting wood) decreased, because of the establishment of large private and government estates, and because of the obligations to grow export crops and to pay taxes. Families were sometimes forced to move, family members were 'recruited' for outside jobs, etc. The social and tribal systems came under stress, and little attention was paid to sustainable land use. Export crops, vigorously stimulated by colonial governments, were at times planted on land much more suitable for other uses. And where these plantations applied less appropriate management techniques (e.g. clean weeding on the hills) and forced the population to grow their food crops on the marginal or steep land, it caused both directly and indirectly much soil erosion.

Box 3.1 *Past and present farming systems in case study areas*

The semi-arid Central Plateau in **Burkina Faso** has been densely populated since the 15th century, when it was a prosperous centre on the trans-Saharan caravan routes. However, for some decades already the extended Mossi families have been unable to retain their self-sufficiency, and are dependent on remittances from family members, who have migrated to the South. Meanwhile they have tried to maintain soil fertility through shifting cultivation systems and by exchanging grazing rights, manure and milk with the cattle keeping (semi-) nomadic Fulani. However, with an increasing population, faster crop rotations, declining soil fertility and reduced marketing opportunities for livestock products, these arrangements led to conflicts and the land is further losing its regulatory and productive functions.

In the semi-arid central and southern parts of **Tunisia** semi-nomads with certain rights to the clan territory (*henchirs*), have gradually settled themselves in villages, and were further encouraged to do so through tree and fodder crop planting campaigns. The *transhumance* with herds of sheep diminished, while mechanization led to an increase in wheat and barley cultivation on the hill-slopes, which were previously used for grazing. The soils have become exhausted, and the few, but heavy, showers cause considerable rill and gully erosion. Attention is now paid to water harvesting and safeguarding groundwater supplies for downstream water uses.

In the sub-humid upland areas of **Indonesia** farm households had small irrigated rice fields in the valleys, while applying shifting cultivation of secondary food crops (*ladang*) on the slopes. Tree crops were grown along the forest boundary. The population increase and the further commercialisation of agriculture (vegetables, dairying, coffee, etc) increased the pressure on the land. The gradual intrusion into the forest land in search of firewood, fodder and cropland, has contributed to the degradation of this forest with its multiple functions.

In sub-humid **Jamaica**, ex-slaves fled into the hilly and mountainous zones, where they applied shifting cultivation on the steep slopes, growing yams and other crops with only hoes and machetes (*scratching the hillsides*). Various tree crops were grown as well and in some areas so-called *foodforest*, a multi-storey cropping system, was established. Since the steep terrain does not generally allow for any intensification, farm households have become heavily dependent on off-farm earnings.

Influence of soil conservation movement in the USA
In the period 1870-1937 increases in the USA corn production were to a large extent brought about by fertility-depleting operations (Hayami and Ruttan, 1985). Soil erosion was rampant. Several federal initiatives were taken after the large floods of the Mississippi river in 1926 and following the publicity surrounding the devastation of the 'Dust Bowl' and the cotton lands of the 'Old South'. In 1933 the Tennessee Valley Authority was created, which would construct over a period of twenty years about 30 large multipurpose dams. In 1935 the US Soil Conservation Service was established. This was organised by district and was engaged in farm planning, legal matters and providing credit and subsidies (Bennett, 1939).

Following these developments in the US, large-scale soil conservation measures (e.g. terracing) became a common feature throughout Britain's colonies in Africa in the 1930's. The French undertook similar large scale conservation works in their former territories and protectorates of North Africa. In most cases the forestry or agricultural engineering departments were responsible for these programmes. These measures were often forced upon the farmers, who were not involved in any decision-making, neither were the agricultural extension services. The measures were not in farmers' interests, and therefore were hardly maintained. Since many farmers associated these activities with colonialism, they were also not very keen to cooperate after independence. As a result, governments of the new nations gradually lost interest in pursuing soil conservation measures. In project preparation insufficient attention is often paid to the analysis of such historical factors or legacies.

Population increase
As a result of the fast population increase at the end of the colonial period and after independence, pressure on land increased further. In most developing countries this led to shorter rotations, use of increasingly marginal land, and to various forms of 'soil mining'. While it has been generally claimed that an increasing population would accelerate land degradation, some cases have been reported where a reverse development took place: more people, less erosion (Tiffen et al., 1993). As Mosher (1969) has shown, farming communities need a certain number of facilities (e.g. input supply, credit) and a basic infrastructure (e.g. roads, schools) to thrive and therefore a minimum number of clients or minimum population density is needed. Such a concentration can improve the exchange of ideas and information, lower transaction costs and allow farmers to produce more with less land, in a sustainable way (in accordance with Boserup, 1981). Such a minimum population density can be achieved and is often achieved in higher potential agro-ecological zones. In zones that are less suitable for agriculture the conditions for concentration-cum-intensification are often not met, despite capital accumulation from sources outside agriculture or outside the region.

Roose (1994) argues that there is no linear relationship between population density and land degradation, but that the relationship shows peaks (of high degradation) at regular intervals, after which new solutions are found which temporarily reduce degradation hazards.

Legal rights over natural resources
In many developing countries the rising population density has increased the pressure to replace traditional tribal forms of land distribution with private ownership of land. In other countries experiments were undertaken with collective organisations, whereby farmer groups were involved in both production and soil conservation activities on land allotted to these groups. In other countries, like in Burkina Faso, land has now officially been nationalized, while emphasis is laid on policies that can improve land management at the village level. In

addition, development projects have often generated new normative regulations for target groups. Despite these efforts to redefine land ownership, the rural population in many developing countries still holds on to property and usufruct rights of the past. As a result one often finds complex and overlapping legal contexts, that constitute potential constraints on the activities of the various actors (von Benda-Beckmann, 1991). The same holds for the use of water resources.

Market integration

Pure subsistence farming has gradually diminished. In order to acquire cash for their non-agricultural consumptive needs, farmers grow cash crops, work as labourers on other farms or engage in non-agricultural activities (Table 3.1). While farm size is therefore no longer the main factor determining rural family earnings, it remains important for food security, for social differentiation and also for soil conservation.

However, in many developing countries there is insufficient off-farm employment in the rural areas, and seasonal and long term migration (with remittances to the remaining family) form an important feature in most areas. In all four case study areas earnings from migration play an important role in the livelihood strategies of the rural population. In Burkina Faso and Tunisia these earnings are often crucial for survival.

While there is generally competition in the markets for both products and production factors, an oligopoly may dominate and the problem of imperfect information still persists. The agricultural trade liberalisation in industrialized countries (through the GATT or WTO) is likely to lead to world market price increases (reduced dumping). This will hopefully have positive effects on local production and leave room for investment in soil and water conservation in developing countries.

3.2 Farm level decision making in relation to soil and water conservation

The farm household

The decision-making unit in agriculture, or the locus of farm decision-making in developing countries is usually the rural or farm household. This makes sense when the major decisions about land use and land management are taken either by one person (the head of the household) or through a consensus among household members, as in the case of nuclear households. In extended families, however, where many relatives live together and share living expenses, decisions about land use are taken by several family members.

In many West African countries the nuclear families are embedded in and conditioned by the extended family. The wealth or poverty of individual men, women and youths depend on their position within the larger household and village system (FAO, 1992). In this case the household may at best be divided in two or more sub-units, that control one or more plots and/or have certain own-account activities. Unless otherwise stated, farm households are here considered to be nuclear families or well-defined sub-units, involved in agricultural enterprises, including pastoralism, forestry, etc. Since long-term soil conservation measures normally presuppose certain long-term property rights, a relatively large amount of attention is paid to households that enjoy such rights on at least part of their land.

Table 3.1 shows that the majority of rural or farm households in such different countries as Indonesia and Peru derive their income from different sources, and that farm size is not necessarily the main factor determining farm household earnings.

Table 3.1 *Sources of rural household income by farm size class in two areas in Indonesia (1988) and Peru (1973).*

Farm size class	Land operated (ha)	Distri- bution (	Own farm activities p e r c e n	Agric. labour[1] t a g e s	Non-agri. income)	Av. annual income/head (US$)[2]
Brantas watershed area, Indonesia, (n = 540).						
Landless	< 0.06	25	2	43	55	104
Very small	< 0.25	21	18	36	46	113
Small	< 0.50	23	35	26	39	107
Medium	< 1.00	19	52	18	30	125
Large	> 1.00	12	48	5	47	294
Average		100	28	28	44	134
Cajamarca Province, Peru, (n = 1,050).						
Landless	< 0.26	13	20	56	24	165
Very small	< 3.5	59	24	49	27	138
Small	< 11.0	17	55	24	21	179
Medium	< 30.0	8	82	11	7	292
Large	> 30.0	3	90	6	4	356
Average		100	47	34	19	156

1. In Peru 'wage labour'. 2. 1988 and 1973 prices respectively.
Sources: Konto River Project; KRP, 1988. Deere and de Janvry, 1979.

The decision-making process regarding soil and water conservation

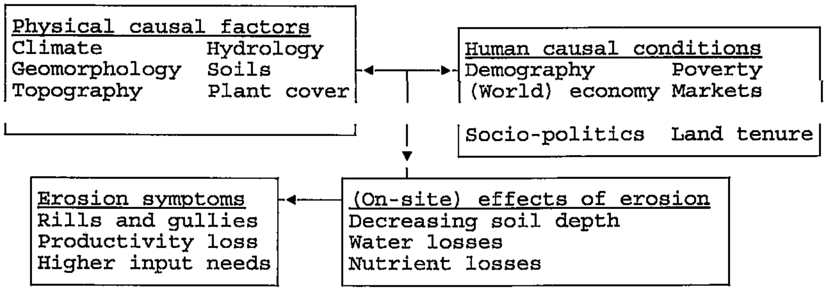
The farm household's decision-making is primarily directed towards crop and livestock production with the purpose of satisfying its different goals. By letting farm households pursue their own objectives, society expects that the common interest is promoted as well (after Ruthenberg, 1980). However, in soil and water conservation private and public interests may differ considerably (Section 3.6).

Classic theories state that farm households first of all consider 'what' to produce or to undertake (choice of output), 'how' to produce (choice between inputs) and 'how much' to produce (inputs needed to reach certain output) (Bishop and Toussaint, 1958). In this decision-making process, a rational farm household takes into account objectives, activity options, resources (endogenous factors) and various biophysical, institutional or socio-economic constraints (exogenous factors). In the past ten years renewed attention has been paid to farm household economics. The focus here was particularly on economic behaviour (e.g. Ellis, 1988), modelling (e.g. Singh et al., 1986), intra-household organisation (e.g. Doss and Senauer, 1994), household interactions (e.g. Hayami and Otsuka, 1993) and on the way households cope with risk and uncertainty (e.g. Huijsman, 1986).

Decisions with regard to long-term conservation measures concern investments and usually require a whole farm analysis and thus a similar decision-making process as the above: the measures may influence the farmer's choice of output (land use) and his choice of inputs (land management). However, there are various additional aspects. It should first be clear whether farmers see erosion as a serious problem and know what they could do about it, before they can decide whether or not to engage in conservation measures. Figure 3.1 shows the steps that could be distinguished in the decision-making process for implementing SCWD-activities. It also states major reasons why farmers will not undertake erosion control measures. Such activities are normally only initiated when all answers are affirmative, but occasionally farmers may undertake them even when not all conditions are fulfilled.

Problem recognition and farmer perception of erosion

The first three steps in Figure 3.1 relate to problem recognition and to farmers' perception of erosion. Farmers may not recognize the *symptoms (1)*, if they do not visit their land regularly or when symptoms appear very slowly and/or are masked by climatic fluctuations. If they have noticed it, they may not know the *effects (2)* of erosion that led to these symptoms. And when they know the effects they may not consider it *serious (3)* enough. In the past decade many studies have been devoted to farmer perception of and attitude towards soil erosion. Shaxson (1985) and Abdelkafi (1989) discuss the stages from perception of the erosion problem to adoption of measures. Jongmans (1981), Gay (1984), Jungerius (1986) and Östberg (1992) found in Tunisia, Lesotho, Morocco and Tanzania respectively that farmers' perception of erosion differs considerably from that of technicians (e.g. 'old, dying land has wrinkles') and that farmers often do not consider erosion as an urgent problem.



FARMER's REACTION:		POSSIBLE REASONS FOR REACTION:
-1- Erosion symptoms recognized?	→ NO	- Climatic fluctuations - Land tilled by labourers - Very slow process
▼ YES		
-2- Erosion effects recognized?	→ NO	- Lack of knowledge - Traditional beliefs - Lack of education
▼ YES		
-3- Erosion taken seriously?	→ NO	- Not their own land - Deep soils/high fertility - More a downstream problem
▼ YES		
-4- Aware of adequate measures?	→ NO	- Lack of local technology - Lack of extension - Neighbours not involved
▼ YES		
-5- Able to undertake measures?	→ NO	- Limited labour & capital - Insecure land tenure - Socio-cultural barriers
▼ YES		
-6- Willing to undertake meas.?	→ NO	- Other preferences/work - No successor - Too much risk
▼ YES		
-7- Ready to undertake measures?	→ NO	- No credit/subsidies - No extension/training - Insufficient fin. returns
-8- ▼ YES (→ **Adoption**)		

Figure 3.1 *Farm household-level decision-making with regard to the adoption of soil and water conservation measures*

De Graaff and Zaeni (1989) found that the majority of farmers in the Konto River watershed in Indonesia recognized erosion symptoms. They ascribed them mainly to such physical factors as intensive rainfall and steep slopes, and rarely to (their own) land use and land management. Similarly Lindskog and Tengberg (1994) found that Fulani in northern Burkina Faso had detailed knowledge of the symptoms of land degradation and of causal variables. These Fulani did not to see the link between variables and symptoms. The authors conclude that these people could not see themselves as influencing the process, in either a positive or negative sense, and just put up with land degradation, as an act of God (Allah).

The adoption process and rationality in farm household decision-making

The next steps (4 to 8) in decision-making concern the adoption process, which is defined by Rogers (1962) as 'the mental process an individual passes from *first hearing (4)* about an innovation to *final adoption (8)*'. The question could be raised whether farmers in traditional societies act 'rationally' in such adoption process. In the past the lack of progress in these societies was often ascribed to 'idleness' and 'lack of thrift'. Boeke (1940) gave examples of farmers in the former Dutch Indies, who spent hours of hard work to obtain something insignificant to the outsider, while they were at other moments reluctant to engage in hard work to seize an opportunity with much higher rewards. The former situation seems to show irrational behaviour, but had to be judged within its own cultural context. The latter could be characterized as a rational drudgery averse behaviour, as described by Ellis (1988). Schultz (1964) put forward the hypothesis that such societies were 'efficient but poor'. They are confronted with a lack of resources, but they allocate these resources efficiently. In his reaction to Schultz' work, Lipton (1968) argued that these small farmers are not efficient in the profit maximizing sense and that Schultz had not accounted for the risky environment in which farmers have to take decisions. Following Anderson et al. (1977), Bakker (1992) therefore proposes to refer to rational behaviour, aimed at maximizing the 'expected' value of the decision maker's 'utility'. Kiome and Stocking (1994) conclude from their research in semi-arid Kenya that, also with regard to soil erosion and conservation measures, farmer perception is basically rational. Farmers' opinions and rate of adoption of several soil and water conservation measures matched closely the economic results from their experimental plots.

Objectives and economic behaviour

Farm households (and their members) have usually various objectives or preferences for certain utilities, that are seldom clearly defined, but that appear in their behaviour. This actual behaviour is also conditioned by external factors, customs, perception, beliefs and values. While values are a fairly permanent property of the individual, goals concern the things one wishes to accomplish, in the short or in the long run. In her article on goals and values of English farmers, Gasson (1973) classifies the latter under the four headings: instrumental (e.g. maximizing income, safeguarding income for future, expanding business), social (gaining recognition, continuing tradition, belonging to community), expressive (meeting a challenge, being creative, self-respect) and intrinsic (doing the work you like, independence, healthy). In her survey area small farmers attached much importance to independence, while large farmers were more concerned with instrumental values. For farm households in developing countries social values still play an important role in decision-making, among others in copying behaviour in the adoption of new technology.

These respective values could be structured according to a hierarchy of needs (Maslow, 1954), starting from basic physiological and safety needs ('food security') and rising through the need to belong to the group to the need for esteem, prestige, power and self-respect.

Considering such a hierarchial order, farm households in developing countries may pursue in their production such main goals or objectives as:

- to assure food-supplies and basic living requirements
- to achieve a living on par with the community
- to improve the physical appearance of farm and equipment (e.g. housing, ox cart)
- to obtain the greatest annual profit from the resources
- to increase the value of the farm household capital

The farm household's values and goals result in certain economic behaviour, that in turn leads to specific 'strategies'. Resource-poor farmers in semi-arid zones have often no other option than to concentrate on the first objective and in their risk-averse economic behaviour to follow a survival strategy. Such risk-averse households are hesitant to invest in soil conservation measures. In sub-humid mountainous zones farmers usually have more options and aim at least partly at profit maximisation goals. Because of market uncertainty they often follow a diversification strategy.

Predicting economic behaviour of farmers with regard to erosion control is cumbersome for various reasons. Past behaviour can be a reliable indicator of certain kinds of value preference, but soil and water conservation activities are often new activities to the farmer. The utility that farm households could derive from soil and water conservation activities is much more difficult to value than other farm activities. Farm households tend to adapt their farming to changing circumstances provided the change is 'satisfying' in terms of the additional benefits involved (Ruthenberg, 1980). Benefits should preferably be twice or three times as high as additional costs, over a short period of time. Although the SCWD measures may increase yields and reduce yield fluctuations (and hence risk), the initial costs are high and the benefits are only obtained gradually over the years. The question is how strongly farm households stick to long-term goals and what their individual time preference is. What do they expect from farming in the future, for themselves and for their children? Since conservation measures are long-term investments, requiring yearly maintenance, extension efforts and incentives should be more geared to changing farmers' value systems regarding conservation than to the short term goal of implementing measures. Goals and values are reflected in the 'style of farming', which constitutes one important criterion for classifying farm households (Chapter 5).

Farm resources and soil conservation measures

Another important criterion for classifying farm households (into farm patterns) concerns their resources and resource utilization (Chapter 5). In farming *land* is a crucial production factor, but in developing countries only 0.8 ha of land is currently available for each economically active person in agriculture (World Bank, 1992). Three features of farm land greatly influence the possibilities for soil conservation. The land tenure situation determines whether a farmer has a real interest in investing in conservation measures. The land capability and suitability determine what measures are technically and economically viable. Farm and plot size determine whether one can make use of economies of scale in long-term soil and water conservation measures (e.g. terracing with waterways). All three features are unfavourable to soil and water conservation in developing countries. Land tenure is often insecure, land is often dry or steep, and farm land is extensively subdivided and fragmented.

Despite the fact that land tenure may be ill-defined and rather diffuse in many developing countries, farm households in many of these countries feel closely attached to 'their land'. This is well illustrated in the study of Loedeman (1975), in which he cited a Tunisian farmer, who said that 'land had to be looked after as a wife by her husband'. An exception was reported by Löwenthal (1961), who found a general lack of attachment to land in the Caribbean, which was ascribed to the historical background of slavery. Attachment to the land does not necessarily imply sustainable use, however.

Where farm households do not have enough land (and financial resources) of their own (or hired in), they may derive part of their living from common property (e.g. grazing land), intrude upon state property (e.g. forests) or use open access resources.

While farm households in developing countries may be reluctant to develop their land, they often show a keen interest in exploiting *water resources* for irrigation or drinking water. Asked which of the 18 activities supported by the Konto River Project in Indonesia was 'most important for them', farmers most often mentioned the drinking water supply schemes (de Graaff and Zaeni,1989). Where groundwater is deep and surface water scarce, farm households spent much time fetching water. When groundwater is not deep, households are keen on digging wells. However, in many rural areas groundwater tables have been lowered considerably in past decades, making it expensive to haul water and worsening living conditions. Despite their interest in water resource development, few farmers take initiatives themselves to control and exploit the excessive surface run-off.

Farm households in developing countries often have little in the way of *capital* goods at their disposal or working capital to buy inputs. Apart from the farm house, grain stores, a small stable with a few cows, oxen or small livestock, and some small equipment, they have hardly any capital means. Because of this lack of assets, they can seldom provide the necessary collateral security for long term loans, which forms another impediment to establishing conservation measures. Seasonal or long term migration of family members may bring in some additional financial resources, but these are usually spent on housing and consumer goods (de Graaff, 1995). Because of this lack of capital resources and the field conditions many farm households do not even use draught animals, and undertake all farm operations by hand.

Because of their specific role in sustainable agricultural development, livestock and trees are sometimes also considered as separate production factors.

The household or family *labour* may seem amply available to smallholders in developing countries. Nuclear families consist on average of about six members, and in countries where extended families dominate, many households have 10 to 20 members. Such large families may form an advantage in the implementation of SCWD activities, but that is not always the case. Some family members, particularly young men, may be involved in seasonal or long term migration, and others may be too old or too young to participate in such hard work. In most societies a clear division of tasks exists between household members, with routine decisions often following this division. The various traditional forms of exchange labour are becoming gradually less important. The outcome of all these factors is that labour for specific production and conservation activities may be scarce in peak periods in the year.

Farm household activities can be divided into productive and general farm activities, off-farm activities, home and social activities, and leisure (Table 3.2). The home and social activities are often disregarded in economic studies and farm models (or grouped with Z-goods), assuming that they do not compete with the direct and indirect income earning activities. But among the rural poor this assumption does not hold. Labour for conservation activities will have be derived from either of the above four categories, and soil conservation will often be given a lower priority than for example firewood or water collection.

Table 3.2 *Percentage distribution of labour inputs for major farm household activities over a one year period*

Sample size of farm survey (no of households):	East Java Indonesia 773	Mossi Plateau Burkina Faso 160
Cropping	17.4	20.5
Livestock (& fodder collection)	7.5	16.9
Post-harvest/marketing	7.2	n.a.
General farm activities (incl. conservation)	n.a.	2.0
Off-farm agricultural labour	11.0	n.a.
Off-farm non-agricultural activities	15.5	10.4
Migration (seasonal)	n.a.	6.0
Firewood & water collection	7.7	16.1
Home activities	19.3	12.0
Social activities/schooling	14.4	16.1
Total household labour inputs	100.0	100.0

Source: KRP, 1990a; de Graaff, 1995.
n.a. = not applicable.

In Burkina Faso household members were involved in burial activities and other festivities during the period most suitable for soil conservation activities. All household activities should be incorporated in labour profiles, that need to be specified by sex, age group and season.

Farmers' *knowledge (education) and management capacity*, as a fourth production factor, is often limited in developing countries and also forms a major constraint for SCWD programmes. Therefore much attention needs to be paid to extension and training.

External constraints

Apart from their objectives and the resources available to them, farmers have to consider numerous outside or external constraints in their decision-making. These are partly discussed in Section 3.1. These constraints are grouped as follows (Smith and Thomson, 1991):

- the natural conditions (climate, soil, diseases, etc.) constraining the alternative feasible activities;
- the state of knowledge and information about agricultural techniques, determining the possible physical production functions of the various activities;
- the institutional environment (land tenure, farm size, taxes, labour laws, credit, extension services, markets, etc.) influencing the farmer's choice of the feasible activities and possible techniques;
- the economic environment influencing, by means of prices of inputs and outputs, the input combination, the output mix and the input intensity;
- the culture and the socio-political state of society, determining farm household demand for food, fibre, fuel, etc, and its behaviour, on the basis of which the household chooses the combination of activities.

Farm household decisions in soil and water conservation

Decision-making about investing in erosion control starts from the moment a farmer realises that he has an erosion problem and knows the reasons why. He has to reconsider what to produce, how to produce and how much to produce, realising that continuing erosion will affect his future production in three ways: by depleting soil depth, by reducing available soil moisture and by reducing nutrient supply (Chapter 6).

In sub-humid mountainous zones with deep fertile soils neither of these factors may limit the farmer's on-site production in the immediate future. Soil erosion may on the other hand cause problems downstream, but farmers may not be concerned about that.

Whereas both soil depth and soil fertility are more or less known variables, water availability is subject to the probability of rainfall. In semi-arid zones farmers' strategies are very much influenced by rainfall (e.g. area prepared, sowing and resowing).

The question of *what to produce* could be rephrased as which land use provides the maximum expected value of the decision maker's utility, including both production and conservation considerations. In semi-arid zones the land use options are often limited to one or two staple food crops (e.g. sorghum and millet) and at most a single cash crop (groundnut or cotton), but the problem of a limited choice among crops also occurs on steep land in sub-humid zones, where diversification options are limited (e.g. coffee areas in Colombia).

The question of *how to produce* concerns the choice of technology. Resource-poor farmers are generally not able to adopt modern technology. In densely populated areas labour saving technologies are not appropriate, and in areas where the markets of inputs and outputs and agricultural services do not function properly, higher levels of technology involve (too) much risk. The choice between alternative soil and water conservation measures (technology) often concerns a choice between physical measures (e.g. earth or stone rows) or vegetative measures (e.g. hedges or grass strips). They may be equally effective in erosion control, but the latter provide wood or fodder and may compete with crops for water and nutrients.

In sub-humid mountainous zones terracing can bring about considerable changes in farming systems, since it allows for new high-value crops (e.g. wet rice, vegetables), new sources of power (e.g. draught animals or two-wheel tractors) and for the use of irrigation water. However, the change from a traditional rainfed farming system to such land- and labour-intensive systems is enormous, and so are the costs. The maintenance of soil fertility constitutes a crucial indicator for sustainability in farming systems. Traditional ways of maintaining soil fertility have gradually disappeared, and have, in semi-arid zones, not yet been followed by new methods. For farmers in developing countries there is still a large difference between 'cash inputs', to be bought on the market, and 'non-economic inputs' or inputs in kind. From the point of view of the farmer not only solar energy and air, but also water, fodder, firewood and materials for mulching in their neighbourhood are free goods. An important efficiency criterion for him may be the 'proportion of system-produced inputs in relation to total inputs'.

Also with regard to the question of *how much* to grow or to undertake, farm households in developing countries usually have little choice. Farm households for whom the self-sufficiency in food and other basic requirements constitutes the primary objective, will grow as much food crops as they need, while adding a certain amount in case of partial crop failure. Whether they will grow more will on the one hand depend on their resources, and on the other hand on the prices and market opportunities. In many developing countries the major food crops (e.g. sorghum, millet, yams) are hardly tradable on the international markets, and in years with good harvests there is no market for surpluses.

Contrary to what is usually proposed in soil conservation and watershed development projects, farmers generally prefer to undertake measures gradually, over a few years time (Kerr and Sanghi, 1993). This is not only the case with physical measures, but also in the case of the planting of tree-crops, such as coffee (de Graaff, 1981).

Decision-making models

Several investment models have been developed to describe private decision making regarding soil conservation measures (Heerink et al., 1994). These are profit maximizing models, focusing on input use to compensate for soil loss. The first model was developed by McConnell (1983), and formed the basis for later models. In McConnell's model, the farmer cultivates his land with one crop and aims at maximizing the present value of profits stream (J) plus terminal value (R) of the farm at the end of the planning period (year T); in formula:

$$\text{Max } J + R\,[a(T)].e^{-rt} \quad \text{whereby: } J = \int_0^T e^{-rt}\,[pg(t).f(s,a,z) - c.z]dt$$

$$\text{and subject to: } \mathring{a} = h(z_1,z_2) \text{ and } \mathring{a}(t) = k - s(t)$$

where:

p = output price; $g(t)$ = neutral technical change; $s(t)$ = soil loss; $a(t)$ = soil depth and a_0 = initial soil depth; z = index of variable inputs: z_1 productive, increasing soil loss and z_2 ameliorative, reducing soil loss; c = cost of input; h = change in soil depth and k = exogenous addition to the soil; r = discount rate of farmer.

The model ignores soil quality aspects and the off-site effects of soil erosion and it assumes that farmers are well aware of the extent of soil loss and its effects. On the grounds that 'output expansion per farm in a given period requires more soil loss' (e.g. steeper slopes), McConnell makes a distinction between 'production inputs' that increase and 'soil conservation inputs' that reduce soil loss. Farmers' strategies (depletion or conservation) are translated into input use. Since such 'productive inputs' as fertilizers and pesticides increase both production and soil cover and therefore normally reduce soil erosion, he probably refers to land and certain labour and machine hours as production inputs.

One of McConnell's conclusions is that under certain conditions farmers may act rationally in leaving their land exposed to soil erosion. Farmers with deep fertile soils in sub-humid climates do indeed not mind that their soil depth decreases and that they lose water and nutrients. This situation is found in the volcanic uplands of Java. The model of Barbier (1990) was focused on this area and confirmed that at least initially (top) soil depletion may be the optimal strategy for farmers. De Graaff and Dwiwarsito (1987) therefore, in the cost-benefit analysis of soil conservation activities in the Konto River watershed, paid more attention to downstream effects.

Barrett (1991) assumes in his model that farmers may mitigate erosion-induced productivity losses by substituting non-soil inputs, such as fertilizers. Farmers may indeed for some time use more fertilizers (symptoms in Figure 3.1), but his assumption that shallow soils with sufficient non-soil input can substitute for deep soils, will often be too simplistic. Shallow soils may not only have insufficient rooting depth, but they may also hold insufficient soil moisture. Besides, fertilizers cannot completely substitute soil organic matter. Miranda (1992) refers in his model to soil quality, which includes soil depth, organic matter content, soil structure and water infiltration capacity, and he takes into account that soil quality is partly inherent and partly influenced by inputs and losses.

When farmers follow a profit maximizing strategy and are well aware of the erosion effects, they should try to maintain the respective functions of the soil to maximize crop production: a certain rooting depth (d), an adequate amount of water or moisture (m) and a sufficient stock of organic matter and nutrients (f). The problem of the optimal choice of labour and material inputs in a dynamic context can then be written as:

$$\text{Max } J; \quad J = \int_0^T e^{-rt} \{pQ.\ (L, Sd, Sm, Sf, T) - w.L - c.Z\}dt,$$

and: $Sd = f(D_0, A)$; $Sm = f(Pr, In)$; $Sf = f(N,P,K;\ OM)$, where:

p = output price; Q = crop (or biomass) production; Sd = soil rooting depth; Sm = soil moisture content; Sf = soil fertility (nutrient (N,P,K) and organic matter (OM) content); L = labour inputs; w = wage or opportunity cost; c_i *= cost of material input i;* Z_i *= amount of input i (including nutrients);* D_0 *= initial rooting depth; A = net soil loss; Pr = precipitation; and In = infiltration (capacity).*

The major drawback with these investment models is that they focus on the profit-maximizing objective, while it has been made clear in this chapter that small farmers have many other goals or utilities. In their household models, Kruseman et al. (1994), for example, make a distinction between utility maximization and risk aversion among peasant households and profit maximization and rent seeking by large farms.

Household decision making in soil and water conservation could be presented in general farm household models (Singh et al., 1986), adding soil conservation and social activities in the utility function and in the time constraint. In the production constraint one could specify the conservation inputs (capital (K) and labour (L)) and the features of land (soil depth (Sd), moisture content (Sm) and nutrient supply (Sf)) that regulate production.

The basic equations are then: $\text{Max } U = U(G_a, G_m, G_c, G_s)$;

cash income constraint	:	$p_m(G_m) = p_a(Q-G_a) - w(L-H)$
time constraint	:	$T = G_c + G_s + H$
production constraint	:	$Q = Q(Kp,Kc,Lp,Lc,Sd,Sm,Sf)$

The constraints can be combined in : $p_m(G_m) + p_a(G_a) + w(G_c) + w(G_s) = wT + \pi$

The measure of farm profits π is : $p_a\, Q(Kp,Kc,Lp,Lc,Sd,Sm,Sf) - wL$

G_a, G_m, G_c *and* G_s *stand for the goals with regard to food, market purchases, conservation and social activities (incl. leisure); p and w are prices and wages; Q is food production; T is total household labour supply; Lp, Lc and L are labour input for production, labour input for conservation and total labour input, and H is household labour input; Kp and Kc are capital inputs for production and conservation; and Sd, Sm and Sf are soil depth, soil moisture and soil fertility.*

In order to be able to run such a model, one should have a data set, that includes information about the goals of farm households, their resources, their resource utilization (land, labour and capital), their expenditures and prices.

These general household models are, however, not focused on investment decisions. Future costs and benefits can be presented as annuities, but this masks the particular problem of having to bridge periods before benefits occur, through financial or other incentives. In this research use is made of spreadsheet modules to calculate the effects of SCWD investment decisions, the results of which are incorporated in financial cost-benefit analysis for the farm types or farm patterns concerned (Chapters 5, 6, 7). Alternative options can then be presented in a farm pattern multiple spreadsheet model, as shown in Chapter 10.

3.3 Collective action

Need for collective action

In the previous paragraph reference was made to the principle that 'society may expect that the common interest is also promoted when farm households are allowed to pursue their own objectives'. Olson (in Sandler, 1992) refers to this as the first major 'law' in social sciences, and makes reference to the famous invisible hand of Adam Smith, ensuring an outcome that is socially efficient (in the Paretian sense). Among many others Hardin (1968) has shown that such an outcome is questionable, at least when dealing with ill-defined property rights or open access resources. Olson therefore adds a second 'law', stating 'that the first law does not always hold, and that no matter how intelligently each individual pursues his or her interest, no socially rational outcome can emerge spontaneously, and that only a guiding hand or appropriate institution can then bring about outcomes that are collectively efficient.'

An important problem in soil conservation is that most of the measures require much labour input and that the effort is much more worthwhile, when the (upstream) neighbours engage in similar measures at the same time. In other words there are external effects. A sub-watershed approach is therefore normally advocated, and that does require at least some form of collective action.

Collective action refers to activities that provide benefits and/or costs for more than one individual and therefore requires the coordination of efforts by two or more individuals (Olson, 1965). The action is normally intended to further the interests or well-being of the members. And as Sandler (1992) puts it: 'individual rationality is not sufficient for collective rationality', in such situations.

Forms of collective action

Groups may be formal (e.g. cooperatives, inhabitants of one village) or informal (e.g. residents of one neighbourhood). The most extreme form of collective action in agriculture is the collectivization of land resources. In China in 1958 village communities were made responsible for land use and conservation, but the central government maintained a very strong influence, and farmers had only 'the right to work'. Production declined and erosion increased. Since the land reforms of 1979 a land contract system is in operation, giving farmers some title to land. But since the land tenure situation is not yet clear and contracts are for short periods only, conservation works and other investment in agriculture declined again after 1984 (Qu Futian, pers. comm.). In the 1960's the rural population in Tunisia was organized in producer cooperatives by the central government, but they resented this policy and some collectively constructed infrastructural works were even destroyed, after which these producer cooperatives were abolished. Many other collectively-oriented land reforms have shifted towards individual holdings (Peru, Dominican Republic, Hungary, etc).

Usually less stringent forms of collective action are sought. The problem remains that one can not add up individual utilities to arrive at a group utility function. Only when there is a strong common interest, may group members be able to agree collectively on a set of preferences, that will imply a unique group utility function (Anderson et al., 1977). Kerr and Sanghi (1993) learned from field observations that farmers prefer to invest in soil conservation individually or in cooperation with an adjacent farmer rather than in large, cooperative groups. For on-farm private-oriented soil conservation measures such as terracing and tree planting, a form of mutual assistance may indeed suffice. However, for measures on common land or alongside private land to control gullies and to protect roads, houses, etc.

larger groups are needed. Such measures are like indivisible collective goods, with a mix of private and public joint benefits (Sandler, 1992). Farmers often consider these a government responsibility.

In many labour-intensive soil conservation and watershed development projects group action is advocated, and the issue is presented as a group responsibility, even though the formation of groups is often merely considered by projects as a practical approach to reach more farmers. The existence of such a group often constitutes a prerequisite to participation in such activities.

Government agencies, projects and NGO's often initiate activities at village level, and approach village elders as representatives for the village communities. It depends both on traditional customs and on the personality of village elders, how 'villages' will respond to such initiatives.

Collective responsibility

It is often assumed that traditional societies may have a common sense of responsibility for their land, and that communal action for soil conservation could be built on this. Land often belonged to the tribe or the extended families (e.g. tribal lands in East Africa, *henchirs* in Tunisia). In Burkina Faso and other Sahelian countries one still finds next to the heads of villages (originally representatives of the Kingdom) also persons that are responsible for the distribution of the land (*chefs de terre*). But these traditional societies were often strongly stratified according to class, ethnic group and tribe as a result of the power of local chiefs. The vertical linkages within villages and families were generally much stronger than the horizontal ones and formed in fact a constraint on forming groups or other horizontal ties between households on the same socio-economic level (FAO, 1992).

Since successive government administrations in many developing countries have brought in a wide range of projects, programmes and selected activities, and imposed these on the villages, expectations among village authorities and villagers that the government will continue such activities are high. This may restrict the number of local initiatives.

The problem with soil conservation activities is that the total gains are generally not confined to the group that would have to take action. This is certainly the case when there are important downstream effects. One should make an assessment of both the individual gains of all group members, and the total (public) gains, and the government should, on behalf of other beneficiaries, pay for the difference by means of incentives to the actual participants (Chapter 11). This makes soil conservation very much dependent on government action.

3.4 The interests and role of governments

It is difficult to assess to what extent mankind can be held responsible for the present desert lands, but it is significant that so many ancient cultures have disappeared or moved from their original habitats, leaving behind highly degraded lands. These ancient cultures were either not aware of the danger, careless, taken by surprise, or lacked the appropriate organisation to combat degradation. In recent times large areas in developing countries have become economically wrecked, at least partly because of severe land degradation. There seems to be a clear interest for governments in preventing such dramatic developments and to take a leading role in SCWD programmes.

Government objectives

When discussing the interests and role of 'the government' in soil conservation, one should keep in mind that it may not constitute one homogeneous body. At national level, government objectives may appear in long- and medium-term development plans, in policy papers, etc., but the various sectorally divided ministries and departments, and their decision-makers, may well have different interpretations of such objectives and policy statements. Although development plans may be based on a national-economic model and may include clear targets, most plans merely comprise a set of good intentions for the plan period, specified by sector. The plans usually lack clear indicators, by which progress towards the objectives could be monitored and evaluated. At regional level, national objectives may be translated into more specific regional target plans, and some conflicting interests and objectives may be reconciled at this level. At the local level the various government services are involved in the day-to-day administration and management of government directives, which may include drawing up plans, selecting firms to carry out certain works, providing training to employees and extension to farmers, and coordinating their actions with other governmental services.

While individual farm households may only care about one or a few functions of their own land and water resources, governments should look after the protection and development of the total mix of functions of land, forest and water resources in the whole country. Therefore they should act on behalf of those groups that can not exert an influence by themselves (e.g. downstream communities and future generations). Referring to the functions listed in Table 2.1, one could think among others of the following, often potentially conflicting, main government objectives with regard to the use of these resources, in relation to soil conservation and watershed development:

Land:

1. To strive towards an optimal allocation of land to its major production and carrier functions, now and in the future.
2. To promote the maintenance of soil fertility (among others by reducing erosion), in order to keep a sufficient stock of fertile land for future generations.

Forests:

3. To maintain forest resources in watershed areas for the consumptive use of wood and fodder, and for tourism.
4. To safeguard natural forests for the conservation of genetic resources.
5. To protect forests in upper watershed areas to perform the regulating function for water resources in the lowlands.

Water:

6. To control surface water in order to prevent erosion and flooding, and to guarantee a regular supply of irrigation and drinking water and hydro-electricity.
7. To prevent the sedimentation in canals, harbours and in the downstream reservoirs.
8. To regulate the use of groundwater resources.

Although governments in developing countries have tried to maintain nature reserves and public forest land, and have undertaken land evaluation studies and conservation projects to attain a more productive and more sustainable use of the national *land resources*, their influence has often been modest. The few instruments to influence private land use, such as legislation, taxation, pricing, extension and promotion, have often not been very effective.

More drastic solutions in the form of settlement schemes and transmigration projects in under-populated zones appear to be extremely costly.

Land hunger, as a result of the fast increasing population and the declining productivity of over-used land, has also greatly affected local *forest resources*, that are being rapidly depleted for rural and urban energy purposes. Large natural forest zones have been rapidly deforested because of low costs to companies and the fact that governments badly needed the forest exchange earnings.

From colonial times governments have seen it as their task to invest in *water resources* infrastructure and to control the hydrological situation. To make optimal use of water resources, dams and reservoirs have been established in many countries. These fulfil various functions, such as down stream irrigation, electricity generation, flood control, drinking water supply, fisheries, recreation, etc. They have often taken the form of prestigious projects, such as the Volta River Dam, badly wanted by president Nkrumah, for his newly independent country Ghana (Chambers, 1970). Many of these large dams had, however, an important and often more adverse environmental impact than expected. The reservoirs inundate large (usually fertile) valleys, alter the hydrological situation and the fisheries downstream, and are subject to gradual or accelerated sedimentation (Chapter 7).

In a few cases, environmental concerns led to the abandonment of water resources development plans. One such case was the Silent Valley Hydroelectricity Project in Kerala State in India, that would have inundated about 815 ha tropical forest, the habitat of the rare bearded monkey. In 1987 the construction plans were cancelled.

The number of possible new sites for the construction of multipurpose dams is gradually decreasing in most countries, and hence restricts the present and future extension of irrigation schemes, hydroelectricity plants and flood control measures. This 'loss of site' may be more serious than the loss of the investment, and warrants the proper protection of upper watershed areas, located above dams.

Public decision-making

While it may be cumbersome to determine individual and collective utility functions, it is certainly difficult to construct a social welfare function for a whole nation. It is not just a matter of adding individual utilities. Besides it is difficult to make judgements about maximizing social well-being on the basis of efficiency criteria only (Bromley, 1982).

Society as a whole will generally value the preservation of life support systems much more highly than individuals reveal through market behaviour. Therefore governments policies and programmes need to consider, apart from efficiency and (intra-generational) equity, also sustainability criteria. Norgaard (1988) refers to coevolutionary sustainability: one should avoid development paths, social structures and technologies that pose serious threats to the continued compatibility of socio-systems and ecosystems.

According to Opschoor (1992) there are three main factors that could cause economic activities to exceed environmental buffering capacities: population growth, economic growth and inappropriate technological change. Through their sectoral and regional policies and planning activities governments can actively aim at mitigating the effects of these factors.

Many developing countries nowadays try to curb population growth. China promotes one-child and Indonesia two-child families. For managing economic growth, attention is focused on putting threshold values of resource use at safe levels. Governments could set standards and make use of permits in order to avoid externalities, and by doing so raise prices to social cost levels. In soil conservation policies safe minimum standards of soil erosion have been applied, but due to a lack of measurement methods this has not been effective in developing countries. The problem with technological change is that it usually takes time to discover whether it is appropriate or not.

Sfeir-Younis and Dragun (1993) distinguish three levels of decision-making in soil and water conservation planning: 1. The policy level, focusing on SCWD objectives, strategies and investment planning; 2. The institutional level, looking at appropriate institutions, regulations, incentives and coordination; and 3. The operational level, focusing on appropriate designs, organisation, training and monitoring. Blaikie and Brookfield (1987) and Blaikie (1989) argue that there is a 'chain of explanation' of causes of land degradation, and that attention needs to be paid to causative factors on all different levels.

Government approaches have generally been very pragmatic. In countries with large (sub-)humid mountainous zones priority watersheds are selected on the basis of several criteria, such as actual state of degradation, downstream interests and future potential. The latter is assessed partly on the basis of land capability and land suitability criteria. In semi-arid zones, where food and extensive livestock production systems show few technological changes, much attention is paid to human carrying capacity as an attribute for sustainability.

Until now insufficient attention has been given by governments to the search for the most appropriate, i.e. effective and efficient incentives (Chapter 11).

Government and market failures

In their development programmes governments are often confronted with two types of failures: 'government failures' and 'market failures'. The former can be subdivided into policy failures and administrative or planning failures (Pearce and Warford, 1993). Policies are often based on past decisions that give insufficient weight to ecological considerations. Typical examples are the artificially low prices for water, timber and energy (previously considered as renewable, ample available resources) and the ignorance of externalities in land and water resources projects. The low prices led to excessive consumption. Now emphasis is laid on the 'user or polluter pays' principle. Administrative or planning failures relate to inadequate policy formulation and implementation, rigidity, lack of integration and communication, etc.

According to Castle et al. (1981) there are three main reasons for market failure with regard to natural resources: the common property nature of some resources, the public goods nature of some production processes and the existence of externalities in production and consumption. The difference between conservationists' goals and farmers' behaviour suggests such market failure. Decentralized decision-making based on market signals and competitive behaviour can lead to 'cost shifting', whereby part of the adverse consequences of one actor's decision are passed on to others. Such cost shifting is influenced by the 'distance' involved, both in terms of space (e.g. the downstream issue) and in time (e.g. the problem of future generations). Effects of environmental degradation are shifted on to other and future people and they have neither the necessary legal rights nor the means to exert 'countervailing power' through the political system (e.g. next generations have no vote) or the market place (e.g. lack of purchasing power).

In order to deal with the respective failures and to avoid cost shifting and other externalities, governments should redirect economic development in such a way that private costs are brought more in line with social costs. For soil and water conservation that would imply: realignment of access and property rights; imposition of duties and/or provision of incentives; improvement of relevant information flows; and where necessary an increase in social pressure on economic behaviour by the actors concerned (Chapter 11).

3.5 Other actors involved

Apart from farm households, farmer groups and governmental organisations, various other entities influence land use in rural areas and soil and water conservation activities. Farm households depend on traders and rural organisations for inputs and credit, and also on marketing agencies and processing plants for the sale of their products. Marketing and processing organizations of such crops as cotton, tobacco, sugar-cane and coffee, may have much influence on the production system applied, in terms of input use, etc. Some of these organisations may also provide assistance in the field of soil and water conservation. However, many commercial companies do not respect such long-term considerations. The tapioca trade in Thailand, for example, led to extensive cassava production and deforestation.

In many countries non-governmental development organisations (NGO's) play an important role in assisting farm households to make their land use more sustainable.

Urban communities constitute in the first place consumers of food and other agricultural commodities. They also derive their electricity and water supplies to a large extent from reservoirs, whose economic life depends on proper land use by upstream farmers. Urban people may also have a direct stake in rural land use, as absent landlords, cattle owners, investors or as users of recreation centres.

International donors
Because of their high initial costs, many soil and water conservation, watershed development and reforestation projects are partly financed by bilateral donors or bank consortia. Decision-making is then highly influenced by this donor involvement. Donor agencies often ask that particular features (e.g. environmental aspects) be included in planning, and all require project appraisal reports. While many guidelines are available for project evaluation and cost-benefit analysis, projects are not always prepared, appraised and monitored according to such guidelines. Many bilateral and UNDP financed multilateral aid projects are initiated on the basis of sectoral strategies and other (non-CBA) decision making procedures of the recipient countries and the donors (Chapter 4). The situation varies according to agency and type of aid concerned (e.g. grants, food-aid, etc.).

3.6 Conflicts of interests between actors

In soil conservation and watershed development projects or programmes there are often conflicts of interests between various groups or actors, directly or indirectly involved in such programmes. Common examples of such conflicts are those between:
- adjacent farm households,
- farmers and pastoralists,
- individuals and their groups/group leaders,
- different groups in a village or region,
- present and future farm households,
- upstream/downstream communities,
- government and (groups of) farm households,
- government agencies.

Conflicts also arise between individuals within one household, and in particular between men and women. Since in this study the household is chosen as the smallest operational unit, little attention is paid to such conflicts.

- Soil erosion may lead to conflicts between adjacent farm households. Erosive farm practices on fields higher up the slope may lead to erosion and sedimentation on plots of other farmers. In implementing SCWD activities upstream fields have to be dealt with first. The establishment of waterways (drainage channels) may also lead to conflicts between neighbours. Neither of the farmers wants to give up much land for such waterway (often planned along the boundary), with the result that its capacity to drain surplus water is insufficient and erosion is accelerated.
- Important conflicts of interest exist in semi-arid zones between farmers and pastoralists. Tribes which for centuries have been involved in nomadic pastoralism are found next to tribes that have made their living predominately from agriculture. In the past, when land was less scarce, arrangements were made between the two groups: certain boundaries were established and a mutually beneficially exchange of grazing rights for manure was agreed upon. With the expansion of farm land, grazing land has diminished. However, the demand for manure has increased too, and stubble grazing contracts remain very important. On the other hand, the presence of nomads with their cattle in farmers' villages often causes unrest, and cattle sometimes damage crops.
- Because of the exposure to other cultures and city life, as a result of migration, the traditionally strong linkages between rural families and their leaders gradually decline. Other customs and legal systems intermingle with traditional ones, and bring about tensions between factions and individuals within villages. Land and water rights are often at the centre of such conflicts and this affects soil and water conservation.
- Villages are often composed of several hamlets, inhabited by different tribal or social groups. Conflicts may arise between these groups (or hamlets) with regard to property rights and access to support activities from the government or NGO's. Such conflicts may affect the implementation of soil and water conservation activities.
- Another less visible conflict of interest in soil and water conservation programmes is that between present and future farm households. Farmers are often reluctant to engage in soil and water conservation activities, because of the high costs and the time it takes to realize benefits. If they undertake terracing, they do it partly for the next generation. Most farm households in developing countries have first to satisfy important immediate needs, before they can consider investments that benefit their sons and daughters. Also, many farmers are not sure whether their children will continue farming.
- In areas where dams and reservoirs have been established, conflicts of interest arise between the upstream and downstream communities. The latter benefit from the regulated supply of irrigation water and hydroelectricity, that is derived from the reservoir, and it is in their interest that seasonal differences of water-supply and sedimentation from the upper watershed area are minimized. However, erosion control may not be very important for the upstream farming community. Farmers in the uplands of Java and Jamaica, growing root crops on deep and fertile soils, are more concerned with the evacuation of surplus water then with soil loss, and prefer outward sloping above reversed sloping terraces (Chapter 10). Tenant farmers in such areas also care little about soil loss and downstream sedimentation. These upland farmers need incentives in order to engage in erosion control measures that accommodate downstream communities.

- Conflicts between generations and between upstream and downstream communities cannot be solved by these groups themselves, since they are separated by time and space. The government should act on behalf of disadvantaged groups, which in the first case are the future land users and in the second case usually, but not always, the upland farmers. Here one also refers to conflicts between the public interest to conserve soil (defended by the government) and the private interest of farmers (to satisfy their more immediate needs first). Similar conflicts arise when small farmers intrude natural or protection forest, to satisfy their food requirements.
- As discussed in Section 3.4, the government is not a homogeneous body. Government departments have often different opinions about the priorities and the mode of implementation of certain programmes. In soil and water conservation programmes such conflicts often arise. Ministries or departments of public works, responsible for the construction and maintenance of reservoirs, favour investment in soil and water conservation in areas upstream of these reservoirs, while 'local government' ministries prefer investment programmes in the poorer (sub-)districts. Conflicts also occur between offices of the ministries or departments of forestry and agriculture, where often both claim the major responsibility for soil and water conservation.

In regional and urban planning the Planning Balance Sheet (PBS) method has been designed in order to assess the costs and benefits of interventions that operate simultaneously in different sectors, and affect a wide range of different actors (Lichfield et al., 1975). The method consists of the listing, in balance sheet form, of various groups (producers, operators), that play a role in the project activities, and these are paired with appropriate groups of individuals who consume or use the goods and services generated by the first groups. Subsequently all transactions and resource costs are elaborated upon. In such a way a comprehensive set of social accounts is obtained. Such an approach could also be followed in watershed development projects, in order to express the various conflicting interests. This could subsequently be used in project preparation and appraisal (Chapter 4).

Conclusions

This chapter has shown that the decision-making process in SCWD activities and projects is complicated because of the many different groups of actors involved and their conflicting interests. Farmers should first perceive soil erosion as a serious problem, and then be confronted with appropriate measures. When they have the means and the will to undertake conservation measures they may adopt them.

In many cases upland farmers only receive part of the benefits from conservation measures, and will not take action on their own. For similar and for other reasons local level collective action has seldom been initiated. In many cases government action is indispensable, although government and market failures may reduce the effectiveness and efficiency of these activities.

In the preparation and appraisal of SCWD activities due attention should be paid to conflicts of interests, resulting from the different views of respective actors. These views should be carefully identified, and in case of opposing views possible trade-offs between objectives should be considered in the analysis. These objectives form the basis for the determination of the evaluation criteria. The next chapter focuses on the choice of the most appropriate evaluation method for SCWD projects.

4 ECONOMIC EVALUATION METHODS

If it does not sufficiently inform the decision-makers and the public so that they can use the information provided in order to arrive at a more rational decision, evaluation is an academic exercise. For this purpose, evaluation will have to be more context responsive (Hill, M; in Shefer and Voogd, 1990).

4.1 Objectives and approaches of evaluation methods

The term evaluation is used for a wide array of activities that provide information for administrative purposes (e.g. auditing), for the management of projects and programmes, or for policy purposes (e.g. impact evaluation). It is often used as a project management tool, and could then either be output or process oriented. Here it is considered as a tool for project management and for policy makers to assess the (direct) 'output' and the (eventual) 'impact' of development activities, that form part of SCWD projects. The output and impact do not have to be confined to physical effects. Evaluation has been defined by a UN committee as: a process for determining systematically and objectively the relevance, effectiveness, efficiency and impact of activities in the light of their objectives (UN, 1984).

In the evaluation of projects or activities one tries to assess whether the results of these activities correspond with their aims (effectiveness), whether their overall benefits exceed their total costs (efficiency) and whether they eventually have positive effects (impact) on the welfare of the community. For soil and water conservation activities it is important to clearly define this community, since it can include different groups: upstream and downstream and within present and future generations (Chapter 3).

An evaluation can either be carried out prior to certain activities (an ex ante evaluation or appraisal), during the implementation of the activities (e.g. mid-term evaluation, monitoring) or after completion of the activities (ex post evaluation). In this study most attention will be paid to *project appraisal*, but in the case studies lessons will be drawn from ex post evaluation. The inter-relationship between the two analyses is evident: project appraisal provides data upon which a subsequent evaluation can be based and project evaluation results can contribute to better project appraisal (Imboden, 1978).

The *functions of evaluation* methods can be listed in chronological order as follows (Ministerie van Financiën, 1992):

- clarify and structure the information regarding the alternatives;
- reduce the number of alternatives;
- arrive at a ranking of alternatives;
- indicate the socio-economic efficiency of the alternatives.

Usually the evaluation method will be selected that can best perform the above functions, with the least resources, and that has proven to be the most successful in similar evaluations. In cost-benefit analysis (CBA), most often applied in the project appraisal stage, the emphasis is on the latter function, whereby the benefit-cost relationship or efficiency criterion of the 'best' alternative is analyzed. It is then assumed that the other functions are properly taken care of during the project identification and preparation stages. In multi-criteria analysis (MCA), on the other hand, much attention is paid to the process of ranking various alternatives, on the basis of several criteria.

Which evaluation approach and method is chosen, for its relevance to a specific decision-making process, depends on various methodological and practical considerations (Figure 4.1). There are three main groups of actors involved: the decision-making body or organisation that has commissioned the evaluation and that will use its results; the target group that is likely to participate in, or will be affected by, the project activities and need at least to be consulted; and the evaluation team that has been requested to undertake the evaluation.

Choice of evaluation approach	Technical considerations	Technically sound method Valuation procedures Data available
	Organizational considerations	Budget constraint Time constraint
	Decision-maker (user) considerations	Objectives of project Purpose of evaluation Relevance of results Credibility of results

Figure 4.1 *Factors affecting choice of evaluation approach*

For the selection of format, scope and methodology of the evaluation, the decision makers and the evaluation team will have to consider the following questions (based on Gregersen et al., 1993):

- Regarding the *objectives*: for what purpose do the users need the evaluation results? Are there many different users, with different objectives? How could the results be made comprehensive and comprehensible to the users and which approach could be followed that relates to their way of thinking?
- Regarding the type of *criteria* that play a role in the evaluation and that are derived from the objectives: is the set of criteria complete, and does it not lead to double counting? Can the method come up with results that are relevant for these criteria and what is the credibility of these results?
- Regarding *method sensitivity*: can the evaluation method produce results that are objective, consistent and allow for a clear-cut comparison between the alternatives, not in any way affected by the choice of method?
- Regarding *cost effectiveness*: what (amount of) data does a method require, how reliable are the results the method can produce, and do the analytical costs not exceed the value of the information?
- Regarding *budget, time, manpower and data availability* constraints: what should be the scope and amount of detail of the analysis, given these constraints? Should a simple or a more sophisticated method be applied?

All these factors play a role in evaluating SCWD projects. In addition these projects have various target groups that are hard to identify (Section 5.1) and that often have conflicting objectives. Besides, the primary 'conservation' effects of such projects are not only difficult to identify, but also hard to quantify and to value. This also complicates the selection of evaluation criteria. Much data need to be collected and analyzed to obtain credible results, which may not comply with budget, time and other restrictions and may not be cost effective.

General procedures of evaluation process

In evaluation as an iterative planning process the following steps can be considered (adapted from Nijkamp et al., 1990):

1. Problem definition
2. Defining alternatives
3. Defining criteria and criteria weights
4. Effect analysis for alternatives
5. Determination scores on criteria
6. Analysis of scores
7. Drawing of conclusions

Grouping the above steps, van Pelt (1993) distinguishes three main phases in project appraisal:

Phase 1: In which the *decision-making framework* is prepared, by choosing the alternatives, the criteria (with their attributes) and the criteria weights;

Phase 2: In which the *impact assessment* is undertaken, by identifying the effects of the alternatives and then determining the scores of the alternatives on the different attributes of the criteria.

Phase 3: In which it is verified first whether the constraints are satisfied. Thereafter the overall performance of alternatives is assessed, which van Pelt refers to as the *integrated evaluation*.

For problem definition relevant information is collected during the project preparation stage. During this stage use is often made of problem analysis techniques, such as the Logical Framework or Objective Oriented Project Planning (OOPP; GTZ, 1989), whereby existing problems are translated into potential project objectives. The selection of alternatives is subsequently based on detailed studies undertaken during this stage. These studies cover all technical, socio-cultural, political, organisational, commercial, etc. aspects, and also provide the data for a first economic and financial analysis (pre-feasibility study).

The decision-making framework not only requires a selection of alternatives, criteria and criteria weights but also a choice for the adoption of an appraisal method. Evaluation criteria, whether monetary or non-monetary, could focus not only on attainability and desirability, but also on certain minimum requirements (veto criteria). Following van Pelt (1993) three main or key criteria are distinguished here for the evaluation of SCWD projects: *efficiency, equity* and ecological sustainability (here focused on *conservation*). As will be shown below (Sections 4.4 - 4.6), effects on alternatives need to be analyzed on the basis of a careful selection of attributes on all three criteria.

The effect analysis, or impact assessment, leads to the construction of an evaluation or impact matrix, in which for each alternative the scores on the respective criteria are calculated. A specific form of such a matrix is a cost benefit balance, whereby the different effects are translated in costs or benefits.

Voogd (1982) makes a distinction between an evaluation matrix, showing choice possibilities and evaluation criteria, and a priority matrix, whereby the weights attached to the criteria are looked at from different angles (e.g. different views of actors). These two matrices combined result in the appraisal matrix: choice possibilities against views. In Table 4.1 an example of each of these matrices is given. A very simple standardization procedure is followed in the evaluation matrix, and the priorities of actors in the priority matrix are expressed as a fraction of 1. When the views of the four groups of actors are weighted equally, the four alternative activities show similar scores. The option 'live fences' scores slightly higher than the other activities. It concerns a clear case of opposing views between upland farmers and landless on the one hand against downstream farmers and the government on the other. Such conflicting views are a common feature of decision-making in land and water management (Section 5.4). Besides that, the three matrices clearly show what decision-making is about, and how a change in priorities or a change in the weights of the respective views can alter the eventual outcome of the evaluation or appraisal.

Table 4.1 *Example of evaluation, priority and appraisal matrices*

Criteria	Unit	Alternative activities [1] Tree planting	Terracing	Live fences	No measures
Max. Production	m US$	25 (0.5)	40 (0.8)	35 (0.7)	50 (1.0)
Min. Costs	m US$	15 (0.4)	25 (0.0)	10 (0.6)	0 (1.0)
Min. Sedimentation	ton	450 (0.7)	600 (0.6)	750 (0.5)	1500 (0.0)
Min. Flood damage	m US$	2 (0.9)	6 (0.7)	6 (0.7)	20 (0.0)

Criteria	Unit	Priorities of actors Upland farmers	Landless	Downstream community	Government
Max. Production	m US$	0.7	0.8	0.1	0.2
Min. Costs	m US$	0.2	0.2	0.1	0.2
Min. Sedimentation	ton	0.1	0.0	0.4	0.3
Min. Flood damage	m US$	0.0	0.0	0.4	0.3

Alternative activities	Appraisal matrix (score by actors) Upland farmers	Landless	Downstream community	Government	Overall score [2]
Tree planting	0.50 [3]	0.48	0.73	0.66	0.59
Terracing	0.62	0.64	0.60	0.55	0.60
Live fences	0.66	0.68	0.61	0.62	0.64
No measures	0.90	1.00	0.20	0.40	0.62

1) Standardization scores in brackets (division by highest score; inversion for negative oriented criteria).
2) Assuming equal weights between actors.
3) 0.5 * 0.7 + 0.4 * 0.2 + 0.7 * 0.1 + 0.9 * 0.0 = 0.50

4.2 Features of most common economic evaluation methods

A first distinction can be made between 'discrete' and 'continuous' evaluation methods. In the case of continuous methods, the number of alternatives is unlimited. These methods are often used in planning and research (e.g. optimization models), but are less appropriate in appraisal studies, where only a few alternative options can be considered. They could sometimes be used to generate discrete options. Discrete methods can be further divided into monetary and non-monetary methods. The first methods can be used, when the various effects of an activity can be expressed in monetary terms. Examples are cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA). Among the non-monetary methods a further distinction can be made between 'tabulation of effects' methods, various multi-criteria analysis (MCA) methods and the 'participatory' methods (Voogd, 1982; Ministerie van Financiën, 1992).

Monetary methods

In *cost-effectiveness analysis* (CEA) one can either look for the alternative that can reach the objectives at minimum cost, or the alternative that can make the maximum contribution to the objectives at fixed costs. The method avoids the painstaking effort required to estimate the various tangible and less tangible benefits. The method is mainly used as a (poor) substitute for cost-benefit analysis, when the benefits are of similar magnitude and when it is too difficult to quantify and value the major categories of benefits. It is a relatively cheap method, but it requires the setting of subjective standards, that may not convince decision makers or tax payers.

Cost-benefit analysis (CBA), is essentially a social evaluation method, based on applied welfare theory (Nijkamp, 1977). It concerns decision making with regard to the net social benefits (that is, aggregate benefits for the society as a whole) of investments made in the private or, more often, in the public sector. The welfare-theoretical basis of cost-benefit analysis is reflected in the use of the principle of the buyer's 'willingness to pay' in determining the worth or value of a good (or service). The theoretical basis for cost-benefit analysis was laid down by the French engineer Dupuit (1844), who introduced the concept of 'consumer's surplus', which has since played a crucial role in welfare theory. The basic idea is that the utility of a certain good is at least equal to the price paid for it, so that a person buying a good against a certain price and attaching to this good a value greater than its price will derive a net profit (Nijkamp, 1977). Consumer's surplus is equal to willingness to pay minus actual payment. The LMST (Little and Mirrlees 1974; Squire and Van der Tak, 1975) and UNIDO (1978) approaches, which form the theoretical basis for present day economic appraisals, no longer use the willingness-to-pay principle for valuation. The LMST method applies world market prices or 'border-prices' and the UNIDO method domestic accounting prices. Prices are attached directly to tradeables and indirectly to non-tradeables, by breaking the latter down into tradeable goods, labour costs, etc. If all social, including environmental, costs were to be covered, many world market prices would need to be adjusted. The market price of timber, for instance, usually covers only a fraction of total production costs (van Pelt et al., 1990). In his survey on project evaluation in theory and practice, Squire (1989) concludes that border prices are the relevant shadow prices for tradeables for small and large projects, in other words, at both partial and general equilibrium level. The appropriate shadow prices for non-tradeables and production factors depend on how budgetary constraints are handled.

Application of CBA

In practice cost-benefit analysis consists of impact analysis, followed by the valuation of the various impacts. It aims at a comparison between the present value of the streams of benefits (positive effects) and the present value of all investment and recurrent costs (negative effects). The sequence of analytical steps in cost-benefit analysis (CBA) includes:

- determination of evaluation criteria
- identification of effects (costs and benefits)
- quantification of costs and benefits
- valuation, including shadow pricing
- determination of an appropriate time horizon
- discounting to present value
- discussion, where appropriate, of income distribution aspects
- sensitivity analysis and policy implications

Specific aspects of cost-benefit analysis are the use of discounting to determine present values of future costs and benefits; and second, the use of certain economic decision criteria. Discounting is based on the principles of 'the social time preference' (for various reasons, people may prefer money for consumption now, instead of later) and of 'social opportunity cost' (the cost of tying up capital that otherwise could be made productive now). The most common economic criteria are the B/C ratio, the Net Present Value (NPV) and the Internal Rate of Return (IRR). All three criteria have limitations, depending on the situation. The last two are the most commonly used, often in combination.

A distinction is made between economic, financial and social cost-benefit analysis. *Economic* CBA (ECBA) concerns a whole project, looked at from a national point of view. This analysis focuses on the efficiency of resource allocation. In the impact analysis for ECBA all direct, indirect and external effects must be incorporated. A *financial* CBA (FCBA) is done to check whether a project is financially attractive as a whole, and for the various participants and other actors. Financial criteria such as 'added net farm income', 'repayment capacity' or 'net return to labour' might be also used to reflect the farmer's standpoint. *Social* cost-benefit analysis (SCBA) is similar to economic CBA, but includes special concern for the distribution of project benefits across social groups: efficiency-cum-equity (Kuyvenhoven and Mennes, 1989). One should then first review the incidence of costs and benefits for selected groups. Although the importance of SCBA is widely acknowledged, the method is not often used in practice. From a survey of evaluation practices in 27 countries Squire (1989) concludes that countries also seldom consider social and budgetary effects of projects and that practitioners, at best, operate within simple partial equilibrium rules.

Limitations of CBA

Cost-benefit analysis has a number of shortcomings and weaknesses. Helmers (1979) states that 'the theory behind project planning focuses explicitly upon the objective of increasing national welfare'. He argues, however, that we cannot measure national welfare by simply using national income as a proxy. While CBA has traditionally focused only on the efficiency criteria, Helmers (1979) has suggested designing an objective function that also includes income distribution aspects. The issue of compensation should be linked to the actual income distribution and subsequent redistribution (after compensation payments). This issue of intra-temporal income distribution is further discussed in Section 4.5.

Much discussion has also been devoted to the role of Pareto optimality in CBA and to the Hicks-Kaldor principle that states that economic change is an improvement if gainers can (in principle) compensate losers (Nijkamp, 1977). But CBA is indifferent to whether actual compensation takes place, and does not object to the substitution between natural and man-made resources (Section 4.5).

Another important shortcoming is that project specific side-effects, multiplier effects and intangible effects, which play a very important role in SCWD projects, cannot be easily assessed in monetary units. In some cases the shadow project approach could then be applied (Klaassen and Botterweg, 1976). Alternatively, use could be made of multi-criteria analysis.

An objection to the general use, in CBA, of real market or imputed prices is brought up by Barlett (1980). He agrees with Chayanov that more attention should be paid to the criterion of returns to labour, as the most appropriate method to gaining an understanding of agricultural decisions.

In particular with regard to environmentally oriented projects objections have been raised to the use of discounting. The major benefits of, for example, conservation projects only appear in the long run, after 20 to 30 years, but the discounted values of these benefits will be very small after such a period. Many suggestions have been made to resolve this problem. These inter-temporal or inter-generational issues will be discussed in Section 4.5.

Maguire and Boiney (1994) mention as additional disadvantage of CBA, that it obscures rather than illuminates trade-offs among non-financial objectives.

The most common replies to CBA critics can be summarized as follows (Bojö et al., 1990):
- in any analysis, not just in CBA, it is often necessary to price the priceless, because comparisons must be made;
- CBA is an evaluation technique which applies one common unit (money), which facilitates analysis and presentation of results;
- while money is not more important than other yardsticks, it is often used to compare values, and values are often available from the market;
- other methods also have substantial data requirements;
- CBA need not be narrow. By using SCBA, it can be extended to cater for social (distributional) aspects; and economic cost-benefit analysis (ECBA) should by definition include external effects, such as environmental aspects. Some authors refer to 'extended economic CBA' (XCBA), in the case of methods devised to fully incorporate such effects.
- in the financial analysis such criteria as 'payback period', 'repayment capacity' or 'net return to labour' could also be used to reflect the farmer's standpoint.

While these arguments in favour of cost-benefit analysis as a tool for use in project evaluation are simply listed, without further elaboration, it should be clear that together they represent a strong rebuttal to critics, and explain why it is so widely used (de Graaff, 1993).

Non-monetary methods

'*Tabulation of effects*' methods are descriptive methods, which aim at structuring the information regarding the effects of certain alternatives. The effects are expressed where possible in monetary terms, and otherwise in other appropriate units.

Examples are the 'Planning Balance Sheet method' (PBS), devised by Lichfield (Lichfield et al., 1975) and the 'score card method'. The first method aims at presenting the effects of alternatives for the distinct social groups involved. No weights are attached to the relative importance of certain categories of effects. Based on the above methods, Hill (1968) developed the Goals-achievement matrix for evaluating alternative plans.

A controversy arose between Lichfield and Hill about the role and derivation of 'social (societal) objectives'. Hill argued that 'these objectives should form the reference framework and not the (aggregated) objectives of individual groups, as in the case of PBS' (Hill, 1968; Lichfield, 1990). But why not use PBS first to expose the conflicting interests of social groups and confront these with official government objectives to arrive at the 'social objectives'? While these methods could play an important role in inter-sectoral planning activities (e.g. in regional or urban planning), they are less suitable for project appraisal.

In '*Multi-criteria analysis*' (MCA) methods, various explicit evaluation criteria are applied, the scores for which may be expressed in different units (monetary, quantitative or qualitative). Weights will be given to the respective criteria, which represent the preferences of the decision maker and/or parties involved.

The traditional framework for the analysis of decision making presupposes three elements (Romero and Rehman, 1989):

- a decision maker (individual or group)
- an array of feasible choices
- a well defined criterion, such as utility or profit

In conventional cost-benefit analysis the complex of project objectives is converted into one basic criterion of 'maximizing utility' (efficiency), while some objectives are dealt with in the form of constraints. However, decision makers in the agricultural sector have a strong motivation to seek optimisation or satisfaction of several objectives or goals, instead of maximising only one. Sustainability concerns, such as soil and water conservation aims are a good example. In MCA alternatives can be judged on their contribution towards different criteria, and the respective variables or criteria do not have to be quantitative, and can each be expressed in their own unit (*numéraire*). Weights have to be given to the respective units in order to find the optimal alternative. These weights can be established through expert knowledge, by interviewing people concerned or directly by the decision-makers themselves (van de Laak and van Ierland, 1988).

The general sequence of analytical steps in multi-criteria analysis (MCA) includes:

- determination of objectives
- defining alternatives
- formulation of evaluation criteria
- determination of effects of alternatives on criteria
- construction of evaluation matrix
- standardization of effects
- formulation of weight vector(s)
- formulation of aggregation rules
- ranking of alternatives
- checking for satisfactory ranking

Specific features of MCA methods

In MCA many different alternatives can be formulated. These alternatives each have their strong and their weak points, in the eyes of the respective decision-makers and other parties involved. The MCA methods offer the possibility of involving these groups in the decision-making process. The methods can easily show how a different choice of criteria alters the ranking of the alternatives.

MCA methods have the advantage that it is not necessary to undertake a detailed quantification and valuation of various effects (costs or benefits).

Since several criteria are allowed, MCA methods require the determination of *weights* to be attached to these criteria. These weights can be estimated directly or indirectly. In the first case interviewees are offered the possibility to express their priorities through specific techniques (Nijkamp et al., 1990): the trade-off method, the rating method (e.g. assigning 100 points amongst the criteria), the ranking method, the seven or five points scale, or through a paired comparison. Once the particular weight sets have been applied, the interviewees may be asked again whether they would like to reconsider their choice of weights. Weights can be derived indirectly from previous choices or actual behaviour in the past (revealed preferences), through a process of interactive estimation or through the preparation of hypothetical weight sets by the analyst himself. Each approach has its advantages and disadvantages. It depends on the situation which is more appropriate.

A wide array of MCA methods have been developed in the past thirty years. They can be classified in several ways. On the basis of the way of aggregation of criteria one can distinguish between weighting methods, sequential elimination methods, spatial proximity methods and mathematical programming methods (Filius, 1993). The latter is also considered as a tool by itself, and referred to as multi-objective programming (MOP). While the other multi-criteria analysis methods address discrete choice problems (with a limited number of alternatives), multi-objective programming is primarily used in optimization problems and provides an unlimited number of solutions.

MCA methods can also be distinguished by their ability to deal with either qualitative, quantitative or both types of data. The Weighted summation method and the Concordance analysis (e.g. Electre method) were developed for analysing quantitative criteria scores. The latter was among others used in a study on the reclamation of the Markerwaard (Heijman and van Ierland, 1984). Regime analysis and the above-mentioned Goals achievement matrix method (Hill, 1968) are so-called 'mixed data' methods.

According to Voogd (1982) MCA has the following positive features: it provides a surveyable classification of factual information; it gives insights into the various value judgments; it can incorporate differences in interest and political views in the analytical framework; it provides options to review policy decisions; and it can avoid detailed research and calculations.

Table 4.2 *Comparing various aspects of CBA and MCA*

Aspects	CBA	MCA
Alternatives	One (out of few) is selected, which is compared with 'without' situation.	Comparison of alternatives is essential feature.
Objectives	One, in terms of maximizing utility; others as constraints.	Various, of different nature (e.g. economic, ecological, social).
Criteria	Economic efficiency; in SCBA also equity.	Various criteria, on basis of objectives.
Attributes	Costs and benefits, directly or indirectly in monetary terms.	Wide variety, quantitative or qualitative.
Procedures	One (standard) method, with well-established procedures.	Various methods, each with own procedures.
Type of data	Quantitative only.	Quantitative and/or qualitative; depends on method.
Numéraire	Monetary unit.	Scores on all criteria expressed in own unit.
Valuation	Prices (market/opportunity/ accounting prices).	Weights, reflecting subjective insights.
Discounting	Essential practice.	Not applied.
Method sensitivity	The efficiency criteria (NPV/IRR) give normally similar results.	Different MCA methods may give different results.
Cost of method	Requires detailed costs and benefits calculations.	Simpler MCA methods do not need much time.
Cost effectiveness	Because of fixed format more effective for large projects.	For small projects simpler methods can be chosen.
Past experiences	Often applied for SCWD-projects. Problems with method to assess benefits.	Not yet often applied for SCWD-projects in developing countries.

Limitations of MCA
The way in which the weights of the criteria are attached to the effects differs for the respective methods. Some use simple arithmetic rules, while other methods use more complicated procedures. These latter MCA methods may therefore be difficult to explain and to comprehend.

While CBA constitutes one single, more or less universally accepted, methodology, various MCA methods have been developed which could be used interchangeably, although each of them has its pros and cons. At times these methods may not yield exactly the same outcome: the same ranking of alternatives. This reveals method uncertainty or method sensitivity (van Pelt, 1993).

Another disadvantage of some MCA methods is the use of qualitative scales (e.g. ordinal ranking of alternatives on criteria), where quantitative (or cardinal) scales could have been used and would have shown more exact differences. That constitutes a loss of information.

In MCA methods it is difficult to incorporate the time dimension.

The fact that MCA can incorporate differences in political views, and can review policy decisions may not always be fully appreciated. The disclosure of policy intentions can be detrimental to negotiations, and it may offer possibilities to manipulate the political opinion making (Voogd, 1982). In Table 4.2 a comparison is made between CBA and MCA, according to the respective evaluation aspects.

Participatory methods
Some MCA techniques follow an interactive approach, whereby decision-makers can evaluate various steps or rounds in the decision-making process, until they are fully satisfied.

In decision-making regarding environmental issues, groups involved often have opposing views, which frequently leads to environmental disputes. CBA and most MCA techniques do not offer much help in structuring negotiations between these groups, since they largely focus on how decision-makers value the utility of the project effects and pay little attention to uncertainty and to possible trade-offs among some of the objectives.

Several simulation-based decision aids have been developed which assist decision-making parties to project the probability of certain consequences of project or policy interventions, and to negotiate toward compromise decisions (Bonnicksen, 1985; Walters, 1986). Much use of such techniques is made in integrated water resources management (Bogardi and Nachtnebel, eds., 1994). Conflict resolution techniques are intended to facilitate consensus decision-making by disputing parties with an independent mediator, but these techniques lack a formal structure. Maguire and Boiney (1994) have developed a framework for resolving disputes that combines conflict resolution with decision analysis.

4.3 Choice of evaluation methods for activities in the field of soil conservation and watershed development

For the large soil conservation and watershed management projects, undertaken in the first part of this century in the USA and in colonial territories, no detailed cost-benefit studies were undertaken. Better use of and control over water and forest resources were often the major aims and the plans were advocated by the water and forest authorities concerned. Since the 1960's such projects have increasingly been used as a tool in integrated regional development in developing countries, and the need has arisen for appropriate appraisal methods. In the SCWD projects initiated by FAO in the sixties and seventies much attention was paid to detailed cost-benefit analysis by component (FAO/Republic of Korea, 1974; Gauchon, 1976; de Graaff, 1981). Since SCWD projects as a whole, with their high initial investment and high overhead costs, generally showed relatively low returns on investment, proposals were put forward at a FAO/Investment expert meeting in 1981 to apply different evaluation methods and criteria for such projects. However, this has not yet led to the general application of other methods, such as MCA.

An assessment is made below of in what respect SCWD projects could be more or less suitably evaluated by one of the two methods. Use is made of the aspects of the methods, as they are compared in Table 4.1.

Alternatives

In SCWD programmes in developing countries the number of concrete options is usually restricted, and decision-making is normally focused on the selection of one out of a limited number of alternatives (combination of components). CBA and MCA methods oriented towards discrete problems are therefore more appropriate appraisal methods than for example multi-objective programming methods. However, considering the opposing views that exist concerning soil conservation measures (e.g. vegetative versus mechanical measures), the selection of only one project alternative, as is customary in CBA, does not seem justified either, unless detailed project preparation has ruled out all but one of such approaches.

Objectives and criteria

SCWD projects are often faced with the problem of conflicting objectives, related respectively to development and soil and water conservation. The soil conservation measures may restrain development, and certain development activities may further increase land degradation. Reforestation, for example, in comparison to arable cropping, contributes less to production and income targets, but more to reducing sedimentation and flood damage downstream. This emphasizes the importance of weighing the respective objectives. MCA is better equipped for that than CBA. An additional problem is that these projects (activities) often affect several actors with multiple goals. The appropriate evaluation method should thus be able to take into account (or weigh) the different goals of different actors.

In SCWD activities one is not only dealing with maximizing or minimizing variables (e.g. outputs and inputs), but also with situations whereby one wishes to keep a variable as much as possible at a constant level (e.g. soil moisture).

Each individual project, with its group of actors and its specific circumstances, has a particular set of objectives. Table 4.3 lists some major objectives of SCWD projects.

Table 4.3 *Objectives in soil conservation and watershed development*

Development	Conservation
Production for local market	Erosion control
Production for export	Fertility maintenance
Food security	Preventing phys./chem. degradation
Income generation	Water supply
Employment generation	Flood control
Cost minimization	Sedimentation control
Equity/social solidarity	Sustainable wood supply
Participation/self-reliance	Bio-diversity

Procedures
For assessing the effectiveness of soil conservation measures (impact assessment) data on effects need to be aggregated from field (LUST) via farm pattern (actor) level to watershed (regional/national) level. The confrontation of the effects on a certain group of actors with those on the community as a whole, can then lead to the assessment of the need for and the level of incentives. Such an aggregation can be achieved in CBA within the framework of the farm level and overall financial analysis. It may be more difficult in MCA, certainly when the attributes of criteria make use of qualitative data only.

Type of data, numéraire
Market prices play a relatively moderate role in the evaluation of investments with environmental aspects or repercussions. When the market mechanism does not provide a realistic price for environmental damage, a monetary amount (shadow price or opportunity cost) must be calculated, that will be sufficient to compensate all affected parties for the damage incurred. While external effects can be valued in terms of either market or shadow prices, intangible effects (e.g. human life, historical sites or natural beauty) cannot easily be expressed in monetary terms; they must then be presented in other quantitative ways, or sometimes in qualitative terms, that can only be conveniently handled by MCA methods. Intangible effects, whether debits or credits, can for example be measured in terms of balance (or imbalance) with the various effects of a similar type, found on the other side of the ledger (de Graaff, 1993).

Valuation of benefits
Since it is hard to identify the effects of SCWD activities and the groups that are affected, the quantification of benefits is difficult and that combined with the above-mentioned pricing problems makes it very cumbersome to attach monetary values to the benefits. Several techniques have been developed for this 'valuation' problem (Section 4.4) and in this research some methodologies have been applied to express physical effects in monetary terms: for example by using on-site water and nutrient balance information to assess yield changes (Chapter 6), and by using hydrological research data to estimate changes in the sedimentation and water inflow in reservoirs (Chapter 7). But such methods require much data, which are not always available.

The CEA approach of finding the least costly alternative could be an alternative to CBA in such cases, particularly, when one accepts the SWC dogma, arguing that 'conserving soil is worth whatever it costs' (Seckler, 1987). According to this philosophy, soil conservation belongs to the same category as improvements to a nation's health or education system: objectives generally accepted as desirable, which need not show an immediate cash profit.

Discounting
There are probably not many other types of investment projects that show such tremendous time-lags between the bulk of the costs and the stream of benefits as SCWD projects. It therefore seems that the discounting procedures in CBA discriminate against these projects. On the other hand MCA has in itself no procedure to deal with different time-frames. In applying another evaluation method for these projects, the results can no longer be compared with those for other projects. Since this issue is central to both inter-generational equity and sustainability, it is discussed in more detail in Section 4.5.

Cost of method, cost-effectiveness
SCWD projects are generally costly and the consequences of choosing the wrong alternative may be grave. An extensive project preparation and appraisal may therefore be justified. Such a preparation phase should, where possible, include thorough hydrological and erosion research and socio-economic studies of the target population and other groups that may be seriously affected.

Past experiences
Multi-criteria analysis is increasingly used in large multi-sector projects in developed countries, but has not yet replaced cost-benefit analysis as the major evaluation tool for SCWD projects in developing countries. Bojö (1992) has reviewed the use of project-level cost-benefit analysis for 20 soil and water conservation projects, undertaken in the period 1973-1988. He found that the quantification of benefits, and in particular of erosion-yield relationships, turned out to be a weak spot in all of the studies reviewed. On the other hand he states that there are good examples of skilful application of CBA, and that it could be a useful tool in the appraisal of such projects.

Summary of comparison between CBA and MCA for SCWD activities
For SCWD activities CBA has the drawbacks that one 'with-case' is usually compared with one 'without-case', that all effects have to be valued in monetary terms, and that it basically concentrates on the efficiency criterion. MCA has on the other hand the disadvantages that it does not allow for an easy comparison of streams of costs and benefits over time, and that it basically relies on subjective weights attached to several criteria by the groups concerned and represented. An intermediate solution is the use of the results of the cost-benefit analysis as one of the criteria (efficiency) to be used in the multi-criteria analysis.

4.4 The efficiency criterion

Since the first cost-benefit studies of public investment in water resources infrastructure in the USA in the 1930's, projects have mainly been evaluated on the basis of the efficiency criterion. This criterion constitutes the difference between gross welfare changes (benefits) and the use of scarce resources (costs). It concerns the changes between the situation with the project and that without or with the best alternative.

In an appraisal one has to assess how well the project alternatives contribute to policy objectives towards social welfare. Welfare has for long been put on a par with the utility derived from the consumption of products and services. National welfare was considered more or less synonymous with national income (GNP), and differences in welfare between countries were assessed on the basis of the GNP per capita. However, this welfare indicator shows several deficiencies. It ignores differences within countries between regions and between social groups, it generally only includes officially recorded income, and it emphasizes the material side of welfare. For the latter reason the UNDP (United Nations Development Programme) has introduced the Human Development Index (HDI), that takes into account real purchasing power, life expectancy at birth and literacy among adults.

Another important shortcoming of the traditional concepts of welfare and GNP is that it does not take into account the environmental degradation of natural resources from which income is derived. In the past two decades several proposals have been made to adjust national accounts for environmental degradation (Hueting, 1989; El Serafy and Lutz, 1989). Peskin (1984) has shown that such adjustments may be considerable: deforestation and its external effects reduced the net national product of Tanzania by 11 % per year. Lallement (1990) has calculated that the crop, livestock and firewood losses due to land degradation in Burkina Faso were equivalent to 8.8 % of GNP, and Repetto et al. (1989) estimated that the losses due to soil erosion and deforestation in Indonesia constituted about 4 % of GNP. Pearce and Warford (1993) show that the annual costs of environmental damage in a dozen countries range from about 1 - 17 % of GNP.

In order to properly incorporate ecological sustainability in project appraisal, Van Pelt (1993) uses a model that includes a socio-economic and an environmental system. While the former concerns the production and consumption processes, the latter contains the natural resources. When welfare is defined in this wider sense, the economic (efficiency) analysis can no longer ignore environmental amenities.

Impact assessment has to be undertaken from both the national point of view and from the private point of view of the major actors. In cost-benefit analysis this means confronting the results of the ECBA with the financial analysis (FCBA) for the respective actors. In MCA different (criteria) weight sets can be applied, representing the different views. This comparison between the overall public impact and the effects on actors is of utmost importance in the preparation of SCWD activities in order to assess the need and scope of incentives to reconcile private and public interests (Chapter 5).

Valuation techniques

As indicated in the earlier paragraphs of this chapter, a major drawback in the application of CBA in SCWD projects and in environmental management projects in general, is the fact that many of the effects of such projects are hard to quantify, and even more difficult to value. Many books have been written to provide guidelines for the valuation of costs and benefits in such projects. Hufschmidt et al. (1983) were among the first to categorize valuation approaches. They divided valuation approaches into three categories:

- 'conventional market prices', or 'market value / productivity approaches';
- 'implicit market prices', or 'market values of substitutes (surrogates)';
- 'artificial market prices', or 'values derived from hypothetical or contingent valuation'.

Where costs and benefits of certain goods or services can be assessed on the basis of market prices and these market prices adequately reflect the willingness to pay, the first group of methods can be applied. Market prices are generally easy to observe and readily accepted by decision-makers. Opportunity costs may have to be estimated, for some items (e.g. unskilled, underemployed labour), if market prices do not reflect the willingness to pay. The 'effect on production'(EOP) approach is the most widely used valuation technique, but the 'preventive expenditure'(PE) and 'replacement cost'(RC) methods, also belonging to the first category, are also useful for SCWD projects (Dixon et al., 1989).

Where costs and benefits can not directly be estimated through market prices, one could look for clear substitutes which do have market prices (surrogate or hedonic prices). The most common in this category is the 'property value' approach. The economic importance of soil loss could be assessed by comparing the market price of eroded upland fields with those unaffected by erosion. A similar method is the 'wage differential' method. Both methods are hard to apply in developing countries, since property and labour markets tend to be imperfect, and choices constrained by income and information (Winpenny, 1991). A useful tool for valuing recreational benefits, but largely restricted to that, is the 'travel cost method', that rests on the observed behaviour of people.

When no direct market prices are available and no substitutes can be identified for which market prices exist, it may be possible to obtain some value information by means of surveys, or through expert judgement (Contingent Valuation, CV). In case of trade-off or bidding games, a sample of households is asked, for example, to what extent they would reduce their sheep and goat herd in case of a certain grazing fee per animal, or what (fictive) fee they would be willing to pay for visiting a nature reserve. It could in exceptional circumstances be used for SCWD-projects. However, results from CV studies depend heavily on how well the studies are designed, carried out and interpreted (Hanley and Spash, 1993).

Possible attributes of efficiency criteria

The most common attributes of the efficiency criteria are on the benefit or income side the marketable and non-marketable goods, and on the cost side the costs of labour and of man-made and natural resources (Table 4.4). For SCWD projects it is important that effects of these attributes are specified according to time (accruing to present and future generations), and to space (upland and downstream population).

Although it may require detailed calculations with data over several years and may have to be based on expert estimates, the effects of erosion, sedimentation and changes in streamflow could eventually be translated in costs and benefits, in monetary terms, accruing to the respective groups. For the assessment of changes in flood damages, use has to be made of probability analysis techniques (Chapter 7).

Table 4.4 *Attributes of efficiency criterion and possibility to value them in monetary terms*

Attributes	Valuation in monetary terms
Direct, on-site effects	
Marketable production (local or export)	Easy
Non-marketable production	Possible
Investments and maintenance costs	Easy
Production costs	Easy
Increased self-sufficiency in food	Indirectly
Productivity losses due to on-site erosion	Indirectly
Indirect, downstream effects	
Productivity losses due to sedimentation	Difficult
Productivity losses due to changes in streamflow	Difficult
Flood damages	Difficult

4.5 Intra-temporal and inter-temporal equity

There are two arguments to consider equity as a criteria next to efficiency, and both are often relevant for SCWD projects. As discussed in Section 4.3, projects may affect (the existing) income distribution, and when a nation strives towards a more equal income distribution, this could also be reflected in the selection of projects. This is referred to as the *intra-temporal or intra-generational equity* criterion. While one generally refers to income differences among social groups (on the basis of income, gender, etc), one could also distinguish a separate spatial equity concept, focusing specifically on income differences between regions. In developing countries there is often a close link between land degradation and poverty, which have been described as two sides of the same coin. SCWD projects often operate in relatively backward upland areas. These projects may affect income distribution in two contradictory ways. By imposing land use restrictions and erosion control measures they may further reduce net income in these areas, while simultaneously preventing income reductions in the low land (the conservation aspect). But SCWD projects also play a role in the development of these areas, and usually provide the upland farmers with much needed incentives. Downstream beneficiaries could be asked to pay for these.

Income distribution is often presented by the 'Lorenz curve' and the Gini-coefficient. This coefficient serves well to compare the income distribution between countries. But the Pareto- and Theil coefficients are more sensitive to change, and therefore more often used to compare income distribution between sectors, industries, etc. (Pen and Tinbergen, 1977). Much use is also made of 'deciles', 'quartiles' and 'percentiles', showing the share of income falling to the respective income groups of households. In rural development and SCWD projects such data may not be available however. The rural population could then be roughly divided in such categories as: traders, landless labourers, small-, medium- and large farmers. The qualification small and large should then not only refer to farm (land) size, but to all resources from which income is derived. One can take the distributional analysis a step further and assign weights to benefits received and costs borne by various social groups. The assignment of these weights is however a subjective decision, and should be provided by the decision maker. A third approach would be to set constraints on the allowable distribution of costs and benefits among different groups (Dixon et al., 1986).

Secondly there is the *inter-temporal or inter-generational* distribution of income, which relates to the present choice between consumption and savings. Although they have few means to save and aim first at self-sufficiency in basic amenities, small farmers in developing countries do also think of their own future and that of their children. They pay school fees, keep cattle and plant trees, such as olive (Tunisia), teak and jackfruit (Indonesia), that only reach maturity after periods of twenty years or more.

However, disadvantaged rural poor in desolate areas may become desperate in looking for food, water and firewood. Their individual time preference rates may then rise to levels that become meaningless to refer to in cost-benefit analysis (Riezebos, 1989).

At national level domestic investment and national savings can be used as aggregate indicators of inter-temporal income distribution. National savings have been very low in many Sub-Saharan countries. For this region as a whole national savings were in the 1980's only about 8 % of GDP, in comparison to a world average of 21 % (World Bank, 1990).

Summarizing, one could distinguish three considerations which have repercussions for the analysis (Table 4.5). The market mechanism is not usually able to deal with these three equity considerations, and governments have to apply the necessary redistributing measures and policies.

Table 4.5 *Type of equity considerations and there consequences for analysis*

Type of equity considerations	:	Consequences for analysis
Intra-generational equity		
- Social equity	:	Distinguish social groups
- Interregional equity	:	Consider downstream effects
Inter-generational equity	:	Consider future generations' interests

Discounting

In CBA all streams of future costs and benefits are discounted to their present value. Discounting cash flows is based on two principles: social time preference, or aggregated personal time preference (one prefers a certain amount of dollars today over the same amount next year), and social opportunity cost (positive returns on investment). Diminishing marginal utility, also mentioned as a reason for discounting, is equivalent to time preference. It presupposes that future generations will be more affluent. It is essentially a weighting process between present and future income. For (public) development projects use is made of the social rate of discount, obtained by aggregating all private discount rates. If the social rate of discount is perfectly chosen, the investment in projects justified by it would just equal the savings society as a whole is willing to make.

Although generally applied, the practice of discounting is much debated. Because of their high initial costs and late benefits, SCWD and other sustainability-oriented projects show a low return in CBA. Therefore the discussion on how to integrate environmental factors into the appraisal of such projects has largely focused on adjusting discount rates or changing the discounting technique.

Some authors wonder whether we really can determine the discount rate. Price (1993) argues that there is in fact a *numéraire*, or reference denominator of value, for each good and for each recipient of income, and therefore potentially a different discount rate too. This is reflected, for example, by the fact that wealthy farmers plant more trees than poor farmers. Price (1993) further states that we can not predict whether and how we will experience expected effects. Circumstances, perceptions and tastes change over time. Hueting (1991) adds that the intensity of preferences for the future availability of functions cannot be established, and that therefore the level of the discount rates, when calculating long-term environmental effects, can not be set.

Other authors have made propositions to adjust discount rates for environmental projects, and to lower them to reflect the interests of future generations. However, it is difficult to indicate which project would qualify for such 'special treatment' and it may result in the implementation of too many projects.

Instead of adapting the discount rate, other correction procedures have also been suggested for long term environmental investments. Pearce and Turner (1990) propose applying a 'rate of demand growth' correction factor (Krutilla-Fisher approach) for preservation benefits (producing an effect similar to lowering of the discount rate) and a 'set of compensating investments', to maintain the flow of services from a given stock of environmental goods. Weisbrod (1964) introduced the concept of 'option value', to be considered in addition to the normal 'user value'. This concept is more useful in dealing with the loss of unique parks or other recreational sites, than in the case of losing agricultural land. Since park owners find it hard to capture such 'option value', the concept has not been applied in financial cost-benefit analysis (Conrad and Clarke, 1987).

Finally, since it constitutes a problem of inter-temporal external effects, several authors have wondered how we can deal with these future generations. As the major group of actors in such projects, they do not have a stake in the decision-making process nor, when applying discount rates of 10 % or higher, do they have any influence on the present relative scarcity. Under conditions of irreversible land degradation one can argue that the value of the remaining land is likely to increase in the future, but the effects thereof are not very significant, since land degradation is a slow process.

In his damage function model, Walker (1982) considered a planning period of 75 years: 25 years for the present farmer and 50 years for the next two generations. He compared conventional tillage, causing an annual erosion of 34 t/ha, with minimum tillage, that reduced erosion to 4 t/ha, but resulted in 3 % lower yields. He applied a discount rate of 4 %.

Klaassen and Iwema (1981) have proposed the introduction of a generation preference factor in the rate of discount formula, which should show how much importance the present generation attaches to the well-being of next generations. In extreme cases of irreversibility and long term benefits it may lower the discount rate to zero.

Cooper (1981) proposed, on the other hand, determining NPV's with multiple base years, for example also using year 30 as base year, in order to show the results of a project from the point of view of the next generation. This concept has been applied by Janvry et al. (1994) for a watershed development project in the Dominican Republic.

A reduction in the discount rate for the next generation has also been suggested, among others by Kula (1988a). Kula (1988b) argues that the use of ordinary discounting is wrong, since this assumes that society resembles a single individual with an eternal life. His modified discounting factor therefore takes into account life expectancy and the estimated lifetime of the public sector project concerned. Although his so-called 'modified discounting method (MDM)' has interesting features, his suggestion has met with convincing theoretical objections, among others by Price (1989).

In their review on the choice of the discount rate, Markandya and Pearce (1988) look at the actual situation of the components of the consumption rate of interest in sub-Saharan countries. For the low and the middle income countries in that region growth in real consumption was negative (-1.9 % and -0.1 % respectively). Taking a typical estimate of the elasticity of the marginal utility of consumption of -1, and a rather high pure rate of time preference of 5 %, social time preference rates in these two groups of countries would only be 3.1 and 4.9 %. Taking into account such evidence and the many uncertainties in choosing a discount rate, Riezebos (1989) suggests lowering discount rates and applying a rate of between 3 - 7 % : the lower for poorly endowed countries (e.g. Sahelian countries), the higher for countries showing high real growth (South-East Asia).

With regard to the *irreversible development* issue, Porter (1982) makes a distinction between the net development benefits (D) and the loss of environmental amenity services, or preservation (P). The net present value over an unlimited period will be:

$NPV = D/r - P/r - C$; where C constitutes the initial investment and r the discount rate. NPV would normally be higher at lower discount rates, but this assumes that D and P will remain constant over time. He argues that, because of its absolute fixed supply (which cannot be influenced by capital accumulation or technical progress), the demand for environmental services will increase over time:

$P_t = P(1+a)^{t-1}$; where a is the exponential growth rate.

On the other hand development benefits are more likely to decline over time:

$D_t = D(1-b)^{t-1}$

As a result the preservation project's NPV over an unlimited period will be:

$NPV = (D/r+b) - (P/r-a) - C$

In that case the project can fail the NPV test on account of both high or low discount rates. With high rates the heavily discounted development benefits may not offset the costs, and at low rates the exponentially growing benefits of preservation are so little discounted that their perpetual loss becomes too great a cost for the development project to shoulder.

Attributes of equity criterion

Social cost-benefit analysis could be applied when much weight is attached to intra- and/or inter-generational equity considerations, but it is not often practised because of the reluctancy of policy-makers to define income distribution weights and because of a lack of adequate data on income differentials (Table 4.6).

It is usually easier to make a separate analysis of the participation rates of target groups and show the effects of SCWD activities in the financial analysis for the respective groups that are affected by the activities (Chapter 5).

The sensitivity of effects of activities on inter-generational equity could be checked in CBA by applying different discount rates and/or different base years, and in the application of MCA methods, one can assess what weight the respective social groups attach to returns obtained in the future. As will be shown in Section 4.6, the inter-generational equity criterion is closely linked to the conservation criterion.

Table 4.6 *Attributes of equity criterion and possibility to value them in monetary terms*

Attributes	Valuation in monetary terms
Intra-generational equity	
Income to different social groups	Complicated
Income to upland and downstream areas	Complicated
Inter-generational equity	
Income to present and future generations	Complicated

4.6 Conservation and ecological sustainability

At the turn of the nineteenth century (1890 - 1920) the Conservation Movement emerged in the United States, which originally focused on natural resources but later on evolved into a more diverse political movement, led by President Theodore Roosevelt. The movement was much influenced by views of Marsch (1865), regarding the complexity of nature-man interactions, and was probably triggered off by the threat of timber shortage. From the Conservationists' ideas about the efficient use of natural resources, Barnett and Morse (1962) derived different forms of 'waste' or 'inefficient use'. The first results from not using the resources in the proper order of priority. They argued that the following rules should be applied:

- The regenerative capacity or potential of renewable resources should not be physically damaged or destroyed;
- Where possible, renewable resources should be used instead of minerals;
- Plentiful (mineral) resources should be used before less plentiful ones;

Page (1977) added what he called a 'modern stressed dictum':

- Non-renewable resources should be as much as possible recycled.

On the other hand the Conservationists also stipulated that (renewable) resources like fish, timber and hydropower should be used to the limits of their sustained physical yield. This maximum sustainable yield was later defined by Samuelson (1966) as 'that perpetually repeatable (or steady state) yield with the maximum yield net of management costs averaged over the production cycle' (without discounting).

One of the important practical contributions of the Conservation movement was the start of a programme to inventory the natural resource wealth in the U.S.

The second rule, mentioned above, may relate among others to the present discussion about soil fertility maintenance and the nutrient drain in the semi-arid zones: where possible use should be made of local, renewable fertilizer materials.

Page (1977) makes a distinction between three type of economies, which differ in their main resources and in the options they offer to future generations. The first has only *hardtack*, a non-renewable resource, for which a depletion strategy has to be worked out; the second has the renewable resource *corn* as its main resource, and has to decide to what extent its stocks are used for consumption or production, and the third or '*manna*' economy lives off renewable resources by hunting and gathering (traditional societies with no population growth). The latter could also be referred to as the recycle economy, or a form of 'spaceship earth' (Boulding, 1966). The conservationist wants to keep the economy in its corn or manna regimes, and to prevent it from drifting into the hardtack one, and will therefore establish the necessary institutions and incentives.

Deviation from efficient use of natural resources

In modern welfare economics attempts are made to explain why natural resources often do not respond to market forces. Three main reasons are given: the external effects of production and consumption, the public goods nature and the common property nature of some resources (Castle et al., 1981). All three play an important role in SCWD projects.

External effects

There are two arguments for considering a separate ecological sustainability or conservation criterion in SCWD projects. Both relate to external effects that are very hard to quantify and to value in an economic appraisal. There is the issue of irreversible land degradation, resulting in production losses in the far future (the on-site, inter-generational issue), and there are the downstream effects of erosion that affect the downstream community. Normally, the consequences of the latter are also felt in the distant future. One could also refer to external effects according to time and space.

Public goods

Land and water resources show features of public goods: commodities that are there to be used or 'consumed' by everybody in a society (Common, 1988). One could argue that services derived from land and water resources (e.g. food and drinking water) should be made available or even guaranteed to society in a manner similar to health services and services of defence and police forces. This position is still held in many developing countries, whose traditional societies believe that land belongs to past, present and future generations (Ballendux, 1968). While in many countries land is increasingly moving into private ownership, some countries have declared that all land belongs to the nation.

Common property

Land and water are de facto often what some call (wrongly) 'common property resources'. Pearce et al. (1989) refer to 'open access resources'. These are non-exclusive, non-divisible resources. Decisions about their use cannot be taken individually or by any group.

Weak and strong sustainability

With regard to ecological sustainability and here the conservation of the functions of land and water resources, there are two broad schools of thoughts, or two interpretations. These are generally referred to as 'weak' and 'strong' sustainability. Those in favour of the first interpretation argue that sustainability is already reached when the total capital stock, including both man-made and natural capital, does not decline. Man-made capital may be a substitute for natural capital (Bojö et al., 1990). Those in favour of 'strong' sustainability state that neither the natural capital stock nor the man-made capital stock should decline. They view the two types of capital as complementary and do not agree that man-made capital can be an unlimited substitute for natural capital.

One could distinguish different categories of natural capital stock. Land is in principle in fixed supply, but land can be (re)claimed from the sea, at high cost in terms of man-made capital. Some functions of natural forests can be performed by man-made forests, but not all.

Sustainability should always be defined according to time and space. In the Sahel many efforts are being made to regain the productivity of some farm land, by controlling erosion with stone rows and applying mulch, manure, etc. to increase soil fertility. However, stones, mulch and manure are removed from other pieces of land and the functions of these may decline. When only manure is used to maintain soil fertility not less than 15 - 20 ha of commons per ha of cropped land are needed (Breman and Traoré, 1987). Such strategies can be followed deliberately, as in 'run-off farming' (in Tunisia called *meskat*): the upper part of a piece of sloping land is given up as farm land and functions solely to accumulate water for a parcel downstream. The cost of depriving this land of its former functions should be fully taken into account. Whereas this is usually considered in cost-benefit analysis of run-off farming, it is seldom done in the Sahelian situation above.

While it is already difficult to express some attributes of the efficiency and equity criteria in monetary terms, this is even harder for possible attributes of the conservation criterion (Table 4.7). The 'effect on production' and 'replacement cost' valuation methods can be used sometimes, but this presupposes that the yield response of measures (EOP) can be determined and that no loss of functions occurs with replacement (RC).

Table 4.7 *Attributes of conservation criterion and possibility to value them in monetary terms*

Attributes	**Parameter(s)**	**Valuation in monetary terms**
Conserving functions of land		
Erosion control	- soil depth	EOP-approach
Fertility maintenance	- nutrient balances	RC-approach
	- org. mat. content	Difficult
Physical degradation	- perc. crusting	Difficult
Conserving functions of water		
Water supply	- streamflow; Qmin/Qmax ratio	Difficult
Flooding	- peakflow	Probab. anal.
Sedimentation	- channel/reservoir capacity	Difficult
Hydroelectricity	- streamflow; Qmin/Qmax ratio	Difficult
Conserving functions of vegetation		
Wood supply	- sustainable annual yield	EOP approach
Bio-diversity	- number of species	Very hard

Conclusions

The review of the main evaluation methods with their different features and suitability for the appraisal of SCWD projects, clearly shows the strengths and weaknesses of both CBA and MCA. CBA constitutes a uniform method, with which the efficiency (and equity) of projects of different type and different time frame can be compared conveniently on the basis of money as the single numéraire. However, CBA requires that all major effects are expressed in monetary units, and for SCWD projects this is often hard to do, certainly for effects on the conservation criterion. Nevertheless, attempts are made in this study to develop methods for calculating the on-site and downstream benefits of SCWD activities in monetary terms (Chapters 6 and 7). These methods are applied in the case studies in Chapters 9 and 10. In these applications discount rates are applied ranging from 0 to 10 % as a form of sensitivity analysis.

On the other hand, MCA has the ability to clearly present potentially conflicting views of different actors. In selecting options attention can then be paid both to the highest possible scores on the evaluation criteria and to the reconciliation of opposing views. MCA can deal with both quantitative and qualitative scores of attributes, which is of particular importance for the attributes of the conservation criterion. The drawback with MCA is that it does not include an efficiency test.

In the case studies use is also made of MCA methods, partly for comparing the results with the two evaluation methods, and partly to see how both methods could complement each other.

PART II

IMPACT ANALYSIS OF SOIL CONSERVATION AND WATERSHED DEVELOPMENT ACTIVITIES

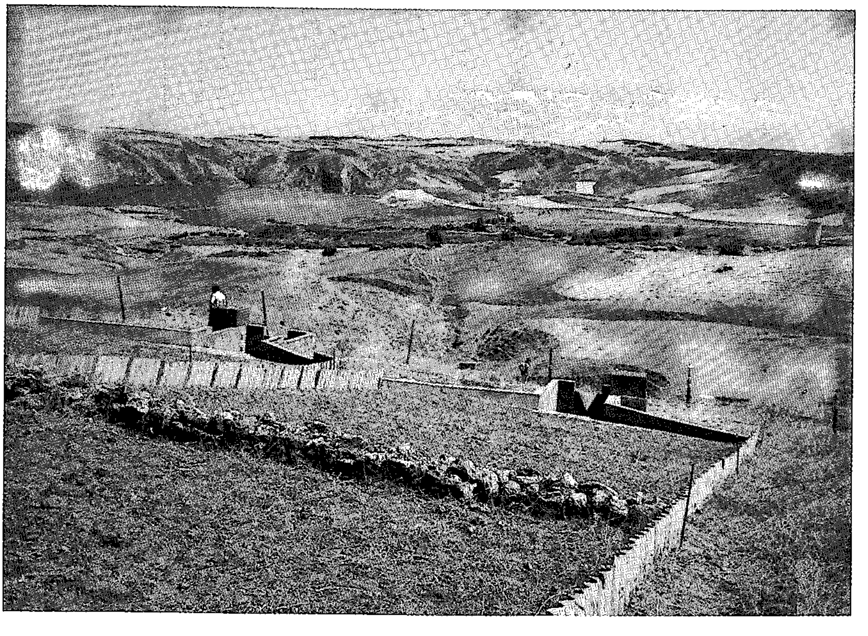


Plate 2 *Erosion research on slopes above Sidi-Salem reservoir, Tunisia*

5 FROM FARM ANALYSIS TO WATERSHED LEVEL ANALYSIS

Things are complicated in this world and are determined by many different factors. We should look at a problem from different points of view and not from one point of view only (Mao Tse-Tung, The Little Red Book).

5.1 Impact assessment and actors concerned

Impact assessment is applied to determine the overall effects of alternatives on selected criteria in an evaluation. In the case of SCWD projects, it requires a good understanding of pre-project ecological, economic, social and institutional circumstances in the watershed area, and of underlying trends and fluctuations around them.

The natural environment also changes in the absence of human interventions. These changes can be irreversible (e.g. natural or geological erosion), cyclic or transient (droughts). When assessing the human-induced effects of SCWD activities, one should be aware of these natural changes.

Human actions, such as SCWD activities, cause environmental effects, that in turn produce environmental impacts. Munn (1975) defines *environmental effects* as 'a process set in motion or accelerated by man's actions' and *environmental impact* as 'the net change in wellbeing of people (and their ecosystem), resulting from an environmental effect'. Wellbeing could be interpreted in a comprehensive way, including economic, social, cultural, psychological, health and aesthetic aspects. Here the emphasis is laid on wellbeing in economic terms, incorporating social and ecological aspects (Chapter 4).

The primary or direct effects of SCWD activities are mainly physical effects, which can be translated into economic terms (as costs or benefits) which have positive or negative impacts on certain categories of people (actors). However, it is not always easy to assess which part of a change in production can be ascribed to the effects of erosion control measures and which part is due to other factors, such as the use of inputs and new technology (Diemont et al., 1991; de Graaff and Wiersum, 1992).

The physical effects of SCWD activities are here broadly divided into the direct *on-site* effects (Chapter 6) and the indirect *downstream* effects (Chapter 7). For the on-site effects of erosion, information is required about erosion factors and on-site water and nutrient balances and for downstream effects also about the hydrological system. This requires hydrological and erosion research data. For the assessment of the subsequent net impact on production and income, information is required about the farm household population, their farm and non-farm enterprises, their resources and resource utilisation, etc. This type of data can be derived from agro-economic baseline surveys. For each SCWD component one can assess the physical effects first and subsequently the resulting impact on production and income for the actors concerned (Table 5.1).

It should be realized that SCWD activities have only a certain probability of producing the (targeted) physical effects. And the impact thereof can only be assessed when one knows which actors will be affected and how these will react to the effects. Depending on rainfall patterns stone rows may in one year out of three have a very positive effect on plant water availability, in another year a slightly positive effect and in the third year a slightly negative effect (waterlogging). Some farmers may judge such probable overall improvements sufficient to participate, while others may find it too risky.

Table 5.1 *Effects and impact of SCWD activities*

Location	Physical effects	Economic effects/impact	Impact on wellbeing of
- On-site inputs	Labour inputs Material inputs	Opportunity costs Cash expenditures	Upland farmer and government
- On-site effects	On soil losses On water balance On nutrient balance On organic matter On groundwater recharge	Production/income On-site & down-stream water supply	Upland farmer, traders and downstream neighbours
- Downstream Lowland	Reduced peak flow Reduced sediment.	Less flood damage Less damage in channels/floodplain	Downstream population
- Downstream Reservoir	Stabilized stream flow Reduced sediment. Better water quality	More irrigated prod. More hydropower More drinking water Less purific. costs Better health	Lowland farmer, and downstream population

In the preparation phase of SCWD projects one needs to investigate for each potential SCWD component successively: the (average) extent of the physical effects, the variability of these effects and the probability of exceeding peak values, over some period of time. Finally one should assess which components comply with the objectives, priorities and constraints of the respective categories of actors.

Identification of actors

Pre-project impact assessment starts with an analysis of the potential involvement of respective actors in activities (or components) that form part of the project alternatives. Which groups of farm households and other actors are likely to participate in or to be affected by each of the activities? Under which conditions will these groups participate and to what extent are some groups positively or negatively affected by activities?

Most components of SCWD projects enable land users to apply more sustainable land use systems and/or their technology. These land users or farm households, that used to contribute to land degradation, are usually the target group or primary actors. In some areas land is still 'under-used' or used beyond land capability and the land can be used more intensively by land users without affecting others. In most other areas, however, land use changes not only affect the land user him/herself, but also other people. Land that is terraced normally requires waterways that will also pass through land of downstream neighbours. When shrubland is reforested in densely populated areas, people can no longer collect firewood and fodder from this particular piece of land (Chapter 10), and have to fetch it from elsewhere. In the past watershed projects often prescribed major land use shifts, which could only be effected by relocating a sizeable number of people (Veloz et al., 1985). Examples are settlement projects along the Volta Rivers in Burkina Faso and in valleys in Jamaica, transmigration schemes in Indonesia, etc. Because of the many adverse effects of such large operations, less drastic solutions are nowadays preferred.

It is seldom taken into account that projects only reach part of the target group. Some non-participants find themselves in a disadvantaged position. They lack the assistance and would have to bear the full costs when they undertake the activity themselves at a later stage. Asked why they did not participate in any SCWD activity in the Konto River watershed in Indonesia, many non-participants answered apologetically that they were 'not selected as participants, although they were listed as candidates' (de Graaff and Zaeni, 1989). Some farmers in this area said that they had even worked voluntarily as forest labourer in order that the Forest service would list them as participant in agro-forestry schemes.

Many other categories of actors can be distinguished. There are many groups that indirectly benefit from the programme, such as the consumers and users of water and electricity downstream (secondary actors). Apart from beneficiaries, some groups are also negatively affected, such as constructors and fishermen who needed the downstream silt. Finally, there are those involved in the organisation and the implementation of the programme, such as extension workers and loan officers (functional actors), and those responsible for planning and policy making at local, regional, national and international level (policy makers).

While the major focus in the evaluation, and in particular in the financial analysis, will be on farm households, attention needs also to be given to groups of secondary actors and of functional actors (extension agents, credit agencies, traders, etc). In all four case studies the initiatives for soil and water conservation came from projects and government services concerned. Local extension agents and village elders also played a major role in site selection and indirectly in the selection of participating farmers.

For each component of a SCWD project a balance sheet could be drawn up, indicating all actors that gain and all those that lose from the intervention. For this purpose use could be made of the Planning Balance Sheet Analysis method (Lichfield, 1988).

Table 5.2 *The actors, the effects on them, and their objectives and preferences*

Group of actors	Component X			Actors' aims	Alternatives		
	Physical impact	Effect (output)	Impact on activities		1	2	3
Upland farm A							
Upland farm B							
Downstr. farms							
Traders							
Gov't agency P							
Gov't agency Q							

The group of actors, referred to by Lichfield as 'Community sectors', form the basis of the classification. The physical effects that the proposed project activities may have are advocated as well as the impact these effects may have on the activities of the individuals within each group (Table 5.2). On the basis of this impact of components, and the objectives and preferences of the actors, the alternatives can already be screened.

Whatever effects land degradation and conservation activities may bring about, what matters is how the people concerned value the impact of these effects. One has to identify whose welfare (in its broadest sense) will be affected, in what way, and the extent to which the different groups will be made better or worse off under each of the alternatives. Lichfield and Lichfield (1992) refer to this as 'community impact analysis'.

Box 5.1 *Farmer participation in Kingston watershed development*

Since the 1930's the Jamaican Government has had difficulties coping with the domestic water demand of Kingston, the supply of which depends to a large extent on surface water stored in the Hermitage and Mona reservoirs. As a result of the high rainfall intensity, the steep Blue Mountain slopes and the erodible soils, 'natural' soil erosion is already quite high in the watershed areas surrounding Kingston (Barker and McGregor, 1988). About 80% of the land is privately owned and mainly operated by smallholders. With their cultivation methods they contribute considerably to soil erosion. The resulting sedimentation has greatly reduced the capacity of the reservoirs.

A FAO project was therefore asked in 1980 to prepare detailed plans, including economic analyses for the integrated development of the nine watersheds areas concerned (FAO, 1982a). It was expected that these plans would be followed by large or even full-scale implementation, assuming a near to 100% participation.

The project did design various physical and vegetative soil conservation measures and tested their technical and socio-economic viability in two pilot demonstration areas. In the first area a 'block'-approach was followed in order to cover the whole of the 35 ha sub-watershed with conservation measures. Already during its implementation it became apparent that this approach would fail in such areas: despite generous incentives only a few of the farm households were prepared to participate (In 1993 it was found that only some of the tree crop plantations had survived and few of the physical measures). In the second pilot zone an approach was followed, whereby attention was mainly focused on improving land use by full-time farmers who had individually asked for assistance.

Meanwhile the 1980 socio-economic survey in the watershed areas showed that 45% of the rural households had only tiny plots of land and were not much engaged in farming. Subsequently a detailed sample survey among 360 farm households (from the other 55% of rural households) showed that only a quarter of these were full-time farmers, keen on developing and conserving their farm land (Appendix 10.2). Most other farmers were either more involved in off-farm activities or too old or not much interested in farm development, and they were not likely to engage in rather expensive soil conservation measures.

While the detailed planning and mapping of the watershed areas was completed, a small follow-up project was identified and prepared for part of the area, with an estimated farmer participation rate of 20%. The eventual follow-up project was mainly directed towards coffee and cocoa production (and partly to off-farm employment). After a few years the number of project participants in these watershed areas amounted to 870 farm households, or 14% of total farm and 8% of total rural households. This result was quite different from the original idea of full-scale implementation (Section 10.7).

Estimating participation rates

One of the alternatives in Table 5.2 could be defined as 'no action', indicating that the component for one reason or the other does not fit in with the actor's objectives, and that he prefers not to participate.

Participation analysis is an important and often crucial part of project preparation for most projects and certainly for SCWD projects. Estimated rates of participation may be based upon participation in similar activities in other areas or in the past, under more or less the same circumstances. However, the activities are often not similar (e.g. new technology), the areas are different and circumstances may change rapidly. SCWD projects should preferably be preceded by an inception phase, not only for erosion and socio-economic studies (Chapter 8), but also for some pilot implementation to test the measures on their effectiveness and acceptability to farmers. In the appraisal of SCWD projects participation rates should be used as one of the parameters for sensitivity analysis.

Box 5.1 illustrates the importance of base line socio-economic studies and of pilot implementation in the project preparation phase, in order to assess participation rates.

5.2 'Upscaling' from field to watershed level

In order to aggregate production and erosion changes at the field level to the watershed level, it is necessary to analyze the four main features of agro-ecosystems: space, time, flows and decision-making, as indicated by Conway (1986). Recently much attention has been focused on the space within which effects of development activities are likely to occur and to the time period, during which the direct and indirect effects will be felt (Fresco and Kroonenberg, 1992). The actual scale(s) applied in impact assessment should be derived from the objectives of the activity or project. However, the further away effects occur in time and in space, the more questionable becomes their inclusion in impact assessment.

In watersheds or upland agro-ecosystems the flow of water and the related processes of soil erosion should play a crucial role in aggregation, as should the flows of inputs and outputs in physical and monetary terms. The upscaling of water flows, with their sediment load (presenting the downstream consequences) is discussed in Chapter 7. The fourth issue in upscaling is how to deal with the decision-making by many individual actors involved in SCWD activities. This is discussed in Section 5.3.

Time scale or phases of impact

With regard to the time dimension of SCWD activities, or the phases of impacts, one can distinguish three main periods. Firstly there is the *establishment phase*, which is here defined as the period from construction or planting, until the measure becomes effective. Conservation measures, involving earth movement, disturb the soil and are not immediately effective after construction. Vegetative measures need some time to cover the soil and often require some replanting in the second or third year. In this first period all investment costs occur.

The second period concerns the *effective life* of the SCWD measure, during which it effectively performs its main function(s). It equals either its physical or its economic lifetime, whichever is the shortest. While check dams as physical structures may last for a very long time, they cease to perform their function as sediment trap, once sediment reaches the crest of the dam. Earth bunds may disintegrate over the years and become gradually less effective. The economic lifetime of interventions may be shorter than the physical lifetime, when their functions are taken over by new techniques (e.g. with the change from basin to drip irrigation terraces are no longer essential).

The physical lifetime of most soil conservation measures and watershed development activities ranges between 5 - 30 years, as long as the structures and vegetation are well maintained (Table 5.3). During this period secondary economic impacts may also occur (backward and forward linkages and multiplier effects), but in SCWD projects these only become important in the distant future, since the conservation activities often imply certain

Table 5.3 *The physical lifetime of SCWD interventions*

SCWD interventions	Life time (range of years)	Establishment period (before effective)
Earth bunds and hillside ditches	5 - 10	1 - 2 years
Idem, planted with grass or shrubs	7 - 15	2 years
Stone rows	10 - 20	< 1 year
Earth bench terraces	10 - 25	2 years
Bench terraces with stone walls	15 - 30	2 years
Check dams for gully control	10 - 30	1 - 2 years
Check dams for sediment trap	1 - 7	< 1 year
Grass strips	3 - 8	< 1 year
Hedges	5 - 15	1 - 3 years
Tree crops[1)]	10 - 50	2 - 5 years
Forest plantations[1)]	10 - 50	2 - 5 years

1) In exceptional cases up to 100 years (e.g. olive, teak).

restrictions on resource use. Such impacts could be assessed through the use of input-output models, which receive much attention in the French evaluation method: *Méthode des effets* (Wiener and Chervel, 1986).

While the direct effects of measures will disappear after expiration of the lifetime of interventions, the impact of certain effects can last longer (*post measures impact period*). While there may be no more effects on the on-site water balance after disappearance of the measure, the effects of losses of soil, nutrients and organic matter, may still be felt for a long time, as may be the effects of accumulated sediment in reservoirs. Much of the secondary economic impacts of SCWD activities are also likely to occur during this post measures period.

However, the analysis undertaken for project appraisal is usually of a descriptive nature only, and does not include very detailed exploratory studies and predictive models. It is therefore hard to make a long term assessment of impacts (after Rabbinge and Ittersum, 1994). It is also hard to predict how these impacts will affect future generations.

For this reason, the period considered for impact assessment should normally not exceed 30 years, and exceptionally 50 years for certain tree plantations. This is the case even without considering the argument that discounting would anyhow severely reduce the weight attached to long term effects. In other words, the effects of most SCWD activities should be analyzed for as long as one generation, and the situation (comprising the state of the natural resources) at the end of this period can be considered as the starting point for the next generation. One can either include the change in resources as an attribute of the sustainability criterion (in multi-criteria analysis) or add in CBA the costs and benefits for the next generations, making assumptions about their response.

While the effective life and impact period of SCWD activities could be derived from technical and economical data or from past experience, the ideas of the actors concerned should also be taken into account. Farm households in developing countries often base their decisions primarily on short term effects and prefer activities with an early return on investment, whatever the overall rate of return.

A problem arises in an appraisal when activities with a different lifetime have to be compared. The lifetime of bench-terraces is, for example, about twice that of hedges. Reinvestment could then be considered (e.g. for hedges in year 11), phased implementation or the calculation of a rest value for the longest lasting intervention.

Spatial aspects of impact assessment

At field and also at farm level one can only analyze the on-site costs and benefits of certain interventions. Off-site effects cannot be considered and prices, policies and institutional arrangements cannot be influenced. In their decision-making farmers generally have to take for granted the existing local, regional and national institutional context.

In order to 'internalize' the off-site or down stream effects of development activities, one should consider that area, within which the majority of these effects can be expected. With soil erosion considered as major adverse effect, such an area would usually consist of a *watershed*, as defined in Chapter 1. Although more important in the humid and sub-humid zones with their steep slopes, the watershed approach is also applied in semi-arid zones (e.g. in India). In francophone West-African countries, the concept of *Gestion de Terroir* is increasingly used, in the sense of integrated management of natural resources in a well-defined area. Depending on physical aspects of the land (e.g. topography) and administrative boundaries, this could either encompass a village, a (sub-)watershed or a district or any other region. When livestock plays a major role in soil fertility maintenance, the livestock migration patterns should also be considered.

Table 5.4 *Hierarchy of spatial levels for impact assessment*

Level		Analytical focal points	
Main levels	Sub-levels	Physical	Socio-economic
Field (LUST's)	Enterprise combinations	On-site effects	Gender differ.
Farm patterns		Intra-farm effects	
	Farm groups		Group action
Village		Village resource use	
	Sub-watershed	Agro-ecological zones	
District/sub-region			
	Watershed	Downstream effects	
Province/region			Regional plans
	River basin	Downstream impact	
Country			National policies (land/water resources)

Table 5.4 shows the various spatial levels that can play a role in impact assessment. The main levels range from the micro level (field and farm) through the meso level (village, district) to the macro level (country). These main levels coincide with administrative units, for which statistical data are compiled, facilitating upscaling. For SCWD activities and land use and biophysical studies in general the sub-levels play a central role. Apart from the hierarchical watershed levels, enterprise combinations and farm groups are mentioned at the lower levels. Sustainable farming often means focusing on a certain combination of LUST's: e.g. maize (for food, fodder and mulch), mulched coffee (for cash and soil conservation on steep land) and livestock (for food, cash and savings). Farm groups also often play an important role in initiating soil conservation activities. On the right hand side the focal points for analysis at the respective levels have been indicated.

When it has been analyzed which primary actors (farm patterns; see Section 5.3) will engage or participate in a SCWD activity, the respective LUST's of these farm patterns will form the starting point for impact assessment. For these LUST's the on-site physical effects (Chapter 6) can be analyzed and their economic impact (yield response). Subsequently one should assess how these changes affect the organisation and management of the farm patterns concerned (enterprise combinations). This could be undertaken by means of simple of more detailed farm models in spreadsheets and/or applying multi-objective linear programming.

Relations between farm patterns within the same sub-watershed then need to be studied, when the SCWD activity causes inter-farm effects, and subsequently the relations between the farm patterns and other actors within this sub-watershed.

Finally attention is paid to possible downstream effects. Figure 5.1 shows the framework used for the analysis of downstream effects of reforestation and other watershed development activities in the Konto River watershed in Indonesia (Chapter 10).

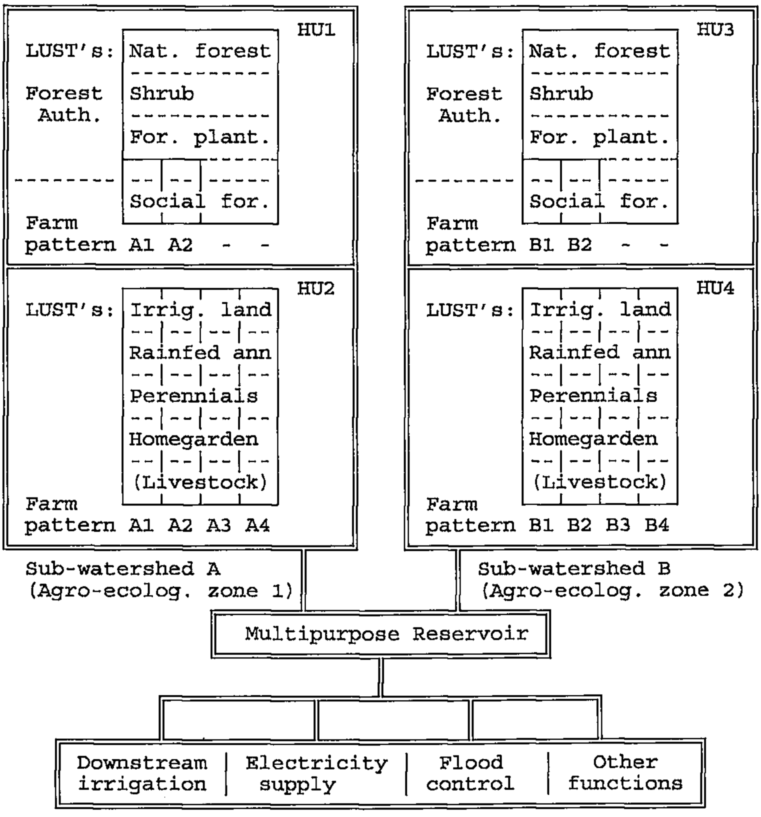


Figure 5.1 *Framework for downstream impact assessment of watershed development activities*

In this case four hierarchical levels played a major role in the analysis: LUST's (39), farm patterns (8; A1-B4), sub-watersheds (4; here referred to as hydrological units HU1-HU4) and the total watershed area. The watershed was first divided into two sub-watershed areas which coincided with two sub-districts and with two agro-ecological zones. Both areas were composed of an upper zone, forming part of the forest land and managed by the Forest Authority, and a lower zone, comprising the so-called 'village lands' or farm areas. The two upper and two lower zones were considered as separate hydrological units, within which it was necessary to study the effects on the hydrological balance (Chapter 7).

The case-study in the semi-arid zones of Burkina Faso, encompasses a limited number of LUST's, 13 different farm patterns, six villages and two provinces (Chapter 9).

Both with regard to the time and the spatial dimension, it is important to note that 'localised events' often cause the bulk of soil erosion, and form a difficulty in upscaling. While the localised 'hot spots' (e.g. squatters on very steep slopes) can be detected through aerial photo interpretation and field surveys, the occasional events (e.g. hurricane damage) can only be taken care of by analysing past events and using probability analysis.

5.3 Farm household patterns

For the preparation of agricultural projects or programmes it is important to develop first a typology of existing farm types. There are usually considerable differences between farms, which affect the way in which farms respond to project initiatives. Because of the wide range of farming systems in the world, reflecting different ecological and socio-economic circumstances, farm classification criteria may differ considerably from one area to another.

In developed countries a farm classification is first of all based on the *main agricultural enterprise*: grain production, livestock production, fruit or vegetable cultivation, or mixed farming (crops and livestock). Subsequently attention is then paid to the *size* of the enterprise(s) or farm. Since 1968 in the Netherlands this has been expressed in so-called *Standaard Bedrijfs Eenheden* (standard exploitation units) which constitute a normative measure of the amount of land, labour and capital involved in the farm production. Since 1978 a new typology has been in use in the European Community. This system distinguishes on the basis of enterprise gross margins eight main farm types: arable farming, tree crops, horticulture (annual crops), extensive (grazing) and intensive livestock systems and combinations of these. Farms can concentrate on one or two main enterprises, and within these main types not less than 54 sub-types are distinguished (Zeeuw et al., 1994). In Latin-American countries farm size is the most relevant classification criterion, because of the enormous differences in area farmed. In connection with that a distinction is also made between farms managed mainly with family labour and those operated largely with hired labour (de Groot, 1991).

In most tropical and subtropical areas a differentiation according to main farm enterprise and/or farm size may not be the most relevant. In semi-arid rural areas in poor developing countries farmers often have a similar mix of farm enterprises. A farm type classification is then usually based on the extent to which these farms are *integrated in the market economy*: subsistence farms, smallholders or peasants (partly producing for the market), emergent or semi-commercial farmers and purely commercial farmers. The *technology* available to these farmers is usually an important related criterion, with the first two categories relying on manual operations, the third to a certain extent on draft animal power and the last on mechanical power.

In regions with subsistence farming and tribal forms of land ownership, farm size may not be useful for a classification of farm households. Agro-economic household surveys in Burkina Faso showed large differences in farm size, but these were highly correlated with family size. The amount of land per capita showed little variation around a mean of about 0.45 ha, needed for self-sufficiency (de Graaff, 1995).

Another important criterion in marginal agricultural zones is the role of *non-farm activities*, which often become more important near urban centres. This was very clear in the

Jamaican case study area, where almost half of the rural households were for that reason not considered as farm households. In a semi-arid area in southern Spain a distinction is made between full-time, part-time and even spare-time (*a tiempo perdido*) farmers, since off-farm earnings in industry, trade and tourism generally outweigh the farm earnings.

Since in developing countries in particular no clear distinction can be made between the farm business as such and the other family affairs, one usually analyzes the total of farm and off-farm activities of a farm household, in order to better understand its resource utilisation for the farm business.

The starting point for a farm type classification could either be the 'farm' with resources available to the land user in quantitative terms, or the land user with his or her personality and objectives in qualitative terms. The first approach is here referred to as the *farm pattern* approach, while the second is the *farming styles* approach. The latter term was introduced by Hofstee, and is nowadays often applied by social scientists (van der Ploeg, 1989).

In the first approach the aim is to group farmers on the basis of production factors (land, labour, assets), combination of enterprises (crops, livestock and other activities), technology, etc. The second approach looks at such personal factors as readiness to accept risk, willingness to invest, initiative in solving problems, etc. It looks at the way farmers perceive their options and the strategies they develop. The emphasis is more on the differences in resource utilisation that result from these personal factors than from those that are related to resource availability. However, farming styles also often differ in resource availability. Roep and Roex (1992), in their study on farming styles and manure surpluses, make a distinction between 'practical farmers', 'thrifty farmers', 'cow farmers' and 'mechanized farmers'. In developing countries an important distinction would be that between farmers that see farming as an investment and those that see it merely as a way of life, or as a survival strategy. Another distinction would be that between those that choose either for intensification or for extensive farming systems.

The two above approaches could also be combined, to arrive at farm types that differ both in resources and in farmer personality characteristics:

FARM TYPE = FARM PATTERN + FARMING STYLE

Alfaro et al. (1994) first make a distinction between farmer types and subsequently between farm types: the first primarily based on objectives of the farmers (farming style), and the second on resource availability. In the Agrimaga case, in Costa Rica, 6 types of farmers were defined (e.g. investors, full-time farmers who occasionally hire labour), which were subdivided subsequently according to biophysical production factors.

Gittinger (1982) states that the financial analysis in the appraisal of agricultural projects requires the selection of major farm types that are expected to participate, to be followed by an analysis of the impact the project is likely to have on them. In an ex post economic evaluation it is possible to find out which farm types have actually participated, and to assess the impact that the project has had on these farm types, as long as base-line data have been collected prior to the implementation of the project activities. According to Gittinger (1982) about half a dozen or so 'pattern farm investment analyses' suffice in agricultural projects, but generalization is dangerous. The number depends on the complexity of the project and on availability of staff to undertake the analysis.

Depending on size and scope of a proposed project, a base-line household sample survey could possibly be undertaken in the project preparation phase. Such a survey can easily yield data on farm resource availability and use, on the basis of which farm patterns can be distinguished, but it may take more time and skills to obtain information on the personality, the objectives and the (not revealed) preferences of the farmer and the household. For this reason emphasis will here be given to the farm pattern approach.

Gittinger (1982) suggests undertaking a pattern farm investment analysis for each major group of soil and water conditions (agro-ecological zone) in the project area and for each major difference in the size of holdings. However, such a simple classification will often not suffice for SCWD projects.

In an economic appraisal of programmes aimed at sustainable land use, such as SCWD projects, the farm pattern classification should also take into account the following factors:

a) Whether the farm (household) is *able* to participate in the soil conservation activities;
b) Whether the farm (household), given the combined objectives of its head and its members, is *willing* to participate;
c) To what extent the participation of the farm pattern *matters* from the national point of view of soil and water conservation.

The first two factors have been discussed in Chapter 3. However, one should not only be concerned about the ability and willingness of certain farm patterns to participate, but also about the importance of this participation. Many farm households with little land and labour resources and/or with land resources that are not (yet) vulnerable to degradation, do not constitute a priority target group for such projects. The bulk of soil erosion is often caused by a relatively small group of tenant farmers or squatters on very steep land. The best solution to the erosion problem in such cases may well be to create off-farm employment possibilities for this small group. That constituted in fact an important component of the Hillside Farmers Project in Jamaica (IFAD, 1994).

The major criteria for a farm pattern classification for SCWD projects can then be grouped under four headings:

1. Locational factors
2. Resource endowments and resource use
3. Willingness to participate
4. Potential contribution towards 'national' conservation objectives.

1. Farm households should first be classified according to *locational* variables. This concerns first the wider regional context: the agro-ecological zonation and the geographical location of villages and communities in a watershed, their distance to rivers, major roads, townships, markets, etc (which could form the basis for a distinction by agro-economic zones). Often related to the location are the infrastructure and the services to farmers (input-supply, extension, etc). Secondly one should look at the location of respective groups of farms within the village (e.g. near the centre or near the forest zone).

2. Farm households may thereafter be classified according to more or less homogeneous groups with regard to *resource endowments* (including off-farm earnings) and *resource use* (similar technology and input/output ratios) and hence to a more or less similar level of income. This is important for the financial analysis and for the social analysis

focusing on income distribution. It is also important to look at the combination of farm enterprises (crops/livestock/off-farm and household activities), and the reasons for certain combinations (e.g. in terms of complementarity or supplementability). This may already give a good idea about the farmers' preferences and strategies.

The quality of farmland, the type of farm enterprises and the technology applied are often closely related to each other. In the northern part of Kasserine Province in Tunisia, with annual rainfall still in excess of 300 mm and with rather heavy soils, mechanized wheat growing is the most important farm enterprise. In the central and southern parts of the province, with lower rainfall and sandy loam soils, tree crops and fodder crops for sheep husbandry are the major enterprises, with use of animal power.

Land evaluation techniques can provide important indications for the most appropriate land use, but in many cases farmers have either already found the 'right' land use or they face one or more constraints in putting this into practice.

3. Thirdly it is desirable to find out which of the categories of farm households are likely to *participate* in certain activities. For assessing the likelihood of participation use can be made of the checklist, presented in Figure 3.1 in Chapter 3. The participation in certain development or conservation activities may relate first of all to the resource endowments (farmers with flat land do not need terraces, farmers without livestock are less interested in fodder production), but it may also relate to such personal factors as the family's interest in farming (preference for off-farm earnings), the age and sex of head of household (or decision maker) and the family composition, the health situation, the attitude towards risk and uncertainty, the readiness to take initiatives, the ethnic group, origin and religion, etc. In many African countries attention has to be given to various sub-systems within the household, that may have a different stake and interest in the project and its effects (Section 3.2).

   When sufficient data can be obtained from households, use could also be made of the concepts applied in the classification by farming style, since personality factors may play an important role in decisions related to participation.

   The willingness to participate is of course also influenced by the incentives provided. Some farm patterns may be willing to engage in soil conservation measures with only some technical assistance (extension), while others will only participate when they receive substantial subsidies.

4. The fourth set of classification criteria is that concerning the actual *contribution towards sustainable land use*: farms having steep and highly erodible land, shallow soils and/or land that is rapidly losing its fertility, should receive a higher priority and may justifiably be given more incentives than other farms. Where the project is first and foremost directed towards soil conservation, this criterion should of course be the first one to consider. In his rating system for assessing soil conservation priorities, Harris (1994) used four parameters: location (near streams), effects on community amenities, potential for erosion and actual erosion. Many SCWD projects tend to concentrate gradually more on development activities and lose their conservation focus, when the conservation measures are not easily adopted. This fourth set of criteria may also constitute a first concrete step towards defining attributes on the sustainability criterion in the evaluation process.

Table 5.5 *Criteria and attributes for the classification of farm patterns*

Factors	Attributes
Locational factors	
Agro-ecology	Climatic zones
	Soil group zone
Markets	Distance to main road, towns, etc.
Natural resources	Distance to forest, rivers, lakes, etc.
Resource endowments and resource use	
Labour	Family size and composition
	Off-farm employment and migration
Land	Farm size (area)
	Land tenure
	Physical features
Capital resources	Livestock
	Equipment
	Off-farm income & migration remittances
Farm enterprises	Combination of enterprises (crop-, livestock and other activities)
Technology	Power (manual, animal, mechanical)
	Conservation measures (already applied)
	Use of fertilizing materials
Likelihood of participation	(Socio-cultural features)
Ethnic group	Way of living
Personal factors	Sex and age of head of household
	Education of head of household
History	Past experiences
Importance for SCWD	
Land degradation	Actual extent of erosion
	Soil org. matter and nutrient status
	Erosion hazard (e.g. slope, soil depth)
Carrying capacity	Potential production levels

In order to comply with the above four considerations many different classification criteria could be considered. While it may be easy to establish clear criteria with regard to resource endowments, it is usually much harder to assess beforehand the likelihood of participation (Section 5.1). In general one should look for 'easily obtainable' classification criteria. Table 5.5 enlists various criteria that could play a role in such a classification.

Since most of the explanatory variables are interrelated in such a way that their different effects cannot be meaningfully interpreted separately, it is necessary to make use of multivariate data analysis. A useful technique for the classification of the farms in homogeneous groups according to the above objectives, is '*cluster analysis*'. The application of cluster analysis can be divided into three major stages (Hair et al., 1992):

1. 'partitioning', during which stage the following are investigated:
   a) how inter-object (farm) similarity could be measured;
   b) what procedure could be used to place similar objects (farm patterns) into clusters;
   c) how many clusters should be formed.
2. 'interpretation', during which stage the statements that were used in developing the clusters are examined, in order to name or assign a label that accurately describes the nature of the clusters.
3. 'profiling', during which stage the characteristics of each cluster are described in order to explain how they may differ for relevant dimensions (e.g. explaining the different attitudes towards participation in certain conservation activities).

If the opportunity arises one could approach the households again, and ask whether they can indeed identify themselves with the (profile of the) respective groups (clusters). This was undertaken in the Burkina Faso case study (Chapter 9).

Selection or construction of farm household pattern
After the main characteristics of the farm patterns have been clearly defined, the details must be filled in, in order to use the farm patterns in the financial analysis.

Two methods for composing farm household patterns could be distinguished, in a similar way as Collinson (1972) proposed for building representative farm models. In the first method, an existing representative farm is 'selected' for each different pattern. In the second method, a sample is drawn from each group, and data is collected from these samples, in order to make it possible to 'construct' typical farm patterns.

The first method has the advantage that after careful selection only one real farm needs to be analyzed per pattern, and that typical, extreme or extraordinary features of this farm can be distinguished and verified at any time. On the other hand, such typical and/or extreme features may blur the general picture, and it will be extremely difficult to select a farm that is 'typical' in all relevant aspects. In selecting a typical farm, values and deviations from the mean value (for the group of farms of this type) must be calculated for a number of criteria. The farm with the lowest percentage deviation from mean values for all or for selected criteria is chosen as typical. Criteria may include the cropping pattern (e.g. percentage under cotton); labour supply and use; labour profile (percentage labour used in peak versus slack periods); farm size (area and/or number of livestock); output (cotton, grains, etc); net returns (per ha or per labour day); number of days of off-farm occupation (Box 5.2).

Under the second method, a typical farm pattern cannot be constructed simply on the basis of aggregation and the calculation of averages. This would give a farm with many small plots, and an atypical, flattened labour profile. One way of constructing typical farm household patterns, would be to take first modal values for the resource data (e.g. family size, land worked, percentage of area under main crops, number of livestock, most frequent off-farm occupations); subsequently an attempt could be made to obtain a representative picture of resource utilisation data (output, material and labour inputs). Once the area per crop is known, the typical crop labour profile could be constructed by calculating for each operation the average rate of work (person days/ha), the average spread in weeks around the modal date when work is done, multiplying the rate of work by area, and dividing the result by the spread (in weeks) of that operation (Box 5.3).

When the farm patterns are to be turned into farm models with the use of modelling, the second approach may be more convenient. But when the farm patterns are directly used for an assessment of the participation in certain SCWD activities and for a financial cost-benefit analysis, the first method may have the advantage, in that one can more easily test hypotheses regarding participation and farmer attitudes towards costs and benefits.

5.4 Conflicting objectives and the use of incentives

More than in other agricultural projects there is a need in SCWD projects to confront the objectives of the various actors with each other, to see where actors agree on the need for interventions, where disagreement remains, and whether that can be solved by the provision of certain incentives.

Box 5.2 *Existing farms selected as farm household patterns in Burkina Faso*

The first or *selection* approach was followed in the Burkina Faso case study. The criteria for the classification were in hierarchical order: - ethnic group; - gender of head of household; - family size (> 16 members); - man/land ratio (> 0.8 ha per person); off-farm income (CFAF 100,000 pp/py); - No of cattle (> 10); - age of head of household (old is above 50 years). Involvement in migration was not included, since it was highly correlated with off-farm income.

Table 5.6 *Farm households that fit farm patterns distinguished in two areas in Burkina Faso*

Ethnic Group	Gender Head of househ.	Labour Family size (No)	Land Area cultiv. (ha)	Off-farm income [1]	Livest. Cattle (No)	Age Head of househ.	Farm pattern name	Conserv. measures (% area cultiv.)
Three villages in Sanmatenga province								
Fulani[3]		14	3	-	20	35	Fulani	10
Mossi	Female	2	1	27	-	55	Female head	0
Mossi	Male	22	11	1,960	1	50	Large family	55
Mossi	Male	10	16	1,189	-	36	Rich	11
Mossi	Male	19	9	589	42	45	Livestock f.	33
Mossi	Male	12	4.5	497	-	59	Old	11
Mossi	Male	9	6	333	1	35	Young	25
Three villages in Zoundwéogo province								
Fulani[3]		20	0.8	37	53	34	Fulani	0
Mossi	Male	11	9.3	210	-	43	Settler	5
Mossi	Male	25	16.6	2,188	6	48	Large family	10
Mossi	Male	13	15.2	1,205	17	40	Rich	20
Mossi	Male	9	3	187	3	61	Old	16
Mossi	Male	6	4	399	2	35	Young	50
Weighted average								
		11	6.3	572	6	45		26

1) Revenues in FCFA 1000 per year (1992/93).
2) From total of 755 farm households listed in the six villages
3) Respectively resident and transhumant household.
Source: de Graaff, 1995.

On the basis of these criteria seven farm patterns were distinguished in the first area (in Sanmatenga province). The criteria man/land ratio and off-farm income together were used for the category 'rich farm households'. In the second area (in Zoundwéogo province) there were hardly any female headed households, and there was a high correlation among Mossi farmers between man/land ratio, off-farm income and number of cattle, that together determined the category of 'rich farmers'. The farmer selected to represent this category was in fact referred to as 'the rich man' in his village. One village in the second area forms part of a settlement area, where all households received 10 ha of land and intensive extension training. These farm households clearly constitute a category of their own (Table 5.6).

After the clustering of farm households according to the above criteria, the farm household was selected for which the score on the criteria most often approximated the modal value for the farms in their group. The selected farms were visited again and all but one head of the selected households agreed that they were indeed a good representative of the farm pattern concerned. The classification, oriented as it is towards factors determining the ability, likeliness and (national) importance of participation, was reasonably well connected with the actual implementation of SCWD activities by the respective farm patterns (Chapter 9).

Box 5.3 *Construction of farm (household) patterns for evaluating Konto River watershed development activities in Indonesia*

Although not entirely based on the techniques described, farm household patterns were *constructed* in the monitoring and evaluation of watershed development activities (e.g. reforestation, coffee and fodder production, terracing) in the Konto River watershed area in East Java, Indonesia (Chapter 10). In order to assess the financial results of these activities at the farm level, an analysis was undertaken of eight typical farm household patterns, constructed on the basis of socio-economic survey data from 270 households in the target villages. For the overall financial analysis of the project, the results of the eight patterns were aggregated and the costs and benefits accruing to other actors were added.

In each of the two sub-districts and agro-ecological zones: Pujon (high altitude volcanic zone) and Ngantang (medium altitude volcanic zone), four typical patterns were distinguished on the basis of these data. Criteria used in the classification of patterns were - the amount and type of land they operated; - livestock kept; - the way they used their labour resources for farm and off-farm work; and certain farming and environmental constraints (Table 5.7). The latter constraints were to a large extent related to locational factors: remote, near forest, closer to market town and hence more involvement in trade, etc.

Table 5.7 *Several features of 8 farm patterns distinguished in Upper Konto River Watershed*

Short description of farm patterns (Pujon P1-P4) (Ngantang N1-N4)	Farm land by type: Irrig. land (ha)	Rainf. land (ha)	Total (incl. homeg.) (ha)	Livestock (No): Dairy cattle	Goats Sheep	Employment (days/yr): Off-farmw.	Hired labour	Dominant farming & environmental constraints
Farm/forest labour	-	0.14	0.17	-	2	465	-	Access; steep
Small mixed farm	0.10	0.25	0.40	2	-	215	96	High pop./manure
Medium veget. farm	0.23	0.20	0.48	1	-	245	63	Prices; pestic.
Med./large mixed f.	0.11	0.57	0.75	3	1	155	170	Labour shortage.
Pujon (average/hh)	0.11	0.29	0.45	1.5	0.7	270	82	
Total area (ha)	*880*	*2320*	*3600*					
Number of animals				*12000*	*6000*			
Farm/forest labour	-	0.15	0.20	-	3	306	-	Remote; forest
Small mixed farm	0.08	0.30	0.41	-	1.5	274	20	Erodib./gullies
Rice & coffee f.	0.22	0.20	0.54	0.4	-	199	50	Low soil fertil.
Large coffee farm & trader	0.30	0.53	0.96	2	-	211	210	Low coffee price
Ngantang (aver./hh)	0.14	0.23	0.50	0.5	1.1	247	60	
Total area (ha)	*1160*	*2195*	*4010*					
Number of animals				*4000*	*9000*			
Total watershed	**2040**	**4515**	**7610**	**16000**	**15000**	**257**	**70**	

Notes: Farm patterns P1-P4, N1 and N2 represent 2000, N3 2500 and N4 1500 households.
Source: Based on de Graaff and Dwiwarsito, 1990.

During the 1994 ex post evaluation mission three farms were visited from each farm pattern, in order to assess in which project activities they participated and what impacts these activities had. Many of the farms belonging to the patterns P1 and N1 had participated in the small ruminant schemes and in reforestation; some of the P2 and N2 patterns had participated in terracing and the larger farms (N4 in particular) had been involved in the planting and rejuvenation of coffee.

In Section 3.5 the different conflicts of interest in SCWD projects were reviewed. The most characteristic conflicts of interest in *(sub) humid mountainous areas* are those between upland and downstream communities. Governments often initiate SCWD activities in the uplands primarily to protect the lowland against floods and against a decreasing water supply from reservoirs. The upland community does not get a share of these benefits and SCWD activities may even reduce their farm results. For their cooperation incentives are required.

The Konto River Project in Indonesia offers a clear case of conflicts of interest in sub-humid mountainous zones, where mountain tops are still under forest. Apart from wood production the forest area has important regulating functions, that the government wants to safeguard (e.g. flood control, reservoir management). The project objective states that 'a balance needs to be found in reforestation activities between maintaining these functions and accommodating the needs of the population to obtain food, fodder and firewood' (Chapter 10).

In *semi-arid areas* the main conflict of interest, although less visible, is that between present and future farmers. The objectives of present farm households are largely focused on short term food production for self-sufficiency. The governments, that are aware of 'soil mining' and the fast decline of land productivity, have to defend the interests of future farmers. But they often have to 'buy' the cooperation of present farmers.

In Burkina Faso, for example, several projects offer transport and other facilities to accelerate construction of stone rows to control erosion. Such measures already existed in pre-colonial times (Savonnet, 1959), but their establishment could not match the fast rate of land degradation. Farmers nowadays invariably await the arrival of a lorry, before engaging in construction, and do not use donkey-carts or wheelbarrows to transport stones.

As a matter of fact there is often a situation of supply and demand of soil and water conservation 'technology', between 'functional or intervening actors' (also referred to as 'technicians', 'externals', etc.), who act in the 'national interest' and farmers. This type of conflict or 'bargaining' situation will be focused upon here.

Conflict resolution

Maguire and Boiney (1994) have developed a framework for resolving environmental disputes between major actors, by combining decision analysis with dispute resolution techniques. The former is able to elicit subjective inputs from the disputing parties; a structure for communicating all facets of the decision environment and a common decision rule (e.g. maximizing expected utility). The latter, conflict resolution, promotes creative thinking, ensures that the formal analysis captures the underlying interests of the actors and facilitates systematic development of new alternatives. The initial decision structure can be based on decision trees and parties involved are subsequently asked to provide probability estimates for each possible outcome and their subjective rating of possible outcomes (utilities). While the expected utilities of the actors may initially differ considerably, after reviewing and sharing information and beliefs, and the generation of new alternatives, expected utilities of some alternatives may become close and may lead to conflict resolution.

Cost-benefit analysis (CBA) and multi-criteria analysis (MCA) may in fact also constitute important tools for conflict resolution. In CBA the use of the financial analysis for the respective actors may show who gains or loses, when alternatives are changed, and MCA can show trade-offs between alternatives and objectives for the different groups of actors.

Since the conflicts often arise from differences between public and private interests (see above), the confrontation between the economic analysis and the financial analysis for major actors in CBA is important in this respect. Chapter 11 shows some examples of this type of analysis for conflict resolution.

Regulations, persuasion or economic incentives

In the past conflicts of interest between the government and farmers concerning the field of soil and water conservation were often resolved by legal action, *regulations* or local arrangements. Pretty (1995) mentions about twenty regulations or by-laws pertaining to agriculture, that existed in medieval Britain to prevent long-term damage to village resources. Licences were required for hunting, gathering and collecting produce, and heavy fines were given for possession of woodcutting tools without license. Trees had to be replanted, stocking rates were limited and manure was not to be sold outside the village. These rules were adhered to, thanks to the high degree of cooperation among farmer groups.

In colonial times regulation and *coercion* were applied: some zones were acquired by the government for protection forest, other zones were declared priority areas for soil conservation where farmland was terraced, with or without the consent of farmers. Since farmers were hardly involved in the establishment of these conservation measures, they did not feel at all responsible for their maintenance. In all four case study countries large scale soil conservation works were forced upon farmers during colonial times.

Such regulations and coercive measures still exist, also in developed countries and particularly when off-site effects are at stake, but the emphasis has shifted to communication and economic incentive schemes. Communication, or *moral persuasion* (Dixon et al., 1989) will always play a role in the promotion of soil and water conservation measures, but it will often not be sufficient. Through communication between actors one tries to reach understanding and to solve conflicts of interest through 'gentleman's agreements'. However, without sanctions such agreements are generally very fragile. The controversy over market-based or *economic incentives* and regulatory commands and controls has a long history in areas as diverse as economic planning, international trade and environmental management. The weak performance of the regulatory approach and the promising potential of the economic approach have encouraged many countries to explore more seriously market-based incentives (e.g. taxes, charges, subsidies).

Colman and Young (1989) distinguish a variety of policy instruments for influencing the behaviour of the agricultural sector, classified according to the level of imposition: at farm level (e.g. grants), at the national frontier (e.g. tariffs) or at other points in the domestic market (e.g. excise taxes). An OECD report (1989) states that 'economic incentives have proved useful in raising revenues but in most cases have not been successful in changing behaviour or stimulation innovation'. Panayotou (1991) finds this a disturbing finding since the *raison d'être* of incentives is not to raise revenues but to change behaviour. He states that economic incentives are usually not given enough time to change behaviour. He further argues that regulatory approaches work generally less well in developing than in developed countries: regulations are more difficult to enforce; monitoring of the scattered small scale operations is extremely hard; budgets and manpower are limited; there is a lack of institutions to influence attitudes and public awareness; and the rent-seeking behaviour (bribing) disturbs regulations. Economic incentives may work better in developing countries, if given the chance. Major obstacles preventing their wider adoption relate to the uncertainties as to whether the incentives will work and what their impact will be on efficiency, equity and sustainability. The effects are difficult to observe and to monitor, and the additional costs to society may make them unpopular among the general public.

Incentives for conservation

In soil and water conservation and watershed development programmes 'incentives' are often required to assure that (national) economically viable measures are also financially attractive for the groups that are supposed to implement these measures. This could easily be in contradiction with the statement by Conway and Barbier (1990) that incentives should be related to 'farmers' needs pull', rather than to 'technology push'. That is, if incentives are to be effective in the long run, they must be oriented towards farmers' needs and problems, instead of focusing on the wide scale implementation of technical measures whose relevance farmers do not understand or do not have the resources to maintain.

Therefore farmers should first of all become aware of the more general objectives and benefits of erosion control, and the financial analysis for farm patterns should show whether the incentives are sufficient to compensate the farmers for that part of the costs of implementing and maintaining the measures, for which the benefits accrue to other groups.

Incentives for conservation activities are often needed for a medium to long term period. Apart from incentives for the initial investment, farmers may also need assistance for maintaining the structures or trees, and for supplementing their income gap in the first few years, when production is still low.

Table 5.8 *Possible incentives for soil conservation and watershed development activities*

Direct incentives (targeted)		Indirect incentives (general)
To individual farmers	**To farmer groups**	**To all inhabitants**
- inputs for free	- village nurseries	- public conserv. works
- subsidized inputs	- access roads	- fertilizer subsidies
- food aid	- water supply schemes	- price measures
- credit	- group extension	- crop zonation
- tax exemption	- input supply centres	- education programmes
- property rights	- savings & credit schemes	- legal measures

Incentives may either be direct (targeted) or indirect (usually more general), and may be channelled to individual farmers, groups of farm households, or villages (Table 5.8).

Direct incentives include the supply of farm inputs (e.g. planting materials, fertilizers) for free, or the provision of subsidies or credit, in cash or in kind. Targeted food-aid and special conservation oriented extension and training activities are other possibilities. Giving free inputs is generally a costly method, which can benefit only a limited number of households. In the Indonesian soil conservation demonstration plot (so-called 'demplots' of 10 ha) approach, farmers within the demonstration area obtain certain inputs for free and intensive extension training, while neighbouring farms are not eligible for such advantages. However, demonstrations with subsidies seldom convince the onlookers.

Many watershed development projects, undertaken in the 1970's and 1980's with technical assistance from FAO, were implemented with *food aid*, supplied by the World Food Programme (WFP). For each specific task to be undertaken by the participating households (e.g. 1 ha of trees, with planting distance 5 x 5 m; terracing of 1 ha on a slope of 15 %) a certain number of food aid rations were allocated. Although farmers were generally satisfied with it, food aid has several disadvantages as an incentive for conservation. Firstly, food aid is not always appreciated. Around 1980 Jamaica declined a food aid offer for soil conservation with the argument that food aid should only be used for poverty alleviation. Further, the composition of food aid rations depends on what is available on the world market, while rural consumers in developing countries have traditional preferences. Thirdly, giving food aid also risks displacement of local food production, directly and indirectly, by depressing farm prices (de Graaff, 1993). Fourthly, food aid involves high distribution costs. Finally, in many cases farmers do not really grasp the relationship between the food aid they receive and the conservation work, and no longer care about conservation, once food aid is stopped. Since 1996 in Eritrea food aid has been sold by the government and the revenues are used for 'cash-for-work' programmes (Stroosnijder, pers. comm.)

Where farmers are expected to have sufficient repayment capacity, *credit* could be provided, either in cash or in kind, and against market or subsidized interest rates. Formal credit markets are often inaccessible to the peasant household because of the small, highly seasonal and annually variable amount of cash income, the high risk of default and the lack of land or other collateral (Ellis, 1988). Since local moneylenders seldom provide long term loans and usually charge high interest rates, the provision of credit to smallholders for soil conservation activities is often seen as a government responsibility. Only the government is able to grant a long grace period, needed because of the long delay in receiving benefits.

In many conservation projects, with down-stream or other public benefits, the concept of 'cost sharing' is applied, whereby the farmers receive *subsidies* and/or credit on the basis of their own contribution. The financial analysis of the various farm patterns distinguished can give an indication of the amount of subsidies and credit required, and of the time-frame within which it is needed. The value of material inputs required, and a task evaluation indicating labour inputs, can provide a basis for setting standards for credit applications. These levels should not be set too high: this apparently occurred in a project in Central Jamaica, where farmers hired labourers to carry out terracing and made a net profit. This was possible because they paid local wages, far below the official wage rates used in the standards for credit allocation (Blustain, 1985).

Indirect incentives can be provided at the *local level* through the creation of certain services and infrastructure such as the establishment of village nurseries, where interested farmers could buy seedlings at low prices; farm input supply centres; creation of savings and credit schemes; and a whole range of development activities which indirectly stimulate farmers to undertake conservation measures. Farmer groups can play an important role in the provision of these services.

However, as argued by Blaikie (1989) in his discussion of the 'chain of explanation' of land degradation, incentives at the local level may not suffice to convince farmers to engage in soil conservation activities. Policies and regulations at higher levels may frustrate efforts at the local level. And there may even exist 'perverse incentives', a term used by McNeely (1988), which in this context concerns measures or policies which induce behaviour that accelerates land degradation.

At *regional or national level* various policies could be pursued to affect farm household decision-making: the devaluation of a previous overvalued local currency, for example, provides incentives to farmers to plant more export crops. In the case of perennial tree crops, such as coffee, this could have a positive ecological effect, but in the case of crops like groundnuts the ecological effect may be negative. Pricing policies are also important. Many developing countries showed considerable price distortions in the 1970's. Countries with modest distortions appeared to have had relatively high annual growth rates of GDP and agriculture (Baum and Tolbert, 1985). In the 1980's and 1990's many countries adjusted their price structures, but overvaluation of exchange rates, excessive trade barriers and underpricing of agricultural products still occur.

Where new pricing policies are intended to change farming systems, it should first be ascertained to what extent farmers will react to such changes. This also holds for fertilizer subsidies: if these are made generally available, it may result in excessive use and pollution in high potential areas, and hardly increase fertilizer use in lower potential areas. In Sahelian countries generalized fertilizer subsidies will mainly benefit the cotton sub-sector. However, agricultural pricing policies, combining high cereal prices with low fertilizer prices (one kg urea equivalent to 10 kg of cereals), allowed China to change within a seven year period from a food importer to a country self-sufficient in grain (Breman, 1987). A similar development in Indonesia led to self-sufficiency in rice in the mid 1980's.

Crop (or livestock) zonation policies, whereby input supply and processing and marketing facilities are strengthened in zones that are particularly suitable for these enterprises, can also be pursued. This could concern in particular tree- and fodder crop production in hilly or mountainous areas and, for livestock, may consist of a differentiation between extensive grazing and breeding zones and zero-grazing fattening zones.

Government policies that stimulate mechanization of farms may, on the other hand, have adverse effects on conservation efforts. An example is the provision of low interest loans for purchase of tractors in erosion-prone areas: such a policy was carried out in the 1970's in semi-arid southern Tunisia, where the richer farmers could suddenly prepare and sow, with multi-disc harrows, large tracts of fallow land on the mountain slopes. Grain yields were very low, not justifying fertilization, and the land became exposed to water and wind erosion and rapid degradation: a clear example of a perverse incentive for sustainable agriculture.

Apart from material incentives to farmers as such, attention should also be paid in project appraisal to institutional aspects and the socio-cultural context that may in itself create incentives and disincentives.

In areas with extreme erosion, governments may, instead of stimulating farmers to investment in erosion control measures, provide incentives to farmers to leave their land fallow or even to quit farming in the area concerned. This is one reason why transmigration projects have been set up in some countries.

Conclusions

In this chapter the importance of starting impact assessment with the proper identification of target groups and other actors concerned is stressed. Before analysing the effects of proposed and alternative SCWD activities, one should know how farmers will react to and participate in these activities. The identification of existing farm patterns is the first step in such analysis. This Chapter has shown how these farm patterns can be distinguished. Thereafter one can assess the ability and willingness of farm households to participate, and determine to what extent this participation is desirable or required from a conservation point of view. Targeted incentives can be used to promote this 'desirable' participation. Subsequently one can estimate the number of participants, the average size of fields and the total area to be treated. After this, attention should be paid to the assessment of on-site and downstream effects (and their impact on these actors), which are discussed in the next two chapters.

6 ON-SITE EFFECTS OF LAND DEGRADATION AND SOIL AND WATER CONSERVATION

We know more about the movement of celestial bodies than about the soil underfoot (Leonardo da Vinci: In Hillel, 1991).

6.1 The effects of soil and water conservation measures on soil erosion and on-site productivity

For the economic evaluation of long term investments in soil and water conservation, the effects of these on soil erosion and on land productivity should be analyzed. Long term refers here to effects that last at least for five years. Attention is focused here on long lasting line interventions (e.g. terraces, stone bunds, hedges) and conservation aimed land use changes (e.g. from annual to perennial crops). These type of measures involve 'discrete' changes of land use and/or technology, or changes in LUST's. Other technological and management measures that are subject to 'gradual' changes (e.g. tillage) are not considered here.

Soil and water conservation measures are primarily aimed at reducing the negative impact of soil erosion, and the losses of water, nutrients and organic matter associated with it. This chapter deals with the *on-site effects* of these losses, while the next chapter will focus on the off-site or downstream effects. The costs of establishing and maintaining the measures should be compensated by the discounted stream of the reduced land productivity losses, over the expected lifetime of these measures. Changes in land use and land management may also have direct effects on land productivity, but the emphasis here is on the effects that are brought about by soil erosion and conservation measures.

In order to assess the effects of soil conservation measures on land productivity, the following are first analyzed:

1. how the measures affect the soil erosion rate and subsequently
2. how the reduced erosion influences productivity.

In this chapter a methodology for impact assessment is devised, using spreadsheet modules.

For the *first step*, use can be made of the Universal Soil Loss Equation or 'Wischmeier formula', still the most widely used soil loss prediction model. The most recent update is called the Revised USLE or RUSLE (Renard et al., 1991). The basic equation (Wischmeier and Smith, 1978):

$$A = R*K*L*S*C*P$$

gives a relationship between average annual soil loss (A in ton/ha.yr) and the determining factors:

- rainfall and rainfall intensity (R, the erosivity index);
- soil properties (K, the soil erodibility factor);
- the topographic factors: length of slope (L) and gradient (S);
- the vegetation or crop (C) and land management (P) factors.

The USLE and RUSLE were developed on standard plots in the United States and the soil loss A is equal to the units selected for 'K' over the period selected for 'R', on a clean tilled fallow field with a length of 22.13 m and a slope of 9 %. Caution is required in using the equation under other climate and terrain conditions, but in many countries adaptations have

THE UNIVERSAL SOIL LOSS EQUATION (USLE) ADAPTED FOR ETHIOPIA

Equation: A = R * K * L * S * C * P (in tons per ha per year)

1. R. Rainfall erosivity

Annual rainfall (mm)	100	200	400	800	1200	1600	2000	2400
Annual factor R	48	104	217	441	666	890	1115	1340

2. K. Soil erodibility

Soil colour	Black	Brown	Red	Yellow
Factor K	0.15	0.20	0.25	0.30

3. L. Slope length

Length (m)	5	10	20	40	80	160	240	320
Factor L	0.5	0.7	1.0	1.4	1.9	2.7	3.2	3.8

4. S. Slope gradient

Slope (%)	5	10	15	20	30	40	50	60
Factor S	0.4	1.0	1.6	2.2	3.0	3.8	4.3	4.8

5. C. Land cover

Dense forest	0.001	Badlands, hard	0.05	Sorghum, maize	0.10
Other forest	0.02	Badlands, soft	0.40	Cereals, pulses	0.20
Dense grass	0.01	Fallow, hard	0.05	Ethiopian tef	0.25
Degraded grass	0.05	Fallow, ploughed	0.60	Contin. fallow	1.00

6. P. Management factor

Ploughing up and down	1.00	Stone cover 40 %	0.80
Strip cropping	0.80	Ploughing along contour	0.90
Applying mulch	0.60	Intercropping	0.80
Stone cover 80 %	0.50	Dense intercropping	0.70

Figure 6.1 *Adaptations of the USLE equation to Ethiopian conditions* (derived from Hurni, 1985).

been made (Figure 6.1). Since it concerns empirical models, adaptations can only be made when substantial local research data are available.

Work continues to define soil loss processes and to adjust the definition of the (R)USLE parameters for a wider range of conditions. The results of erosion (or Wischmeier) plots often serve better to show the relative extent of erosion under different land use systems and technology than to predict absolute levels of soil erosion.

An important feature of rainfall (R factor) is the amount of energy it carries, since this contributes to the disaggregation of soil particles, which as a result are more easily carried by overland flow. Therefore one is interested in the frequency of high intensive showers over a short period (in the USLE formula 30 minutes). Data on rainfall intensity are not easily available however, and information on the total (annual, monthly and daily) rainfall, is sometimes used as a proxy indicator of water surpluses affecting soil erosion through overland flow, e.g. R factor = 0.5 * P (annual rainfall; Roose, 1977). In many cases, however, sheet and rill erosion are caused by intensive showers of about 25 mm or more in a few hours' time. In semi-arid climates such showers occur only a few times a year.

The extent to which soil particles can be easily detached and transported by overland flow is reflected in the erodibility factor of the soil type (K). The topographic factors are often expressed in one formula: $SL = (L/100)^{0.5} * (0.76 + 0.53\ S + 0.076\ S^2)$ (Roose, 1977). The rainfall, soil and topographic factors are generally fixed, and only the cropping factor (C) and the management factor (P) can be influenced by land use changes and conservation measures. Line interventions such as terracing also affect the slope (S) and slope length (L) factors. The C factor also incorporates the extent of canopy and ground cover, and therefore changes throughout the year. Averaging to obtain annual figures should be proportional to the monthly rainfall factor (R). Of all the (R)USLE factors, values for the P factor remain the least reliable (Renard et al., 1991). Table A6.1 in the appendix gives examples of the values of the C- and P-factors.

Once it has been assessed how land use and land management changes affect levels of erosion, *the second step* is to analyze the relationship between soil erosion and land productivity. Soil erosion can bring about 'reparable' (or reversible) and 'residual' productivity losses. The first concern those types of fertility losses that can still be restored by an increased fertilizer use. The latter concern among others the reduced moisture infiltration, the diminished rooting zone and weakened soil structure (van Kooten, 1993).

For analytical purposes the effects of SWC measures are here divided into three main categories, according to the way in which the aim of reducing land productivity losses is reached:

- by preventing a diminution of the rooting zone;
- by retaining water;
- by reducing losses of nutrients and organic matter.

While the first category concerns the land as a 'fund' or 'stock' element, the other two concern the major 'flow' elements in the soil.

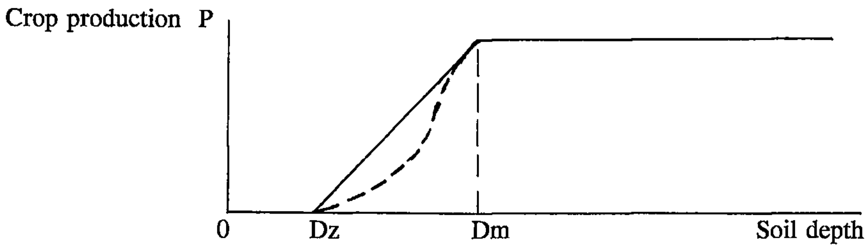
A considerable amount of research has been undertaken in the past to establish direct relationships between soil erosion and productivity losses. However, according to Stocking (1984) no less than 85 % of the studies on the impact of soil erosion on crop productivity, have been conducted in the United States. Even there the level of quantification of the impact of erosion on productivity is considered grossly inadequate (Pierce, 1990).

Empirical evidence has been obtained in three different ways: the continuous monitoring of erosion and crop yields at the same site over a long period of time; the comparison of yields from plots with different 'remaining' topsoil depth; and the method of simulating erosion processes by artificially removing layers of topsoil. The most comprehensive research of this kind in the tropics has been undertaken by Lal in Nigeria, and Stocking in Zimbabwe. The patchy evidence of the research suggests that the impact on yield of a unit loss of soil is higher in tropical than in temperate environments, partially due to less favourable soil properties and a concentration of fertility near the surface (Peake, 1986).

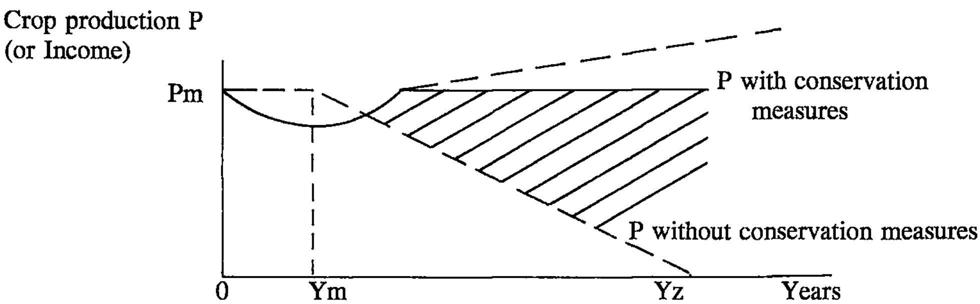
Instead of looking at the overall relationship between erosion and productivity, the above three effects are here considered consecutively (Sections 6.2, 6.4 and 6.5).

6.2 Traditional methods of assessing on-site benefits of soil and water conservation

A traditional method for estimating the long term benefits of physical soil conservation measures (e.g. terracing with annual cropping), focuses on the *diminishing rootable soil depth*. This method is based on the premises that soil depth reflects past erosion, and that there is a certain relationship between crop yields and soil depth (Gauchon, 1980). Depending on the soil type one could either consider total soil depth, the rooting zone, or the top soil layer, which contains the bulk of the nutrients and most of the feeding roots.



(Dm is minimum non-depressed soil depth and Dz is soil depth at which production is zero).
Figure 6.2 *Simplified relationship between crop production and soil depth on eroding soil*



(Ym and Yz are years in which Dm and Dz are reached respectively).
Figure 6.3 *Development of crop production and farm income on sloping land, with and without soil conservation*

It is then sufficient to know the present soil depth, the annual rate of erosion and average yields for a few selected soil depths to derive a time series of crop yields over the period considered for the economic analysis (often 20 years). The most important levels of soil depth are those where root development is impaired and crop production starts to decline (Dm in Figure 6.2), and those where no real production can be expected any more (Dz).

To arrive at projections for future yields in the 'without-case', the above method requires erosion research and a series of crop studies to estimate the relationship between soil depth and crop yields under otherwise homogeneous agro-ecological conditions. If the development (decrease) of soil depth (X) over time (T), or the rate of soil erosion, is described as: $X = b - aT$ and the relationship between the yield (Y) and the (remaining) soil depth as: $Y = d + cX$ one can calculate the annual yield reductions for different crops under different soil, slope and management conditions. Such a method was applied in the framework of a cost-benefit analysis of soil conservation measures on eroded land in Jamaica. Table 6.1 shows the linear relations found in this study. But there appeared to be a higher correlation between yields and management factors (labour and fertilizer inputs) than between yields and soil depth. Similar research for the appraisal of soil conservation measures has been undertaken in Indonesia (de Graaff and Wiersum, 1992). To avoid the costs of such research, in many project studies it is simply assumed that yields will decline by a small percentage per year (e.g. 2 %).

Table 6.1 *Relationship between soil depth and yields on eroded soils in watersheds surrounding Kingston, Jamaica*

Crop	No of plots	Soil depth range (cm)	Relationship (Y in kg/ha; X in cm)	Correlation coefficient
Yam	18	50 - 90	Y = 621 + 106 X	R = 0.65
Sweet potatoes	17	45 - 90	Y = -441 + 77 X	R = 0.43
Red peas	16	60 - 90	Y = -371 + 10 X	R = 0.71

Source: Laumans, 1982.

Besides the method has several weaknesses: for reasons of simplicity it assumes a linear decline in yields because of erosion, whereas in tropical soils a very steep (exponential) initial decline can be demonstrated, which more easily justifies the introduction of conservation measures (Wiggins, 1981) (Dotted line in Figure 6.2). Secondly the method assumes that physical soil loss constitutes the major factor in declining productivity, which could be the case on steep land, but on gently sloping land nutrient losses through soil erosion may only be a fraction of the nutrients extracted by crops and by-products. Most serious of all, the method does not apply a clear approach for the situation with conservation measures (Figure 6.3). It is in principle assumed that yields will remain constant, since they are no longer affected by erosion. However, it is often the case that yields will first decline, because of the disturbance of the soil, and will thereafter slowly increase over the years thanks to complementary effects (e.g. better use of water and nutrients).

It is in fact these latter effects of soil erosion (water and nutrient losses) that determine the decline or restoration of productivity as a result of erosion and conservation. Since methods and models have been developed to assess the effects on yields of changes in soil-water and nutrient balances, use should be made of these to obtain more reliable estimates for future yields in the economic evaluation of soil conservation measures.

6.3 Limiting factors in plant production affected by erosion

Whether it is the water or the nutrient losses associated with soil erosion that have the greatest effect on productivity, depends on the production situation concerned. In analogy with the classifications by de Wit and Penning de Vries (1982) and the slightly revised one by Lövenstein et al. (1993), the following four production levels will be distinguished here:

The level of *potential production (1)*, whereby the supply of nutrients and soil water is unlimited and the absorbed radiation and temperature are the growth limiting factors. The intensity of the irradiation, the degree of interception and utilization of light and the efficiency of use of energy in the plant are the key factors for understanding the growth rate. In this research not much attention will be paid to these factors, since soil and water conservation activities have only an indirect influence on these factors. Some assessment of potential production has to be made however for further analysis.

The level of *water limited production (2)*, where the growth is for some time limited by water shortages. At this level attention should be focused on the soil-water balance and processes that influence water availability (e.g. evapotranspiration, infiltration, run-off).

The level of *nutrient limited production (3)*, whereby growth is at least part of the time limited by the availability of nutrients. At this production level emphasis should be given to the nutrient balances, to the forms in which nutrients are available in the soil and for the plant, and to the response of growth to nutrient availability. The availability and role of organic matter should also be considered at this level (Chapter 9).

The *actual production level (4)*, that apart from the above factors is further limited by the occurrence of plant diseases, insect pests and competition of weeds, and various socio-economic factors. The limitations imposed by pests and weeds will not be discussed here since they are not directly influenced by soil erosion.

From the farmer's point of view the *yield gap* between potential and actual yields, may relate to his lack of means to apply (irrigation) water and fertilizers and to engage in weeding and spraying. Yields may also be restrained as a result of a decision-maker's objectives and various socio-economic constraints at the farm household level (Chapter 3).

Before evaluating soil conservation measures, one should first have a closer look at the production situation and at the degradation process. It should first be assessed what the most limiting factor is in the 'with-' and in the 'without-case': water or nutrient availability. Where water is the most limiting factor, soil and water conservation measures contribute to a diminution of run-off and to an increased availability of water to the plants, on the basis of which yield increases may be expected (Section 6.4). On the other hand soil and water conservation measures play an important role in reducing nutrient losses, and help to enhance yields when certain nutrients constitute the major limiting factor (Section 6.5).

6.4 Soil erosion and the soil-water balance

The aims of soil and water conservation measures may differ to some extent between the (sub-) humid and semi-arid zones, but in both situations it will focus on the reduction of the impact of raindrops, on the increase of infiltration and on the safe evacuation of surplus water. Through a higher infiltration rate more water is made available to the plant, while the reduction of the impact of raindrops and the 'safe' evacuation of surplus water should contribute to lower soil erosion rates.

For an assessment of the efficiency of a soil conservation measure under the production level 2 situation, one should first assess how the conservation measure affects water availability to the crop, and subsequently how the crop reacts to this increased water availability. For an analysis of the effects of measures on the infiltration and run-off one can make use of *water balances*. Water balances can be drawn up for a field, for watersheds and for whole river basins. In the case of large zones one refers to the hydrological cycle, and at field level to the soil-water balance (Figure 6.4).

For a *soil-water balance* one can use the following formula:

$$\text{Inflow} = \text{Outflow} + \text{Change in Storage}$$

or: $$P + Ir + Sf + Rn = Rf + E + T + D + \Delta S$$

where: *P = Precipitation, Ir = Irrigation, Sf = Sub-surface flow, Rn/Rf = Run-on and run-off (lateral overland flow), E = Evaporation, T = Transpiration, D = Drainage (percolation) and S = Storage in rootzone of soil.*

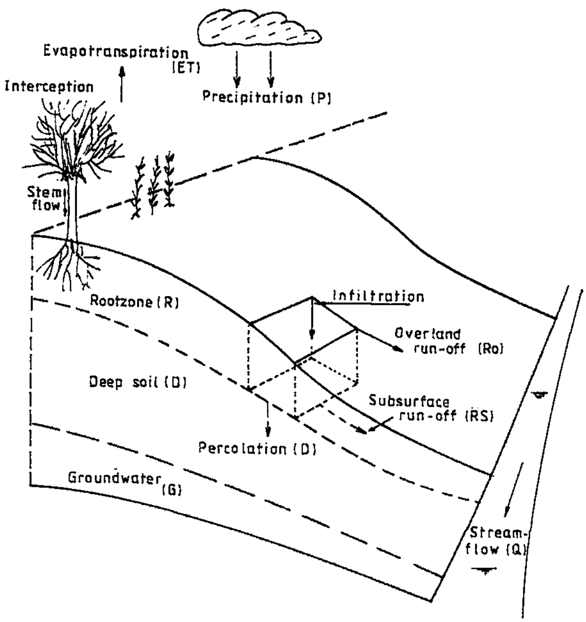


Figure 6.4 *Water balance parameters at the field level*

In particular in forests and perennial crop systems interception and stemflow play an intermediate role in the hydrological cycle, but this is omitted here. The formula can be further simplified. Water is supplied by precipitation, irrigation, by overland flow and by subsurface flow. The latter can consist of a lateral and of a vertical flow. Since groundwater levels in the tropical (sub-)humid mountainous and semi-arid zones are generally quite deep, vertical upward flow from groundwater (capillary rise) can be ignored there. It is further assumed that the incoming lateral subsurface flow will equal the outgoing. Irrigation will not be taken into consideration here. Evaporation and transpiration are often combined in evapotranspiration. The formula can then be rewritten as:

$$P - (Rf-Rn) = ET + D + \Delta S \qquad \text{(water balance, 1)}$$

For soil conservation activities it is important to know to what extent water either infiltrates in the soil or contributes to run-off. This depends on the following factors (Jackson, 1989):

- the amount, intensity, duration, occurrence interval and seasonal distribution of precipitation;
- the slope of the terrain, and the length of the slope;
- the effective or rootable soil depth;
- the surface roughness;
- the hydraulic permeability of the soil;
- the storage capacity of the soil (per cm soil depth);
- the sensitivity to crusting;
- evapotranspiration.

One should subsequently assess, if possible quantitatively, how soil conservation measures influence the above factors, by slowing down run-off and increasing infiltration (Stroosnijder et al, 1994). Rainfall patterns, slope and surface roughness together greatly influence the run-off, while various soil characteristics determine the infiltration capacity.

Rainfall and rainfall intensity can not be influenced directly. The role of plant cover is important in reducing the impact of rain. Obstacles such as stones, ridges, plants, etc. decrease the rate of flow and give more time for infiltration. The importance of reducing the rate of flow is shown by Wrigley (1969), who has stated that if the rate of flow is doubled, it has four times the scouring capacity, thirty-two times the carrying capacity and can carry particles sixty-four times as large.

The slope of the terrain and the effective soil depth can be easily measured and for this reason these two factors have been used as major criteria for land capability classification systems, which indicate the most intensive land use permissible for safe cultivation, and the treatment required for such land use intensity (Sheng, 1972).

After infiltration not all water is available to the plant. The available soil moisture depends on soil depth and soil texture. The maximum amount of 'available' soil moisture (SMm) that can be stored in the root zone is defined as the amount present at field capacity (SMfc) less the amount retained at permanent wilting point (SMpwp) (Driessen and Konijn, 1992). Between these two extremes there is a critical volume fraction of moisture (SMcr), below which water is made less easily available. In the spreadsheet modules use is therefore made of exponential depletion formulas. Withers and Vipond (1974) give the following average values (in mm per m soil depth) for water availability (Sa) of different soil types: clay 135 mm; clay loam 150 mm; sandy loam 120 mm; fine sand 80 mm; sand 55 mm. Maximum available soil moisture SMm = Sa * m (rooting depth) (Table A6.2 in Appendix).

For the assessment of benefits related to more optimal water management, information is required about the response of crops, and vegetation in general, to water shortage (and in some cases of excess water). For this a response function is required. In the above indicated production level 2 situation (Section 6.3), one can relate the production (yield response) to the evapotranspiration, as follows (Doorenbos and Kassam, 1979):

$$1 - Ya / Ym = Ky\ (1 - ETa / ETm) \qquad \text{(response function, 2)}$$

where: *Ya and Ym are actual and maximum yield; ETa and ETm are actual and maximum evapotranspiration and Ky is the yield response factor.*

The yield response factor depends on the crop and the growing stage, and has been calculated in many cases on the basis of experiments (Doorenbos and Kassam, 1979).

Crop water requirements are normally expressed by the rate of evapotranspiration (ET) in mm/day or mm/period. For a given climate, crop and crop development stage, the maximum evapotranspiration (ETm) = Kc x ETo, in which Kc is the crop coefficient and ETo a reference evapotranspiration. ETo can be computed on the basis of meteorological data. The crop coefficient depends on crop characteristics, on the growing period and growing stage, on climatic conditions and on the ETo method applied. Doorenbos and Pruitt (1977) provide values for the ETo Penman coefficient for many different crops, climatic conditions and growing stages. Table A6.3 (see Appendix) provides Kc and Ky values for various crops. For most field crops the average Kc for the total growing season is 0.85 - 0.90, except for such crops as banana, rice, coffee and cocoa which have a somewhat higher

Kc (around 1.00) and for citrus, sisal and pineapple that have a slightly lower Kc (around 0.70). Clean weeding practices clearly lower the Kc value, and in general Kc values are lower for dry land agriculture, with their incomplete ground cover and well drained soils, than for irrigated agriculture where soils are kept moist and evaporation losses are high. The rainfall distribution also greatly influences evaporation losses.

The above 'Doorenbos and Kassam' or 'crop water requirement' method has been developed for irrigated agriculture, and for optimum agronomic conditions, including high yielding varieties, high fertilization, etc. In rainfed agriculture production levels fall very much short of potential levels. One deals with production level 3 and 4 situations, whereby both water shortages and a lack of soil nutrients as well as other factors limit productivity.

Spreadsheet module for impact assessment of soil water changes

Crop growth models are often used for the analysis of effects of water availability on crop production. In the framework of economic evaluation, however, a simpler method is envisaged. Applying the water balance method of Thornthwaite and Mather (1955) and the response function of Doorenbos and Kassam, spreadsheets could be developed to calculate critical water shortage periods and the related crop yield reductions. One can then assess to what extent measures aimed at soil and water conservation and increased infiltration can reduce these water shortages and improve yields. A slightly different approach has been followed by Day et al. (1992).

The following input data are required: rooting depth (Dr) and storage capacity per metre of soil depth (Sa), together determining the maximum soil moisture availability (SMm); the precipitation (P) and a reduction factor for run-off (R) to arrive at the effective rainfall (Pef); reference evapotranspiration (ETo), and the Kc and Ky factors for the crop(s) concerned during the respective growing stages (GS), essential for the response function. The start of the growing season is normally the moment when the effective rainfall exceeds half of the potential evapotranspiration (Pef > 0.5*ETm). The output constitutes of reference yield Yref minus the yield reduction (Yred, or 1-Ya/Ym). Pef minus ETm is referred to as Pbal(ance).

The general procedure (*Mode 1*) is as follows: actual evapotranspiration (ETa) is equal to the potential, under a rainfall surplus (Pef > ETm, or Pbal < 0), and is equal to effective rainfall minus the change in available soil moisture (ΔSMa, in spreadsheet dSM), when rainfall is deficient (Pef < ETm, or Pbal > 0). ΔSMa is obtained by subtracting the SMa in a given period from its value in the preceding period. Values for SMa are calculated using the Thornthwaite-Mather method. From the first period onwards when the maximum evapotranspiration exceeds the effective rainfall, the accumulated potential water losses (APWL) are given for the whole 'dry' period. Then the actual soil moisture availability (SMa) is calculated, assuming an exponential depletion: SMa = SMm * Exp (-APWL/SMm). Once ETa is known, one can calculate the actual yield in two different ways: either by considering a yield response factor (Ky) for the whole season, or by considering the period with the highest water stress and the largest yield reduction (Yred = Ky * (1 - ETa/ETm).

The spreadsheet module also provides an indication of the percolation (D), which is of importance for the replenishment of the groundwater. Figure 6.5A shows that in a wet year sorghum production in Kaya, Burkina Faso, is not much affected by water shortage.

There are however two situations in which the method has to be adapted. When rainfall is lower than the reference evapotranspiration (in semi-arid zones), and when the accumulated rainfall surplus in the wet season (Pbal, pos) does not lead to soil moisture level at field capacity at the end of that season, some additional calculations have to be made (here

Calculation of the water balance and yield reduction

Location:Kaya Burkina Faso — Crops: Sorghum — Prec: wet — Year:1994 — Run-off: P>25:0.30 P, P<25:0.15 P — Yref 100, Yact 91, Yp 88

Soiltype Depth 0.7 — Sa 120 — SMm 84 — Mode: 1 (SMa reaches SMm)

	P	Rof	Pef	GS	ETo	Kc	ETm	Pbal	APWL	SMa	dSM	ETa	D	Ky	Yred
jan	0	0	0		187	0.1	9	-9	26	62	-7	7	0	0.0	0.00
feb	0	0	0		188	0.1	9	-9	35	55	-7	7	0	0.0	0.00
mar	0	0	0		216	0.1	11	-11	46	49	-7	7	0	0.0	0.00
apr	26	8	18		178	0.1	20	-1	47	48	-1	19	0	0.0	0.00
may	26	8	18	i	155	0.4	62	-44	91	28	-19	38	0	0.2	0.08
jun	98	29	69	d	136	0.7	95	-27	118	21	-8	76	-0	0.6	0.12
jul	208	62	146	d	129	0.7	90	55	0	76	55	90	0	0.6	0.00
aug	218	65	153	m	116	1.1	128	25	0	84	8	128	17	0.5	0.00
sep	126	38	88	l	126	0.7	88	0	0	84	0	88	0	0.2	0.00
oct	110	33	77		149	0.1	7	70	0	84	0	7	70	0.0	0.00
nov	0	0	0		165	0.1	8	-8	8	76	-8	8	0	0.0	0.00
dec	0	0	0		160	0.1	8	-8	16	69	-7	7	0	0.0	0.00
														Aver	0.09
Tot	812	244	568		1905		536	32				482	87	**Peak**	0.12

Growing stage (GS): i=initial; d=developing m=mid- & l=late season — Pbal pos: 150, Pbal neg: 118 — Yact: % of reference yield Yref due to general water stress; Yp: idem, due to peak shortages

Figure 6.5 A *Water balance Mode 1; Kaya, Burkina Faso*

Calculation of the water balance and yield reduction

Location:Kasserine Tunisia — Crops: Olive — Prec:aver — Year:90/91 — Run-off: P>25:0.20 P, P<25:0.10 P — Yref 100, Yact 45, Yp 35

Soiltype Depth 1.7 — Sa 100 — SMm 170 — Mode: 2 (SMa never reaches SMm)

	P	Rof	Pef	GS	ETo	Kc	ETm	Pbal	APWL	SMa	dSM	ETa	D	Ky	Yred
jan	11	1	10	r	59	0.1	6	4	0	49	4	6	-0	0.2	0.00
feb	18	2	16	r	68	0.2	14	3	0	51	3	14	0	0.2	0.00
mar	76	15	61	r	93	0.3	28	33	119	84	33	28	0	0.2	0.00
apr	24	2	22	i	117	0.5	59	-37	156	68	-16	38	0	0.7	0.24
may	25	3	23	d	162	0.5	81	-59	215	48	-20	42	0	0.7	0.33
jun	23	2	21	d	203	0.5	102	-81	295	30	-18	39	0	0.7	0.43
jul	0	0	0	d	235	0.5	118	-118	413	15	-15	15	0	0.7	0.61
aug	0	0	0	m	177	0.6	106	-106	519	8	-7	7	0	0.7	0.65
sep	47	9	38	m	162	0.6	97	-60	579	6	-2	40	-0	0.7	0.41
oct	12	1	11	l	106	0.6	64	-53	632	4	-2	12	0	0.7	0.56
nov	30	6	24	l	76	0.5	38	-14	646	4	-0	24	0	0.7	0.25
dec	76	15	61	r	66	0.3	20	41	0	45	41	20	0	0.2	0.00
														Aver	0.55
Tot	342	57	285		1524	5.2	731	-446		76		285	0	**Peak**	0.65

Mode 2: r=rest period — Pbal pos: 81, Pbal neg: 526 — APWLmin 119, STmax 84 — APmax 646, STmin 4

Figure 6.5 B *Water balance Mode 2; Kasserine, Tunisia*

Calculation of the water balance and yield reduction

```
Location:MavisBank  Crops:    Yam        Prec:aver Run-off:       Yref 100
         Jamaica              Cabbage    Year:       P>60 0.40 P  Yact  90
Soiltype Depth Sa      SMm                           P<60 0.20 P  Yp    83
         1.0   140     140               Mode:     3 (Two dry seasons)
```

	P	Rof	Pef	GS	ETo	Kc	ETm	Pbal	APWL	SMa	dSM	ETa	D	Ky	Yred
							(mode 3:		692	1)					
jan	53	11	42	m	109	1.0	109	-67	67	87	-37	79	0	0.5	0.14
feb	64	26	38	l	101	0.9	91	-52	119	60	-27	66	0	0.6	0.17
mar	48	10	38		127	0.4	51	-12	131	55	-5	43	0	0.0	0.00
apr	99	40	59	i	130	0.5	65	-6	137	53	-2	62	0	0.5	0.03
may	165	66	99	d	120	0.6	72	27	79	80	27	72	0	0.6	0.00
jun	150	60	90	d	152	0.7	106	-16	95	71	-9	99	0	0.9	0.06
jul	102	41	61	d	130	0.8	104	-43	138	52	-19	80	0	0.5	0.12
aug	178	71	107	m	130	1.0	130	-23	161	44	-8	115	0	0.4	0.05
sep	218	87	131	m	110	1.0	110	21	0	65	21	110	0	0.4	0.00
oct	338	135	203	l	113	0.7	79	124	0	140	75	79	49	0.4	0.00
nov	195	78	117	i	108	0.5	54	63	0	140	0	54	63	0.2	0.00
dec	91	36	55	d	103	0.7	72	-18	18	124	-16	71	0	0.4	0.01
														Aver	0.10
Tot	1701	660	1041		1433		1043	-3				929	112	**Peak**	0.17

```
Growing stage (GS):       Pbal pos: 235
 i=initial; d=developing  Pbal neg: 237
 m=mid- & l=late season
```

Figure 6.5 C *Water balance Mode 3; Mavis Bank, Jamaica*

Figure 6.5 (A-C) *Examples of calculation of available soil moisture (water balance) and yield depression (response function)*

referred to as *Mode 2*). In this case one has to calculate the APWLmin value at the maximum SMa value (STmax), and to insert these values in the last period (month) with a rainfall surplus (Pbal > 0) (Koopmans et al., 1993). Figure 6.5B shows that olive trees in southern Tunisia have to rely heavily on occasional rainfall surpluses (in March and December) and are under heavy stress in the dry summer.

Another complication occurs when there are two dry periods, and potential soil moisture SMm is not reached in the short wet season. This is referred to as *Mode 3*. For an exponential depletion the formula APWL=SMm*Ln(SMm/SMa) is then applied for that period. Such a situation occurs in Jamaica, with minor rainfall peak in May (Figure 6.5C).

Of the two types of soil conservation measures distinguished here, the physical measures influence the water balance either by preventing a decrease in soil depth and in maximum available soil moisture (SMm), or by reducing run-off and increasing infiltration, and thus increasing the effective rainfall (Pef). Land use conversion affects the water balance and the response function in various ways, and in particular through changes in evapotranspiration.

Changes in the water balance brought about by these soil conservation measures, will contribute immediately, in the same season, to a smaller yield reduction (Yred). An example is given in Chapter 9.

6.5 Soil erosion and soil fertility aspects

Traditional shifting cultivation systems more or less guaranteed a sufficient supply of nutrients for a few crop harvests. However, as a result of the shortening of crop rotations, farmers in developing countries now often find themselves in a situation in which nutrients are the most limiting factor in crop production (production level 3 in Section 6.3).

In steep sub-humid zones soil conservation measures are primarily aimed at reducing soil losses and in particular the loss of precious topsoil, which contains a relatively large amount of nutrients. In semi-arid zones, with their scarce and erratic rainfall, erosion control forms only one part of the battle against land degradation. Farmers in these zones withdraw more nutrients from their soil, through the harvests, than they add to it in the form of fertilizers, etc. This process is referred to as chemical degradation or 'soil mining' (van der Pol, 1992). In this situation soil conservation measures can help at least to make the nutrient balances less negative.

For an assessment of the efficiency of a soil conservation measure under the production level 3 situation, one should:

1. assess how the conservation measure affects the availability of nutrients to the crop;
2. assess how the crop reacts to this increased nutrient availability.

For an analysis of the effects of measures on the availability of nutrients (*first step*) one should analyze the *nutrient balances*. Bruijnzeel (1982) refers to biogeochemical cycling in the analysis of forest ecosystems.

Under natural, undisturbed, conditions the different nutrient cycles are in equilibrium. The total ecosystem, consisting of soil and plants, obtains as much nutrients as are lost. The aim of sustainable agriculture is to achieve and keep a similar balance (Veldkamp, 1992). Janssen (1982) emphasizes the need to carefully delineate the area for which a nutrient balance is drawn up (e.g. parcel, farm, watershed). He also introduced the term 'balanced nutrients'. It is important that nutrients are made available in an optimal combination that relates to the needs of the plant, but the balance of the most limiting element should be restored first.

Plants obtain all the elements they require from the soil, except for carbon (C), and nitrogen (N) in the case of leguminous plants. This complicates the carbon and nitrogen cycles. Other main nutrients needed for plant growth are phosphorus (P) and potassium (K).

The nutrients, or chemical elements in the soil are found in three pools: pool A, consisting of the minerals readily available to the plants (often from chemical fertilizers); pool B, elements present in organic matter; and pool C, the mineral reserves in the soil (van der Pol, 1992). The first two pools largely determine soil fertility and these are also most subject to erosion. The organic fraction, pool B, is mainly fed by manure and residues. In stable organic matter one finds carbon, nitrogen and phosphorus often in a ratio of about 100:10:1. Through weathering minerals become available very slowly from the mineral reserve.

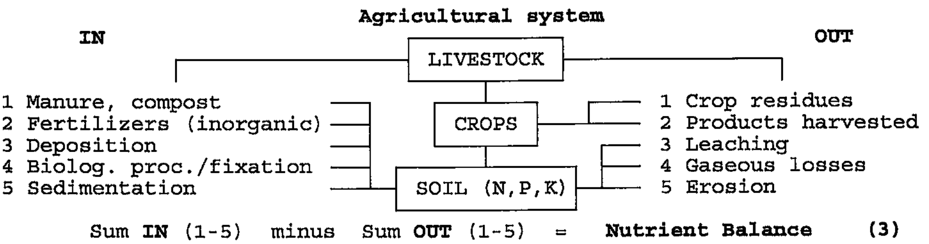


Figure 6.6 *Nutrient fluxes in the soil* (adapted from Stoorvogel and Smaling, 1990).

Stoorvogel and Smaling (1990) conducted a study in 1983 on the N, P and K balances or budgets in arable soils of 38 Sub-Saharan countries. Each nutrient balance consists of certain input (IN) and certain output (OUT) categories (Figure 6.6).

One can draw up the respective nutrient balances, for nitrogen, phosphorus and potassium for both the situation without and the situation with the soil conservation measures, and determine the change in the nutrient balances.

The second step concerns the crop response to the changes in the nutrient availability (response function). As discussed above, the existence of certain amounts of nutrients in the soil does not automatically imply that they are available to the plant and are taken up by the plant. One refers for chemical fertilizers (in pool A) in this regard to the recovery fraction, to indicate which part of the supplied nutrient is actually absorbed. This fraction may range between 0.1 and 0.9, depending on type of fertilizer, mode of application and soil characteristics (Lövenstein et al., 1993).

The uptake-yield relationship of nutrients consists of a curve, that is initially linear, under low uptake levels, and that subsequently flattens off at higher uptake values.

The initial yield response or 'initial nutrient use efficiency' (INUE in kg dry matter or harvested product per kg nutrient supply) can be derived for nitrogen in grain production from the formula (Lövenstein et al., 1993):

$$INUE=\{1/(N_{grain}+(W_{straw}/W_{grain})*N_{straw})\}/(\%DM/100) \qquad \text{(response function, 4)}$$

whereby: *N_{grain} and N_{straw} are the minimum N concentration in grain and straw (about 1 % and 0.4 % respectively); W_{grain} and W_{straw} the dry weight (in kg/ha) and DM the dry matter content in grain (about 85 %)*

Table 6.2 shows the minimum and maximum nutrient concentration in some major harvested products and their residues. The yield response to one kg N, at sub-optimal levels of fertilizer application, can then be obtained by multiplying the recovery fraction with the INUE (Centre for World Food Studies, 1985).

Under the conditions of 'soil mining' it is unlikely that many 'pool A' nutrients will be found in the retained soil or sediment. In this case nutrients only become available after the process of mineralization (from pool B), at a rate of about 2 % per year (Pieri, 1989).

Table 6.2 *Nutrient content in harvested products and residues*

	Harvested product			Crop residues (straw/tops)		
	N	P	K	N	P	K
	Minimum and maximum nutrient concentration (%)					
Wheat	1.0-3.3	0.16-0.6	0.3-0.8	0.4-1.0	0.03-0.4	0.7-2.7
Maize	0.9-2.2	0.16-0.8	0.2-0.6	0.4-1.4	0.04-0.4	0.4-2.4
Sorghum	1.0-3.2	0.13-0.6	0.2-0.7	0.3-1.2	0.05-0.3	0.8-2.8
Potatoes	0.9-2.5	0.10-0.6	1.1-4.6	1.4-3.2	0.13-1.0	0.8-4.6
Cassava	0.2-0.9	0.08-0.2	0.3-1.4	0.5-1.8	0.09-0.5	0.4-1.8
Pulses	2.5-5.8	0.25-0.7	0.7-2.2	1.0-2.9	0.06-0.3	0.8-3.5
Sunflower	1.8-4.7	0.35-1.3	0.6-2.4	0.5-1.9	0.07-0.4	0.9-4.7

Sources: Lövenstein et al., 1993.

In this case the yield response is very low initially, but because of the continuous mineralization it increases slowly over the years (Chapter 9).

Spreadsheet modules for impact assessment of soil nutrient changes

As indicated above (Figure 6.6), a nutrient balance is composed of the following elements:

Inputs		Output and losses		Saldo	
Fert+Manu+Depo+Fixa+Sedi	-	Prod-Resi-Leac-Gase-Eros	=	Balance	(3)

In drawing up a nutrient balance for a particular LUST, one needs to know on the input side: the fertilizer and manure inputs and the conversion factors in pure nutrients (Table A6.4), the average annual precipitation to estimate deposition and the extent of N-fixation. Stoorvogel and Smaling (1990) used the following equations in Sub-Saharan Africa for the relation between deposition and precipitation (P): DepoN = $0.14*P^{1/2}$; DepoP = $0.053*P^{1/2}$ and DepoK = $0.11*P^{1/2}$. While all crops benefit from non-symbiotic N fixation and from contributions of scattered N-fixing trees (about 4 kg N per ha), leguminous crops obtain about 60 % of their nitrogen demand from N-fixation. Sedimentation takes place mainly in valleys and irrigated areas and will be ignored here.

Table 6.3 *Nutrient contents of soil at three levels of soil fertility (in %)*

Soil fertility class (F)	N	P_2O_5	K_2O
1	0.05	0.02	0.05
2	0.10	0.05	0.10
3	0.20	0.10	0.20

Source: Stoorvogel and Smaling, 1990.; Note: 100 kg P_2O_5 = 22 kg P.

On the output side information is needed about the amount and nutrient content of harvested product and residues (Tables 6.2 and A6.5), and about the leaching, erosion and gaseous losses. Stoorvogel and Smaling found that leaching (of nitrogen and potassium) was positively correlated with the average annual rainfall (P), the soil fertility (F; class 1=low; 2=moderate, 3=high; Table 6.3), the application of fertilizers and manure and negatively with the uptake of nutrients. They found the following regression equations (kg/ha):

$$\text{LeacN} = 2.3+(0.0021+0.0007*F)*P+0.3*(\text{Fert}+\text{Manu})-0.1*(\text{Prod}+\text{Resi})$$
$$\text{LeacK} = 0.6+(0.0011+0.0020*F)*P+0.3*(\text{Fert}+\text{Manu})-0.1*(\text{Prod}+\text{Resi})$$

Gaseous losses of nitrogen or denitrification processes take place under anaerobic conditions, and are greatest in wet climates, on highly fertilized, clayey soils. Stoorvogel and Smaling (1990) found the following relationship (kg/ha):

$$\text{GaseN} = \text{'Base'} + 2.5*F+0.3*(\text{Fert}+\text{Manu}) - 0.1*(\text{Prod}+\text{Resi});$$

with '*Base*' denitrification ranging from 3 in dry zones to 11 kg/ha/year in wet lands.

```
Calculations with nutrient balances and response function     (N)
------------------------------------------------------------------------
Country : Indonesia      Farm type:     Rainfall: 2000 mm   Slope% 15.0
Reg/site: Malang            Q4          Soil    : Cambisols
------------------------------------------------------------------------
Soil charact:           Crops 1    2          Erosion    I n p u t s  (kg)
Soiltype:                Maize    Groundnut    20 t/ha FertN        Manu  Comp
FertF   2               Biom  5.5        -      5 t/ha Urea A/sul Cattl  Mix
pH    5.5               Pr/Re 0.6        -             235     0   2000  400
Depth  70 cm            Prod Resi                      108   0.0   20.0  4.0
Bulkd 1.5          Q kg 1200 2000    -   -
OrgM% 1.5          AvN%   1.7    1   -   -     Fert 0.1
Ncont 6.0          MinN% 0.9   0.4   -   -     Enr   2.0 INUE 75.1 INE2    -
Min%  2.0          DryM%  85         -                   Recov 0.3 Recov   -
TotN  189          Leg     0         1        Base  6.0 Yresp  23 Yresp    -
------------------------------------------------------------------------
Nutrient balance without conservation    (erosion = 20 t/ha) Resp.formula
     Fert Manu Depo Fixa Prod Resi Leac Gase Eros Saldo      Y=a+bN-cN2
      108 24.0  6.3  4.0 20.4 20.0 44.9 46.6 40.0  -30          a =    0
                                                                b =   23
Nutrient balance with conservation       (erosion =  5 t/ha)    c =  0.1
     Fert Manu Depo Fixa Prod Resi Leac Gase Eros Saldo        (example)
      108 24.0  6.3  4.0 20.4 20.0 44.9 46.6 10.0    0
------------------------------------------------------------------------
Effect of erosion on nutrient balance, determined by yields & fertilizer
Fert       Yields   Eros:20t/h 5t/ha   Less fertil. thanks to conserv.
 N   Crop   1    2  Nutrient balance    Amount (kg/ha)  Value (Rp)
------------------------------------------------------------------------
 108      1200            -30     0     74 N=160 kg urea    18,000
 182      1200              0    30
```

Figure 6.7 *Example of calculation of nitrogen balance and crop yield response (hypothetical example; kg N/ha)*

Whereas soil losses can be estimated on the basis of the USLE formula, the nutrient content of eroded soil varies with the level of inherent soil fertility according to Table 6.3.

Since the finest soil particles are detached and transported first, eroded soil material tends to contain more nutrients than the original soil. Therefore an 'enrichment factor' needs to be defined, that is here set at 2.0 for the three macro nutrients. P and K losses are on the other hand offset (here assumed by 25 %) by the downward extension of the rootzone.

Figure 6.7 shows a hypothetical nutrient balance for maize in a cropping system in Malang, Indonesia, with and without erosion control measures. Without measures soil erosion is 20 ton/ha and with measures only 5 ton/ha. To compensate soil nutrient losses due to erosion, an additional 160 kg urea (74 kg N) is needed per ha and per cropping season, which can be valued at about Rp 18,000.

In the Burkina Faso case study, presented in Chapter 9, use is made of these spreadsheet modules. Since hardly any use is made of fertilizers, no use is made of the INUE formula for the crop response to nutrients in pool A. With regard to the crop response to nitrogen availability, the future production in the 'with-' and the 'without-case' are calculated on the basis of the extent of the depletion of the organic matter in the soil and its mineralization (pool B). Some attention in this case study is also given to the crop response to the availability of phosphorus. Phosphorus (P) deficiency is a major constraint in soils in sub-Saharan Africa, and P-fertilizers differ from the other two macro nutrients N and K, in that they become more gradually available to the plants, over a period of several years, and therefore have more the character of investment than of recurrent costs (World Bank, 1995).

6.6 The use of water and nutrient balances in on-site impact assessment

The above discussed water and nutrient balances and the response functions could be used to arrive at better estimates of the effects on production of certain soil conservation measures (in the so-called 'with-case') and of continuing soil erosion (in the 'without-case').

A first evaluation of the on-site effects of a specific measure (e.g. terracing) is undertaken at *field level*. These fields correspond with certain LUST's, defined on the basis of both physical and agro-economic survey data. These fields could be public land (e.g. forest land), or form part of private farms. In the first case one has to know which of the respective publicly owned LUST's will be affected (e.g. reforested). In the second case one should identify (on the basis of agro-socio-economic data) which farm patterns comprise one or more LUST's that are earmarked for treatment, and are likely to participate in the programme (Chapter 5).

Subsequently one has to determine whether water or nutrients constitute the most *limiting factor*. A rapid assessment could be made of the relative scarcity of one of these factors. To obtain a quick impression about the relative scarcity of water, use could first be made of the 'transpiration coefficient (TR)', specifying the amount of water (in kg) needed to produce one kg of dry matter. The transpiration coefficient for a cereal like millet (a C4 crop) in the Sahel, is about 150 kg water per kg above ground dry matter, which, at a harvest index of 20 % (and a root/stem weight ratio of 25 : 75), means that for an average grain production of 600 kg/ha only about 60 mm water is required (adapted from Stroosnijder and Eppink, 1992). Subsequently one has to assess the amount of evaporation from the soil, which is mainly influenced by radiation and wind. In the Sahelian areas evaporation is about 2 mm per day, or about 240 mm over the growing season. Since 'normal year' effective rainfall in the growing season clearly exceeds this total amount of 300 mm, the use efficiency of water is apparently low, and actual production is more likely limited by nutrient shortage. In a dry year, and at high levels of run-off (low infiltration) the situation may be different however.

In order to assess the relative scarcity of the macro-nutrients (top)soil and/or plant samples should be analyzed. From (top) soil samples indications can be derived about the total organic matter and nutrient (N, P and K) content. The organic matter (C) content already gives a good indication about the general level of soil fertility. In order to determine the relative scarcity of the respective nutrients in relation to the total amount, available amount and the recovery fraction are also required. When the C/N ratio exceeds 15, some nitrogen may be withdrawn from the system and not be available for the plants. However, when yields are low much of the nitrogen requirements may be obtained from deposition, which can be close to the base uptake. It is hard to determine the availability of phosphorus (P), which depends on soil type, pH, etc. A low N/P ratio (<4) does not necessarily mean that P is relatively abundant.

It should be added that various forms of *complementarity* exist between the two major growing factors: water and nutrients (N, P and K). Increased water availability, for example, also enhances the yield nutrient uptake ratio, improving fertilizer efficiency. Where soil and water conservation activities bring about considerable changes in water- or in the respective nutrient-balances, and more than one factor is relatively scarce, it may be necessary to analyze the changes in availability and use of more than one factor (e.g. water and N or P).

The simple response formula shown in Figure 6.7 of the type: $Y = a + bN - cN^2$ for one factor (N), should then be transformed into a formula of the type $Y = a + bN + cP + dN^2 + eP^2 + fNP$. Special attention to this problem of the resultant crop response of the three (potentially limiting) macro-nutrients is given in the QUEFTS model (Janssen et al., 1990). Following a four-quadrant approach they first established relationships between soil parameters and the potential nutrient supply (step 1), then between actual uptake and potential supply (step 2) and thereafter between crop yield (expressed in a range) and actual uptake (step 3). The latter relation is transformed to crop yield versus soil fertility or fertilization in the fourth quadrant. The crucial fourth step combines the possible yield ranges (per nutrient) into one yield estimate. Such method is outside the scope of simple spreadsheet modules however.

Where *water* is the most limiting factor one has to assess the run-off pattern (Rof) for the 'without-case' and the gradual reduction of the soil depth (Dr) over the year. For the 'with-case' it is necessary to determine how the physical soil and water conservation measures will change the run-off, and how land use conversion affects the actual evapotranspiration (ETa).

When one of the major *nutrients* is the most limiting factor, one has first to determine whether nutrients can still be made available from pool A, or will only become available after mineralization. In the first case one can use the spreadsheet module to calculate the yield response by multiplying the initial nutrient use efficiency (INUE) by the recovery fraction. In the latter case one needs to know the nutrient content in the retained soil, the mineralization rate and the nutrient content in the main product (e.g. grains), in order to assess the yield increase as a result of the reduction in erosion (Chapter 9).

Conclusions

After an introduction about the effects of soil and water conservation measures on soil erosion and on-site productivity, and a review of traditional approaches in estimating SWC benefits, this Chapter focused on simple impact assessment methods. These methods make use of spreadsheet modules, in which first the effects of SWC measures on water respectively nutrient balances are determined and subsequently the effects of these changed balances on crop or bio-mass production. The aggregation aspect of upscaling these field- and farm level data to watershed level was already discussed in Chapter 5, and is of crucial importance in Chapter 7, where the focus is on the analysis of downstream effects that need to be taken into account for the (national) economic cost-benefit analysis of the measure(s) concerned. An overall framework is presented in Chapter 8, with all steps required in impact assessment.

APPENDIX (with Chapter 6)

Data on erosion factors in (R)USLE, and data to determine crop response to water and to nutrients.

Table A6.1 *Empirical average values for crop (C) and conservation practice (P) factors in USLE formula.*

In West Africa: Crop	Factor C	In Indonesia: Crop	Factor C
Bare plot	1.0	Bare plot	1.0
Millet/sorghum	0.4 - 0.8	Maize	0.6
Peanuts	0.4 - 0.8	Cassava	0.4
Cotton	0.5 - 0.6	Grains with beans	0.3
Maize	0.4	Annual & strawmulch	0.1
Fallow	0.3	Rice (sawah)	0.01
Rice (paddy)	0.3	Orchard	0.2
Overgrazed pasture	0.1	Grass (1-2 year)	0.3-0.02
Well kept pasture	0.01	Production forest	0.2
Dense forest	0.001	Natural forest	0.003

In West Africa: Conservation practice	Factor P	In Indonesia (in Konto model): Conservation practice	Factor P
Conventional ploughing	1.0	Paths, impeded land	1.0
Contour ploughing	0.6 - 0.9	Conventional ploughing	0.8
Terraces	0.3 - 0.9	Contour ploughing	0.6
Grass fallow	0.1 - 0.5	Dryland terraces	0.4
Strip cropping	0.1 - 0.4	Strip cropping	0.3
Contour trenches	0.1 - 0.2	Irrigation terraces	0.2
Dry stone ridges	0.1	Grass (and grass-strips under trees)	0.1
Straw mulching	0.01		

Sources: Bishop and Allen, 1989; Utomo, 1989.

Table A6.2 *Readily available soil moisture for relevant crops and different soil types (fine, medium and coarse).*

	Average rooting depth (m)	Fraction available soil water (p)	Readily available soil water (p.Sa; mm) Fine	Medium	Coarse
Total available soil water (Sa; mm/m):			200	140	60
Indonesia					
Carrots	0.8	0.35	70	50	20
Grass	1.0	0.50	100	70	30
Maize	1.3	0.60	120	80	40
Potatoes	0.5	0.25	50	30	15
Shallots	0.4	0.25	50	35	15
Burkina Faso					
Cotton	1.3	0.65	130	90	40
Groundnuts	0.8	0.40	80	55	25
Sorghum	1.5	0.55	110	75	35
Tunisia					
Olives	1.6	0.65	130	95	45
Wheat	1.2	0.55	105	70	35
(ripening)		0.90	180	130	55
Jamaica					
Bananas	0.7	0.35	70	50	20
Cocoa	n.a.	0.20	40	30	15
Orchards	1.5	0.50	100	70	30
Peas	0.8	0.35	70	50	25
Yam/Sweet pot.	1.2	0.65	130	90	40

Source: FAO, 1989. n.a. = not available.

Table A6.3 *Crop coefficient (Kc) and yield response factor (Ky) for several crops by period.*

	Length of development stage (days)					Crop coefficients (Kc)					Yield response factors (Ky)				
	Init	Devl	Mid	Late	Total	Init	Devl	Mid	Late	Total	Init/ Veget	Flow	Form	Late Ripe	Total
Indonesia															
Carrots	30	30	20	10/10	100	0.4	0.8	1.0	0.9	0.8	0.2	1.0	0.5	0.6	1.0
Maize	20	30	40	20/10	120	0.4	0.8	1.1	0.8	0.8	0.4	1.5	0.5	0.2	1.2
Potatoes	20	40	-	50/10	120	0.4	0.8	1.1	0.8	0.8	0.6		0.7	0.2	1.1
Shallots	20	40	20	10	90	0.4	0.8	1.1	0.8	0.8	0.4	1.1	0.8	0.4	1.1
Burkina Faso															
Cotton	20	30	60	30/20	160	0.4	0.8	1.1	0.8	0.8	0.2	0.5	0.4	0.3	0.9
Groundnuts	20	30	40	30/10	130	0.4	0.8	1.0	0.7	0.8	0.2	0.8	0.6	0.2	0.7
Sorghum	20	30	20	40/10	120	0.4	0.7	1.1	0.7	0.8	0.2	0.5	0.5	0.2	0.9
Tunisia															
Olives	-	60	60	120/30	270					0.5					n.a.
Wheat	20 /	50	40	40/10	220	0.4	0.8	1.1	0.5	0.8	0.2	0.6	0.5		1.0
(winter)		/(60 days dormant)													
Jamaica															
Banana	90	90	60	60/60	360	0.4	0.8	1.1	0.9	0.8					1.3
Citrus	-	60	30	120/90	300					0.9					n.a.
Peas (dry)	20	30	20	20/20	110	0.4	0.8	1.1	0.7	0.9	0.2	0.9	0.7	0.2	1.1

Source: Doorenbos and Kassam, 1979; FAO, 1989. n.a. = not available

Table A6.4 *Conversion of fertilizers and manure to pure nutrients*

Ammonium Sulphate	: 20 % N	Cattle and small	0.5 % N
Urea	: 46 % N	ruminants' manure	0.4 % P_2O_5
Super Phosphate	: 20 % P_2O_5	(% of fresh weight)	0.6 % K_2O
Triple Super Ph.	: 45 % P_2O_5	Poultry manure	1.0 % N
Muriate of Potash	: 60 % K_2O	(% of fresh weight)	0.7 % P_2O_5
Sulphate of Potash	: 50 % K_2O		0.4 % K_2O

Sources: Ilaco, 1981.

Table A6.5 *Average nutrient content in harvested products and residues (in kg per ton yield), and yields and nutrient uptake of some crops under more or less unrestrained conditions (Ym)*

	Harvested product			Crop residues			Yield	Uptake (kg/ha)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	t/ha	N	P	K
Cassava	4.2	1.1	5.1	4.6	2.1	1.7	30.0	90	20	175
Maize	16.8	9.4	5.7	9.7	4.4	25.7	6.0	150	25	40
Potatoes	4.4	3.0	8.3	2.3	1.6	5.4	50.0	200	38	300
Pulses	20.0	7.8	13.3	10.4	2.3	15.7		(n. a.)		
Sorghum	14.5	12.6	4.5	10.8	10.5	35.0		(n. a.)		
Wheat	22.3	9.9	7.0	4.3	4.1	32.0	7.0	165	30	80
Bananas	1.2	0.7	5.4	1.6	0.7	14.3	30.0	80	10	20
Citrus	1.8	0.5	2.8	0.6	0.5	5.3		(n. a.)		
Coffee	35.0	6.0	20.2	4.4	8.7	11.1	7.5	50	7	65
Cotton	18.7	22.2	10.8	13.9	13.9	35.8		(n. a.)		
Groundnuts	37.2	13.7	9.8	15.9	5.5	17.9	1.2	80	10	70
Vegetables	9.0	2.1	3.1	3.2	3.2	9.4		(n. a.)		
Fodder/Grass	6.8	3.0	5.7	-	-	-	20.0	300	45	300
Fallow	2.0	2.0	1.0	(in kg per ha)				(n. a.)		

Note: cassava/potatoes tubers, maize/wheat grains, coffee berries and groundnut seeds.
Sources: Stoorvogel and Smaling, 1990; Janssen and Beusichem, 1991.

7 DOWNSTREAM EFFECTS OF LAND DEGRADATION AND SOIL AND WATER CONSERVATION

All the rivers run into the sea; yet the sea is not full; unto the place from which the rivers come, thither they return again (Bible: Ecclesiastes 1:7).

7.1 The effects of land degradation beyond the field level

From a spatial analysis point of view, the effects of land degradation, and of soil erosion by water in particular, can be divided into several categories, as follows:

- Intra-field effects: the effects of erosion on the same field where it occurs;
- Intra-farm effects: erosion from one field affecting another field or a structure (e.g. building, road) on the same farm;
- Inter-farm effects: erosion from a field of one farm affects one or more fields and structures on neighbouring farms;
- Direct downstream effects: erosion from upstream fields directly affecting land and structures downstream (e.g. flooding, sedimentation on fields, in canals and harbours);
- Indirect downstream effects: erosion from upstream fields leading to the silting up of reservoirs that perform one or various functions downstream (e.g. hydroelectricity, irrigation and drinking water supply).

Here only the first type of effects are strictly considered as on-site effects. The field is then considered as a homogeneous unit with regard to physical features (e.g. soils, slope), land use and land management (including land tenure and inputs and outputs). These on-site effects have been discussed in Chapter 6. Although intra- and inter-farm effects may play an important role in the implementation of soil and water conservation measures in watershed projects, not much attention is paid here to these effects.

At field and at farm level only on-site effects (costs and benefits) of interventions can be analyzed. Downstream effects can not be assessed at these levels, and farmers will only take them into account in their decision-making when they receive the necessary incentives to do so.

In order to 'internalize' off-site or downstream effects of development activities at the 'project level', one should consider that area, within which the majority of these effects can be expected. With soil erosion considered as major adverse effect, such an area ideally consists of a drainage basin or a *watershed* as defined in Chapter 1. Uplands and lowlands are physically linked in a watershed via the hydrological cycle. A river basin (Marchand and Toornstra, 1986) is similarly defined, but is of a larger scale, and since it becomes more and more difficult to clearly ascribe adverse downstream effects from inappropriate upstream agricultural activities as one moves further away from the source, the watershed area is usually more relevant as 'project region', than the entire river basin. The latter often encompasses parts of different countries (Table 7.1).

There is a continuous debate about the relative importance of on-site (or on-farm) and downstream (off-farm) effects of soil erosion. Crosson (1986) has calculated the costs of on-farm productivity losses due to sheet and rill erosion in the United States. He arrived at an annualized present value (5% discount rate) of around US$ 600 million, or about 1% of total annual production costs. Clark et al. (1985) have estimated the economic cost of the downstream impacts of soil erosion in the Unites States at over US$ 6 billion (at 1980 values), of which US $ 2.2 billion due to sediment from the nation's cropland. Clark et al. (1985) concluded that off-farm erosion costs exceeded on-farm productivity losses.

Pimentel et al. (1995) have arrived at another conclusion. Applying the replacement cost valuation method they arrive at on-site costs of soil, nutrient and water losses in the United States of US$ 146 per ha per year, against off-site costs of about US$ 50 per ha per year. The replacement of lost nutrients by fertilizers constituted the largest single cost component.

In tropical sub-humid mountainous zones the situation is probably different. Magrath and Arens (1989) estimated the annual on-site costs of soil erosion on Java at US$ 315 million (4% of annual crop value), against off-site annual costs (sedimentation in reservoirs, harbours and irrigation systems) of only US$ 26 - 91 million. They admit that the latter are very crude estimates. Besides, the on-site costs may be overestimated, since recent studies show that the bulk of the eroded sediment is generated on the risers rather than the beds of the terraces (Critchley and Bruijnzeel, 1995).

With regard to off-site costs both Clark et al. (1985) and Pimentel et al. (1995) made a distinction between in-stream (e.g. recreation, navigation) and off-stream uses of water (e.g. flood damage, irrigation). Here downstream effects are sub-divided into direct and indirect effects, depending on the existence of dams and reservoirs, that can regulate the flow of water and sediment. Direct downstream effects include flooding and sedimentation affecting farm- and other land, canals, other waterways and harbours, and all kinds of structures. Generally, however, more attention is paid to the indirect effects, since it concerns the safeguarding of the often huge investment in dams and other water resources infrastructural works.

7.2 The loss of functions of reservoirs as a result of erosion

Dams and reservoirs have been used in many countries throughout the ages in order to make optimal use of water resources. In Jordan the remains of a barrage are believed to date from 3200 BC. Reservoirs behind dams are generally created to fulfil various functions, such as down stream irrigation, electricity generation, flood-control, drinking water supply, fisheries, recreation, etc. In 1950-1982 the number of dams worldwide increased from 5,000 to 16,000, China excluded, and up to 35,000 if China is included (ICOLD, 1984). Almost half (43%) are registered as multi-purpose (van Duivendijk, 1995). The uses to which they are put may be both complementary and conflicting.

Reservoir functions

Irrigation is often a major reason for the construction of dams. With fast increasing population and food demand, and in order to accommodate (or complement) the increased use of high-yielding varieties and fertilizers, irrigation development has received considerable attention in the past decades. Largely thanks to these dams, the total irrigated area in the world increased by 26% over the period 1973-1980. Since large scale irrigation projects have shown many drawbacks, more attention is now paid to small scale irrigation schemes.

Hydroelectricity is another important reason for constructing large dams, particularly in countries without mineral oil reserves, which would otherwise have to spend disproportionate amounts of foreign exchange to purchase oil. It is an environment-friendly source of energy and, where water is abundant, it is a relatively inexpensive way to rapid modernization. Low income countries may for example need large amounts of energy if they want to process mineral ores into high-value metals themselves (e.g. bauxite into aluminium) and therefore make use of hydroelectricity.

Flood control is a third reason for constructing dams. Flooding still constitutes a major problem in many developing countries. In the period 1960-81 over 300 major floods occurred, with about 80,000 deaths. More dramatic are natural disasters such as cyclones, which have claimed about half a million victims during this period, but these also include flooding as well. Most multi-purpose dams have a mitigating effect on large floods, but not all have sufficient capacity to prevent the enormous damage of peak floods occurring once in 50 or more years.

Other functions of dams with reservoirs include drinking water supply (Jamaican case study), fisheries and recreation (important in developed countries). In Tunisia much attention is nowadays paid to the construction of small dams, with only temporary reservoirs, that are meant for restocking groundwater reserves.

These reservoirs lose (part of) their functions in two ways as a result of upstream erosion: Either through siltation or through changes in stream flow of the river system.

Reservoir sedimentation

Apart from the adverse effects of soil erosion on the productivity of the land, soil particles are carried with the run-off water to rivers and are deposited somewhere downstream. From the on-site erosion in the uplands only a part will eventually be deposited behind dams (or in coastal deltas). The part concerned is determined by the *sediment delivery ratio* (SDR), that is determined by various factors, but is to some extent related to the size of the drainage basin. It may vary from 0.03 - 0.90 (Morgan, 1986), or range from more than 0.50 for small catchments of only 1 km^2 to 0.05 or less for large drainage basins of 1,000 km^2 and more. The great variation in topography and rainfall very much affects this ratio.

Table 7.1 *Sediment yield from selected river basins/watersheds*

River	Countries (main)	Drainage area (1,000 km^2)	Aver. annual suspended load (million tons)	Aver. annual erosion rate (tons/ha/yr)
Amazon	Brazil	5,776	400	14
Congo	Zaire a.o.	4,014	71	3
Nile	Egypt a.o.	2,979	122	8
Parana	Argentina	2,305	90	8
Niger	several	1,114	5	1
Ganges	India/Bangl.	1,060	1,600	302
Yellow	China	715	2,083	583
Chao Phrya	Thailand	106	13	24
Tana	Kenya	42	12	57
Brantas	Indonesia	16	4	43
Zeroud	Tunisia	9	n.a.	23
Yallahs	Jamaica	0.2	0.3	225

Sources: Sfeir-Younis, 1985; KRP, 1988; FAO, 1982a.

In many countries the gradual sedimentation of large man-made reservoirs now constitutes the most important downstream effect of soil erosion. The sedimentation of the reservoirs has in many cases been underestimated (Knoppers and van Hulst, 1995). In a study of 21 dams in India it was found that actual sedimentation was in most cases at least twice or three times the amount anticipated, and in one case the amount was 22 times as high. Only in one case it was less than expected (Tejwani, in Sfeir-Younis, 1985 p.131).

Table 7.1 shows the average annual sediment yield from selected river basins and watersheds. Erosion and sedimentation problems are generally more severe in Asia, with its higher rainfall and steeper slopes, than in Africa. The Ganges and Yellow rivers reflect the impact of intensive land use (after deforestation) and of considerable mass wasting. The Yallahs watershed in Jamaica is characterized by very steep terrain. Sedimentation can also be considerable in smaller basins and watersheds in Africa. The last three watersheds in Table 7.1 feature in the case studies (Chapters 9 and 10).

The costs of reservoir sedimentation

Reservoirs are built to regulate direct run-off into base flow, which in 1986 constituted about 36% of total river flow in the world. In that year the total gross volume of reservoir storage in the world amounted to almost 5,000 km^3, or 13% of total annual run-off. About half of this capacity is usable (active storage), and used once every year. The reservoirs augment total base flow with 16 % (Table 7.2). But about 1 % of gross capacity of reservoirs is lost to siltation. Taking into account that the average age of reservoirs in 1986 was about 22 years, total loss of usable capacity amounted to around 540 km^3, with a resulting loss of base flow augmentation of about 220 km^3. This means that around 1,100 km^3 of gross capacity had to be added to replace what had been lost in the period up to 1986. The replacement costs were estimated at about US$ 130 billion (Mahmood, 1987).

Table 7.2 *Estimated augmentation of base flow by storage reservoirs around the world (1986)*

Area	Annual run-off		Gross Reservoir Capacity	Share of (%)		Augmentation of base flow	
	Total (1000 km^3)	Natural base flow (1000 km^3)	Volume (1000 km^3)	World capac.	Total run-off	Volume (1000 km^3)	Share (%)
Asia	13.2	3.4	1.77	37	13	0.71	23
Africa	4.2	1.5	1.28	26	30	0.51	39
N.America	6.0	1.9	0.98	20	16	0.39	23
S.America	10.4	3.7	0.34	7	3	0.14	4
Europe	3.1	1.1	0.45	9	15	0.18	18
Australia	2.0	0.5	0.07	1	3	0.03	7
World	38.9	12.2	4.88	100	13	1.96	16

Source: Mahmood, 1987.

Pearce and Turner (1990) have estimated the developing world's annual loss of hydroelectric power through siltation caused predominantly by deforestation, for up to the year 2000. Total electricity demand in the developing countries during 1980 was 1,090,000 GWH. By the year 2000 keeping this demand constant, the estimated sedimentation loss is given as 148,000 GWH. The quantity of oil needed to produce that power is about 37 million tonnes. At US$ 25 per barrel this equates to US$ 6,700 million.

Apart from reducing the reservoir's capacity, sedimentation has also harmful effects on hydroelectric equipment, such as abrasion of turbines (Sfeir-Younis and Dragun, 1993).

Changes in annual streamflow

Changes in upstream land use and land management may be accompanied by more or less dramatic changes in the flow regime and quality of streams. While some go as far as trying to convince people that deforestation will automatically lead to flooding, to the drying up of streams and eventually to desertification, others have tried to be more objective in their presentation of scientifically established facts (Hamilton, 1986). Bruijnzeel (1993) makes an attempt to reconcile these conflicting views by describing the impacts of specific activities and types of conversion. He agrees with Hamilton, that terms such as 'deforestation' are meaningless, if no clear description is given about the type of degradation process and the land use and land management to which it is converted. Forests that are subject to fire, cyclones and well-conducted selective logging, may recover to their previous state if left alone for a sufficiently long period. In such cases Bruijnzeel refers to disturbances of intermediate intensity. Forests that are converted to some form of agriculture are then classified as undergoing disturbances of high intensity. The latter may indeed show important effects, not only on the stream flow and on sedimentation, but also on soil fertility and, when large zones are affected, even on the climate (rainfall).

Tree cover generally exhibits a higher evapotranspiration than annual crops, and annual stream flow can therefore be increased or reduced by de- and reforestation respectively. However, forestry systems with good groundcover and large rooting systems can withhold water for some time, contributing to a more even streamflow over time (days, months, years). If this so-called 'sponge effect' is considerable, it may be beneficial to the functions of reservoirs in dry periods. Little is known about the costs of changes in annual streamflow.

Loss of sites

The number of possible new sites for the construction of multipurpose dams is gradually decreasing in most countries, and hence restricts the present and future extension of irrigation schemes, hydroelectricity and flood-control measures. This loss of site may be more serious than the loss of the investment made in dam construction, and warrants the proper protection of upper watershed areas, located above dams.

7.3 Previously applied methods for estimating downstream effects

The benefits of soil conservation and watershed development projects consist of the sum of the net on-site benefits, as discussed in Chapter 6, the net downstream benefits and other indirect or secondary benefits.

The downstream benefits can be subdivided into *soil* conservation related benefits, that constitute of the reduced sedimentation in rivers, canals, etc. downstream, and *water* conservation related benefits such as the contribution to an increased dependable flow in the dry season, and a reduction in flood damage.

In the case of upper watersheds draining into a multipurpose reservoir these two categories of benefits can become more pronounced since the reduced sedimentation in the reservoir and the increased dependable flow in the dry season may result in longer term benefits of hydroelectricity, downstream irrigation and flood-control.

Box 7.1 *Economic evaluation of Loukkos Watershed Project (Brooks et al., 1982)*

The 1,820 km^2 watershed in the Loukkos river basin is characteristic of the Rif Mountain area of northern Morocco. In 1979 about 42% of the watershed was cultivated, 21% was forested, 28% were rangelands and 9% devoted to other uses. About 50% of the watershed exhibited severe erosion. The watershed provides stream flow for the Oued El Makhazine reservoir that provided irrigation water for 25,200 ha downstream, hydroelectric power, water supply and flood control.

A 20-year, US$ 26 million, project was proposed in 1979, covering reforestation, pasture management and olive and fruit tree plantations over an area of 40,000 ha. Channel stabilisation, gully control and road construction were also major components.

The existing level of sedimentation in the reservoir was estimated to average 3.8 mill. m^3 per year or 22 m^3/ha/year. Using a modified Universal Soil Loss Equation, whereby the C and P factors are replaced by one vegetation management factor (VM): A = R.K.LS.VM, with R=400, K=0.15, LS=10 and VM=0.15 (ground cover about 30%), the estimated annual soil loss (A) in the 'without-case' was 90 ton/ha, or 56.3 m^3/ha/year, with a sediment density of 1.6 ton/m^3. The sediment delivery ratio was therefore 39%.

The effectiveness of watershed management practices was evaluated by alternating the vegetation management/erosion control factor (VM). During the first five years the project was assumed to have no effect on sedimentation, after which time dead storage capacity was reached. After five years the gully control/channel stabilization was assumed to have been working for a period of five years, reducing total sedimentation to 2.18 million m^3. Thereafter the vegetation measures would keep annual sedimentation at a level of 2.80 million m^3, up to year 50.

Without the project irrigation water downstream would be reduced after five years. It would also be reduced with the project, but at a lesser rate. The difference in reduction of irrigation water with and without the project was translated into *irrigated crop value losses prevented*. Assumptions had to be made of the differences between the 'with-' and 'without-situation', with regard to changes in cropping patterns, irrigation operating and maintenance costs, etc. Other major benefits included the long term increased productivity in terms of animal production, the wood, olive and fruit production, and the reduced soil nutrient losses. Of these only the olive and fruit production benefits were included in the analysis. On the basis of these two major categories of benefits alone, the internal rate of return of the project was 15.9% and the net present value at 10% discount rate was $ 18.8 million, and these measures were not very sensitive to changes in costs and benefits.

In cost-benefit studies emphasis has mostly been given to the on-site benefits, for which it is relatively easy to make projections. But since the 1980's some methods have been developed to assess the two types of downstream benefits, distinguished above.

Soil conservation related benefits from reducing sedimentation

Since it has been realized that sedimentation in costly reservoirs is usually higher than anticipated, more attention has been paid to effects of SCWD activities on reducing sedimentation. Methods have been designed to assess benefits of SCWD activities in this regard. A classic study is that of Brooks et al. (1982). They developed a practical methodology for the economic evaluation of projects aimed at reducing upland erosion and sedimentation in multipurpose reservoirs. They used the example of the Loukkos Watershed

Project in Morocco to illustrate their approach (Box 7.1).

In this method use is made of the USLE formula, and in particular of the cropping or vegetation factor (C) and the conservation practice factor (P) used in this formula. However, as discussed in Section 6.1, the insight into the relative magnitude of these factors in different environments is still rather limited and in most areas based on a limited number of empirical studies. The formula only covers sheet and rill erosion and not stream-bank erosion and land slides that are also partly influenced by land use. Besides the formula implies a static situation and does not directly relate to surface run-off. Morgan et al. (1984) therefore developed a somewhat different approach, whereby an explicit distinction is made between the detachment and the transport of soil particles (Section 7.5).

Water conservation related benefits from changes in streamflow

The effects on the streamflow can be subdivided into effects on the total water yield, on the dry season flow and on flooding (see also Section 7.4). For the evaluation of the costs and benefits of implementation activities of the Konto River Project, an attempt was made in 1987 to assess the order of magnitude of the effects of increased vegetation and better water infiltration (storage). These effects could lead to an increase of the minimum flow in the dry season and to reduced flows in the wet season, and so contribute to longer lasting downstream benefits of the reservoir (Box 7.2).

Box 7.2 *Economic evaluation of Konto River watershed development activities (de Graaff and Dwiwarsito, 1987)*

The 232 km^2 Upper Konto River watershed area is situated in East Java, Indonesia. It constitutes an upland plateau surrounded by steeply sloping mountains of volcanic origin. About two third of the area consists of forest land, but part of that has been degraded to shrubland. The watershed area drains into the Selorejo reservoir, that provides hydro-electricity and irrigation water for 5,700 ha land downstream. From 1979 - 1990 an Indonesian-Netherlands project studied the deforestation process in the area and from 1986 onwards implemented various watershed development activities in the area, such as reforestation, coffee rejuvenation, terracing, gully control, grass planting, etc. (see also Chapter 10). In 1987 a preliminary economic analysis was made of these activities, whereby attention was also paid to downstream effects. For the analysis of the soil conservation (sedimentation) related benefits use was made of a similar procedure as that applied by Brooks et al. (1982). But it was argued that the SCWD activities were also likely to affect the minimum and maximum seasonal streamflow (or Qmin/Qmax relationship) of the Konto river and hence the water supply to the reservoir. Therefore an attempt was also made to estimate that type of benefit.

On the basis of research data, values were first estimated of evapotranspiration, infiltration (sub-surface storage) and direct run-off for the various types of land uses: natural forest, open forest, shrub, coffee land, poorly and well terraced rainfed land, irrigated land and built-up areas, etc. (Table 7.3). It was then estimated which amount of infiltrated and run-off water would be available in the dry and wet seasons respectively, and subsequently how the interventions or changes in land use (e.g. shrub into forest, poorly terraced into well terraced) would affect the water availability in the reservoir in the dry season (important for irrigation and electricity) and in the wet season (relevant for flood control).

Box 7.2 *continued*

Table 7.3 *Estimated values of water disappearance and use for all land use categories, and effects of changes on mean dry and wet season streamflow (expressed in mm)*[1]

Land use[2]	Forest	Shrub	Irr. land	Gardens (shaded coffee)	Rainfed l. terraced bad	good	Housing & roads	Total (average)
Area (ha)	9000	6440	1900	1957	1966	983	820	23066
Evapotransp.	1200	1000	1100	1100	750	750	600	1050
Storage [3)]	950	900	450	750	550	850	200	820
Direct run-off	250	500	850	550	1100	800	1600	530
Made available via run-off and infiltration (storage) in:								
Dry season	500	450	400	200	300	500	100	420
Wet season	700	950	1100	900	1350	1150	1700	930
Land use/mgt	+ 1470			+ 200		+ 207		+ 1877
changes (ha)		- 1470			- 407			- 1877
	< - - - - - - >			< - - - - - - - - - >				New relation
Changes in streamflow:								dry/wet season:
Dry season	+ 3%			+ 1%	+ 1%			425
Wet season	-16%			- 4%	- 2%			908

1) Moderately steep slopes, permeable soils, 2400 mm annual rainfall, Epot (open water) = 1300 mm and ETo = 1050 mm; 2) Limited grassed area not considered; 3) Sub-surface storage, after infiltration.
Sources: de Graaff and Dwiwarsito, 1987.

The ratio found between the wet and dry season flows corresponded to a large extent with the actual data observed in the hydrological research programme (Rijsdijk and Bruijnzeel, 1990). The calculations in Table 7.3 show that the land use and land management changes had hardly any measurable effect (1% increase; from 420 to 425 mm) on the average streamflow in the dry season, but may have had some slight effect (2.5% decrease; from 930-908 mm) on the average streamflow in the wet season (mainly resulting from the reforestation).

Since the activities contributed little to an increase of the dry season flow, they must have brought about only minor monetary benefits through the supply of irrigation water and electricity. Although also modest, the decrease of the wet season flow was more pronounced. On the basis of a review of some past flood patterns and of the probability of exceedence of certain discharges leading to respective levels of flood damage, it was assessed that the reduced wet season flow would reduce average annual damage by 5 - 10%.

These (flood-control) benefits appeared to be of a lower order than sedimentation related benefits of the conservation activities. Together, however, these two categories of downstream benefits were of a similar magnitude as the direct on-site benefits (of wood, coffee, etc).

This method grossly simplified the hydrological system, in particular where it divides the average annual amount of water made available to the streamflow (through run-off and temporary sub-surface storage) arbitrarily over the two seasons. The method would also require detailed insight into infiltration and sub-storage characteristics of the respective forms of land use on the various soil and slope conditions. While the overall results were similar to the measured data on the dry and wet season streamflow, the relative contribution of the respective land uses could not be verified. The relatively high extent of the reforestation component greatly influenced the results. Because of the ongoing debate on this issue, it was assumed that the conversion from shrub to forest would not contribute to higher infiltration, and hence hardly affect the dry season flow. This change from shrub to forest would however contribute to the flood control related benefits, since increased evapotranspiration would reduce wet season run-off (de Graaff and Dwiwarsito, 1987). Chapter 10 discusses these issues in more detail for the same case study area.

7.4 The impact of SCWD activities on the downstream water flow

Both types of soil and water conservation measures considered in this analysis, i.e. physical structures and land use conversions, bring about changes in infiltration and evapotranspiration and in soil detachment, which in turn determine water flows, sediment flows and water availability to plants.

Water flows are the prime agents that cause changes in both total or seasonal streamflow and erosion and sedimentation. Therefore one should analyze first the effects of SCWD activities on the water flow, and subsequently assess how the water flow changes affect downstream water supply, sedimentation, flooding, pollution, etc.

The changes in the field level water balance bring about changes in the water balance at higher aggregation levels. The parameters in the field level or agricultural water balance (5; see Section 6.4), could be transformed into a watershed level or hydrological water balance (6). The field level run-off becomes overland run-off (Ro) and together with the interflow or subsurface run-off (Rs) contributes to the direct run-off or quickflow (QF). The field level percolation or drainage (D) contributes to the baseflow (BF) and to the net addition to groundwater storage (ΔG). Quickflow and baseflow together form the streamflow (SF).

Inflow = Outflow + Change in Storage, or:

$$P = ET + Ro + (D + \Delta SM) \qquad \text{(at field level, 5)}$$

becomes:

$$P = ET + (QF + BF) + \Delta G \qquad \text{(at watershed level, 6)}$$

where: P = precipitation; ET = evapotranspiration; Ro = overland run-off; D = deep percolation; ΔSM = change in soil moisture; QF = quick flow; BF = base flow; ΔG = change in groundwater storage.

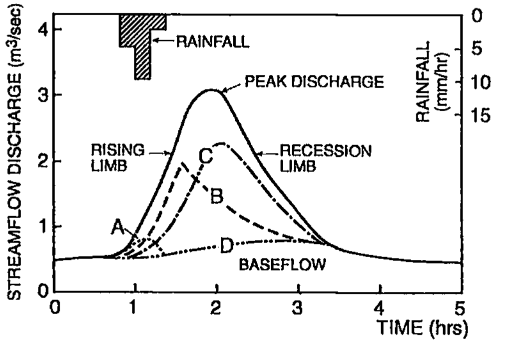
Where the phreatic divide does not coincide with the topographic divide, the watershed water balance may not be correct. One refers then to watershed leakages (Koopmans et al., 1993).

Water is redistributed through irrigation infrastructure, and where only part of a watershed is considered, irrigation water may be the second source of inflow.

In the spreadsheet model discussed in Section 7.6, the emphasis will be on the changes SCWD activities bring about in the streamflow. In the Tunisia case-study reference is also made to effects of soil and water conservation measures on ground water levels (Chapter 9).

The composition of streamflow differs considerably between semi-arid zones and humid zones. In the former zones rainfall often exceeds the infiltration capacity, because of a lack of vegetation and organic matter, and leads to considerable (Hortonian) overland flow. In the latter, with its more abundant vegetation and high infiltration capacity of (undisturbed) soils overland flow is relatively modest (Benning, 1995).

While most rivers in the sub-humid zones are continuously fed with a base flow, derived from water percolated to groundwater and subsequently entering the stream, they receive quick flow only after excess precipitation. In semi-arid zones, where potential evapotranspiration mostly exceeds the precipitation, baseflow is very low and streams may be dry for extensive periods. A few times a year, however, some intensive rain showers (above 25 mm a day) may cause much overland flow which as a result of a fast concentration time (T_c) may cause massive quick flow. While the baseflow may go through a narrow channel, after peak rainfall the river may extend to the whole floodplain.



A is channel interception; B is overland run-off;
C is subsurface flow; D is groundwater or baseflow.

Figure 7.1 *Hydrograph*
Source: Brooks et al., 1990.

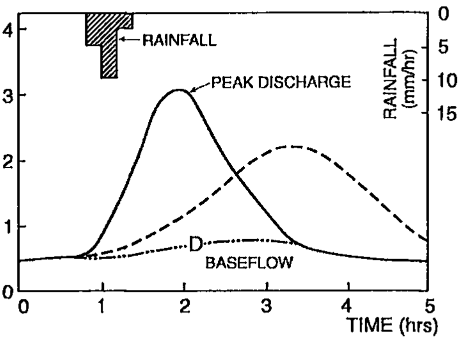


Figure 7.2 *Timelag & attenuation*

The accumulated discharge over time, after a precipitation period, can be shown by 'hydrographs' (Figure 7.1). When the system can be considered linear and time invariant, the hydrograph for the quick flow or direct run-off may be superimposed on the base flow hydrograph. While baseflow is quite slow and constant, the quickflow is fast and shows peak waves. The flow velocity differs widely: from 1 m/h or less for groundwater (except in jointed limestone) to more than 100 m/h for overland flow and more than 10,000 m/h in open channels (Weyman, 1975). On average water will only remain for 10-20 days in the system of a medium sized river, but this period may fluctuate widely.

Apart from the precipitation features and the antecedent soil moisture content, the shape of a hydrograph is influenced by geology, soils, landform, catchment, channels, land use and land management. Since SCWD activities influence the latter factors, they will also affect the hydrograph.

In order to reduce the stream flow fluctuations, more water should infiltrate the soil and be stored as long as possible in the upland system. This will usually cause both a longer time lag of the peak wave, and attenuate the peak. As in the case of reservoirs (Figure 7.2).

Depending on the type of hydrological data required, many theoretical and empirical mathematical formulas and models have been developed. Deterministic hydrological models try to explain the complicated hydrological systems and need calibration to compare the computed with the observed response (Chapter 10). Several general simplified empirical methods have also been developed. Most of these methods consider only overland flow, and assume that this is uniformly generated by excess rainfall over the entire watershed.

Sherman (1932) found that bursts of any amount of rainfall within a specified time interval over a particular watershed tended to produce storm hydrographs of similar shape and duration. If data are available on precipitation and streamflow for a watershed, one can derive a so-called 'unit hydrograph', or the hydrograph of quickflow resulting from 1 unit (e.g. cm) of effective rainfall over a specific time period (e.g. 1 hour). Once the unit hydrograph is known, hydrographs for more rainfall over longer periods can be predicted.

For situations where no streamflow data are available, the U.S. Soil Conservation Service has developed the Curve Number (CN) method, to access effects of rainfall on infiltration and run-off in small watersheds. The watershed index $CN = 1000/(10+S)$ and the direct run-off $Q = (P-0.2S)^2/(P+0.8S)$ need to be defined. P is the precipitation and S the recharge capacity or the potential maximum retention (both in mm). The value of CN depends on basin characteristics, and in particular on land use, treatment, soils and on hydrological conditions, and can be obtained from tables.

To estimate (quickly) the peakflow from rainfall over a watershed, in order to calculate the minimum size of structures, the 'rational method' can be applied: $Q_p = c*I*A$, where Q_p is the peak discharge (m^3/sec), c is a run-off constant, ranging from 0.1 to 0.5, I the (design) rainfall intensity (m/sec) and A is the area of the watershed (m^2). The rainfall should concern a storm with a duration of at least the time of concentration (T_c; sec.) of the watershed, or the time needed for water to travel from the most distant point to the outlet.

The relative speed with which rainfall excess contributes to streamflow can also be expressed by the 'hydrologic response' (HR), or the annual direct run-off as a percentage of annual precipitation (Woodruff and Hewlett, 1979). This can be used to compare the relative 'flushiness' of watersheds.

Probability of rainfall

Because of the unpredictability of rainfall, water resource management has to make use of probability analysis. In the design of structures for flood control the probability of river discharge exceeding certain levels has to be calculated, preferably using flood peak records over periods of 100 years or more (Section 7.6). For the estimation of drought sequences stochastic models are applied.

Seasonal water demand

Although one generally aims at stabilizing the streamflow throughout the year (better Qmin/Qmax ratio), one should also look at the respective requirements of different users for particular patterns of flow. Downstream communities may need more irrigation water during the dry season, more electricity during cold periods and short days, and more water for recreation during the holiday periods. Fortunately for reservoir management irrigation demand is often highest in periods in which the threat of large floods is slight. More water could then be stored in the reservoir for irrigation water supply than would be permitted in the 'flood season'.

7.5 The impact of SCWD activities on downstream sedimentation

Sediment transport is generally more difficult to predict than run-off (Newson, 1992). Because of geomorphological and other differences, Schumm (1977) has proposed dividing basins and watersheds into supply, transfer and deposition zones. In the supply or headwater zone, the coupling between slopes and channels controls the amount and timing of sediment removed from the system. The transfer zone consists of floodplains and valley floors that intervene to store sediments. In this zone in particular a distinction has to be made between sediment size, resulting in either suspended load and bedload and an intermediate form of saltating transport.

Soil erosion rates within a watershed can be assessed in three different ways: 'upstream methods', whereby actual soil losses are measured (e.g. through run-off plots), 'midstream methods' based on the sediment load carried by rivers; and 'downstream methods' based on the volume of sediment deposited in lakes, reservoirs or at other drainage points of a water basin (WRI, 1988). It is clear from the above that a combination of these methods would provide a more thorough understanding of erosion processes.

There are clear differences in the sedimentation process between areas in (sub-)humid mountainous and in (semi-)arid zones, since there are few permanent rivers in the latter.

Pollution

In Chapter 6, mention has been made of the 'enrichment factor' in soil erosion: the eroded material from the topsoil generally contains more nutrients and organic matter than the soil from which it is derived. In the watershed this material will, depending on its grain size and other factors, be deposited in upland or lowland depressions and valleys or in reservoirs. Due to their low specific gravity organic particulates will be mobilised relative frequently (Walling, 1988). It may have beneficial effects when it is deposited on agricultural land or fishing grounds, but because of its concentration and its less balanced composition it can also create pollution problems, as it does in many developed countries. In the Konto River watershed (Indonesian case-study) an estimated five percent of the sediment was derived from the excreta of the large herd of dairy cattle.

Seasonality of sedimentation

In very small watersheds only small amounts of sediment will be stored for longer periods, resulting in an annual sediment delivery ratio close to 100%. However, this ratio may vary by season between from 30 - 300% as a result of short term channel storage and subsequent remobilisation. Given the seasonality of rainfall, erosion and streamflow, it is to be expected that the sedimentation will follow a similar seasonal pattern. However, that is not necessarily the case. The phase difference between sediment supply and sediment output generated by such channel storage (Walling, 1988) should be taken into account. Such a temporal discontinuity in the sediment delivery system also exists, of course, between (dry and wet) years. In Jamaica it appeared that a high proportion of the sediment in a reservoir was due to the high rainfall intensity accompanying hurricanes.

Sediment flushing and sluicing in reservoirs

Reservoirs do not retain all sediment. The trap efficiency depends, among others, on the type of sediment and on the type of reservoir. In a narrow, gorge type, reservoir sediment will travel further, since the velocity of flow is higher than in wide, floodplain, reservoirs. There are basically three methods to reduce sedimentation in reservoirs: upstream watershed management, including checkdams or debris basins; sediment flushing and sluicing; and dredging.

Sediment flushing is used to clear existing sediment accumulation in a reservoir hydraulically, through a low-level outlet. It is relatively more effective in gorge type reservoirs, and when the reservoir is drawn down. Sediment sluicing is an operational design, whereby the suspended sediment is released along with the flow, before it can settle down. Around 1900 this method was successfully applied to the Old Aswan Dam on the Nile, so that downstream farmers would not be deprived of their fertile silt. However, such a system reduces the reservoir capacity (Mahmood, 1987).

Dredging

One way of removing the sediment from a reservoir is to initiate dredging operations. This is often seen as an alternative to costly watershed management. However, there are several problems with dredging. The first is where to leave the silt. Secondly dredging only addresses the symptoms in stead of the cause of sedimentation. The costs of dredging are considerable, although they vary according to technical (e.g. location and type of sediment), logistical (e.g. accessibility) and financial (e.g. contractual) factors. According to Mahmood (1987) the cost of conventional dredging alone, without the additional cost of providing disposal areas and containment facilities, varied (in 1985) from US$ 2 - 3 per m^3. Another dredging specialist estimates that cleaning a reservoir (3 million m^3 per year over 5 year) in an arid and accessible area with nearby dumping grounds, would cost about US$ 3 per m^3, and the one time cleaning of a small reservoir (0.7 million m^3) in tropical areas about US$ 7.5 per m^3 (Loman, pers. comm.). In the Hermitage reservoir, supplying much of the drinking water for the capital of Jamaica, dredging took place up to 1975. In that last year 0.2 million m^3 (10% of reservoir capacity) silt was removed at a cost of US$ 0.5 million, or US$ 2.5 per m^3. In 1992 the total cost of dredging were estimated at US$ 2.5 million (US$ 5.2 per m^3), while the potential revenues from the water supply, gained through dredging were estimated at about US$ 0.1 million per year at water rates of US$ 0.22 per m^3 (derived from Miller, 1992). In the Selorejo reservoir at the downstream end of the Upper Konto River watershed, dredging has not yet been carried out, but studies have been undertaken to initiate dredging operations in other similar reservoirs in the neighbourhood.

7.6 The use of water and sediment flow effects in downstream impact assessment

In this section a methodology will be developed for the analysis of the effects of SCWD activities, and in particular land use conversions, on (bio-mass) production, stream flow and downstream sedimentation. The focus is on situations with permanent rivers in the (sub-) humid mountainous zones. The general framework of a spreadsheet model is described in this paragraph. The model makes use of water and sediment modules and is applied in the Konto River case study, discussed in Chapter 10.

A watershed usually covers too large an area for monitoring its effects. The watershed could be first divided into several sub-watersheds on the basis of specific agro-climatic conditions. Hydrological monitoring could take place in small catchments within such sub-watersheds, which are representative with regard to morphological features. The sub-watersheds may be further sub-divided into upper, middle and lower parts, according to altitude and physical characteristics. These parts are here referred to as hydrological units (HU), in analogy with land units. Each hydrological unit contains a certain number of Land Use Systems and Technology (LUST's). The inputs and outputs per HU are a summation of the inputs and outputs of all LUST's in the HU, multiplied by the area covered by each LUST (Figure 5.1). The spatial organisation of the sub-watersheds is such that all water flows and sediment flows go from an upper (HU1) to a middle (HU2) to a lower hydrological unit (HU3) and finally enter into the next (sub-) watershed through the river system (HU4) (van Loon et al., 1995). Considering that in most upper watersheds in the (sub-)humid mountainous zones in the tropics land use is very much scattered, the spatial organisation of LUST's within HU's is not specified. Only the HU's can be mapped, and not the LUST's.

Water module

Each hydrological unit (HU) can keep water in three 'stores': the root zone, the deep soil and the streams, which supply water to the plants, the groundwater and to the lower parts of the sub-watershed respectively. Where such an upper watershed area contains irrigation channels these could be considered as a separate 'store'. Transport between stores is a constant proportion of the amount in a certain store. These constants are difficult to estimate but can be obtained through calibration. Rainfall and evapotranspiration data should be known for each HU. The incoming rain is separated into a fraction that infiltrates and a fraction that runs off.

The water balance of each HU is obtained through adding together the water balances of the various LUST's in the HU. Water balances are calculated first for each LUST in a similar way as described in Chapter 6. The actual evapotranspiration is calculated as the maximum evapotranspiration (under rainfall surplus) or the total rainfall plus the change in soil moisture (under rainfall deficit). The soil moisture at the end of the month constitutes that of the previous month plus the moisture recharge minus the actual evapotranspiration. On the basis of this the on-site production changes can be determined (see below).

Subsequently the distribution of surplus water at the LUST level over overland run-off (Ro), subsurface run-off (Rs) and deep soil layers (D) should be determined for the months with surplus water. The latter two constitute the horizontal and vertical movements of the infiltrated water respectively. The fraction of excess water that will be channelled to deep layers depends on the saturated conductivity of the soil. Here a fixed fraction (VF = vertical flow) is used, empirically determined from watershed calibration, and it is specified

Table 7.4 *Distribution of excess water over run-off and deep percolation*

```
Excess water ---> NO ---> no run-off (RO), no deep percolation (WD)
     ↓
     ↓
   YES, amount is X
Most permeable soil layer:
     --->   Topsoil: subsurface flow    ROs = HF (=VFT-VFS) * (X)
           (VF=VFS)  deep percolation   WD  = (VF-HF) * (X)
                     overland flow      ROo = (1-VF) * (X)
     --->   Subsoil: subsurface flow    ROs = 0
           (VF=VFT)  deep percolation   WD  = VF * (X)
                     overland flow      ROo = (1-VF) * (X)
```

for two soil layers: topsoil (VFT) and subsoil (VFS). Table 7.4 shows how excess water is distributed over overland and subsurface flow and deep percolation. If the topsoil is less permeable than the subsoil, all infiltrated excess water will contribute to deep percolation and no sub-surface flow will occur (ROs). If the topsoil is more permeable, subsurface flow will constitute a fraction HF of excess water, equal to fraction VFT minus fraction VFS.

The weighted average LUST data for ETa, WD and SF (ROo and ROs) are then added together to arrive at the HU water balance. The streamflow is the sum of quickflow (the sum of subsurface and overland flow), baseflow and streamflow from a HU upstream (Equation 7).

$$(SF_t)_h = (ROs_t)_h + (ROo_t)_h + (BF_t)_h + (SF_t)_{h-1} \qquad (7)$$

The baseflow is described in Equation 8, as a sine function with an average that is equal to the water stored in deep soil layers (D). Deep percolation (Dp) is assumed to be a constant fraction of total water in deep soil layers for each HU.

$$(BF_t)_h = (1\text{-}Dd)*[(1\text{-}Dp)*\Sigma_t\ WD_t/12 + BFV * SIN(t\text{-}(9\text{-}Mbf)*\pi/6) \qquad (8)$$

where: Dd and Dp are fractions of water in deep soil, that flow to a HU downstream and percolate further down respectively (deep groundwater, GW out of drainage basin); BFV the maximum variation in baseflow; Mbf the month in which the minimum baseflow occurs (usually September (9) in Konto watershed in Indonesia) and t the month for which the baseflow is calculated (month, 1-12).

Sediment module

Sediment moves in a similar way, with the water, from the upper HU1, via HU2, etc. to the river system (HUn), but only two 'stores' can be distinguished: sediment in the streams (SS) and sediment on the land (SL). Part of the sediment remains on the land in the same HU (e.g. HU1), or is deposited through the stream on land in lower HU's, while part constitutes the eventual sediment output in the river system. The sediment delivery ratio (SDR) is then this final sediment output at some point in the river, divided by the total amount of sediment moved from the respective hydrological units (HU1-HUn).

The potential transport rate of sediment is determined by both slope (steepness) and the flow rate. This flow rate depends both on the slope steepness and on the soil surface, representing the resistance to overland flow. The soil surface could therefore be broadly distinguished into undisturbed, disturbed (cultivated) and impeded (paths, etc).

With the Wischmeier or USLE formula, monthly soil erosion (ERw_t) can be derived from:

$$ERw_t = R_t*K*L*S*C_t*P \qquad \text{(see Chapter 6)} \qquad (9)$$

The erodibility factor R (in J/m3) is calculated by month, according to a formula derived from Richardson et al., 1983:

$R_t = a * (P/Pn)^b$, *where: P = annual rainfall (mm), Pn = number of rainy days (-) and a and b are regression coefficients, fixed at 0.077 and 1.300 respectively.*

A monthly crop factor is considered, on the basis of the monthly variations in Kc-values:

$$C_t = C * (Kc_t / Kc)$$

where: C and C_t are the annual and monthly average crop factors and Kc and Kc_t the annual and monthly Kc factors.

Although the sediment-concentration of the surface run-off was considered the most important component of the erosion process, the Wischmeier or USLE formula makes use of the amount of transported soil material. No adequate run-off formulas were available. Williams (1975) replaced the R-factor with a run-off factor in his sediment yield (Ys) formula: $Ys = 95 (q_p*Q)*KLSCP$, where Q is the volume of direct or storm runoff (acre-feet) and q_p the peak flow rate (cubic feet per second). This equation was developed to estimate sediment yield (rather than soil loss) at the outlet of a watershed directly, on a storm by storm basis. This may be particularly suitable for areas where most sedimentation is caused by a few storms a year.

Morgan et al. (1984) have instead used a model, whereby both the amount of detached soil and the transport capacity of the run-off are calculated. The USLE formula is here somehow split in two parts: a part responsible for detachment (factors R and K), and a part consisting of the factors responsible for the transport of soil particles (the runoff, the slope and the C and P factors, influencing surface roughness).

Part one is referred to as the '*water phase*':

$$E = P * (11.9 + 8.7 \log_{10} Pe) \quad \textbf{(10)}$$
$$Q = P * \exp(-Pc/Po) \quad \textbf{(11)}$$

with: $Pc = 1000*SMfc*BDt*Rt*(ETa/ET0)^{0.5}$;

where: E = Kinetic energy of rainfall; Pe = Threshold value of erosive rain (e.g. 25 mm); SMfc = soil moisture at field capacity (%); BDt = bulk density topsoil (Mg/m^3); Rt = soil rooting depth (m); Po = rainfall in mm (P), divided by number of rainy days (Pn).

Part two is referred to as the '*sediment phase*', described by the formulas:

$$F = K * (E*e^{-0.05I})* 10^{-3} \quad \textbf{(12)}$$
$$G = C * P * Q^2 * \sin S * 10^{-3} \quad \textbf{(13)}$$

where: F = rate of splash detachment (kg/m^2); K the soil parameter for detachability; I percentage rainfall contributing to interception and stemflow. G = transport capacity of overland flow (kg/m^2); C, P and S the erosion factors (as in USLE); and Q the volume of overland flow (mm).

This method compares the predictions of detachment by rain splash (12) and the transport capacity of the run-off (13) and assigns the lower of the two values as the annual rate of soil loss, thereby denoting whether detachment or transport is the limiting factor: $ERm_t = Min(F,G)$. The method has the advantages over the USLE formula that it is more closely linked to the actual processes and that it focuses on erosive rainfall (Pe).

Using a method similar to that for the water module, the data on sedimentation at LUST level are totalled to arrive at the sedimentation at HU level. With the erosion per HU the sediment that arrives in the stream is described as a linear function of the average erosion over two months, with the sediment delivery ratio as a constant (Equation 14).

$$SS = (TCs_{t-1} * ERm_{t-1} + TCs_t * ERm_t) * SDR \qquad \textbf{(14)}$$

where: SS *= sediment in stream (kg/ha);* TCs_t *= transport coefficient (fraction,* TCs_t *and* TCs_{t-1} *sum to unity) and SDR = sediment delivery ratio.*

Spreadsheet model

The spreadsheet model calculates the water balance at LUST, HU and watershed level for respective scenarios and time periods, and subsequently assesses the erosion, sedimentation and production changes brought about by the mix of activities in that scenario. The model inputs are data on the distribution of land use systems (scenarios), climate (rainfall) and various land and crop characteristics, as outlined in the description of the water-, sediment and production modules (Figure 7.3).

The major output consists of the production changes resulting from land use changes and water shortages and of the streamflow and the sedimentation at the outlet of the watershed or in the reservoir. An example of the watershed level results is given in Appendix 7.1.

The streamflow and erosion/sedimentation data can subsequently be used for the calculation of the downstream effects on irrigation water supply, hydroelectricity and flooding, as discussed below and further elaborated in Chapter 10.

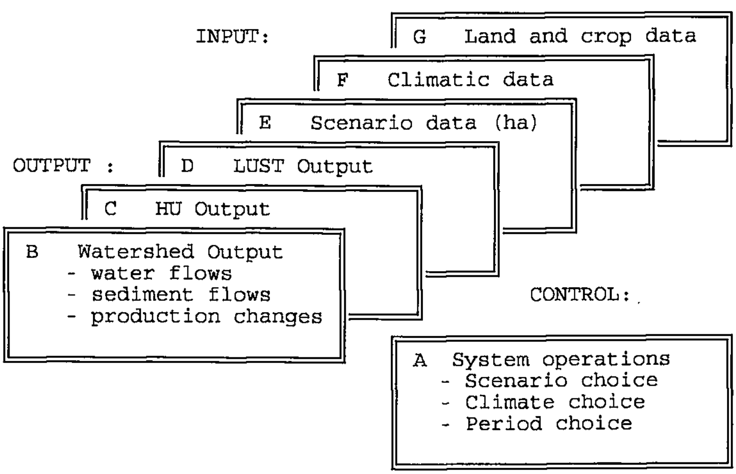


Figure 7.3 *Structure of multiple spreadsheet watershed model*

On-site production changes
For the on-site response of increased water availability to biomass production use is made again of the Doorenbos and Kassam (1979) formula: Ya = Ym * (1 - ky * (ETm-ETa)/ETm), as shown in Chapter 6. For Ym use is made of reference yields (Yref), obtained from data on locally obtained yields under more or less optimal growing conditions.

Downstream effects
Once the changes in annual sedimentation in the reservoir and the changes in the annual streamflow (brought about by SCWD activities) are known, one can calculate how these two types of changes affect the respective reservoir functions.

For water supply purposes the changes in dry season supply are normally of major importance. For flood control the changes in annual peak flows are more important. SCWD activities will not be able to realize such changes overnight, but once these changes occur they will have an immediate effect on the water supply in a reservoir, and reservoir managers may adapt allocations accordingly.

It is often assumed that the effects of increased sedimentation will only start when the dead storage part of the reservoir is completely filled with sediment. However, that is not completely true. While much (finer) sediment will settle itself in the lower reaches or the dead (non-usable) storage part of a reservoir, much (coarse) sediment will remain in the upper reaches of the reservoir. This will immediately reduce active storage for water demand and for flood control (Figure 7.4).

The water-supply to *irrigation* schemes will be affected in the first place by a decrease in the average streamflow in the dry season. This is likely to reduce (immediately) either the yields and net returns of the last crop in the yearly crop rotation or the irrigable area, or both. Other water uses in the dry season are also immediately affected. Sedimentation will on the other hand affect long term water availability for the respective reservoir functions.

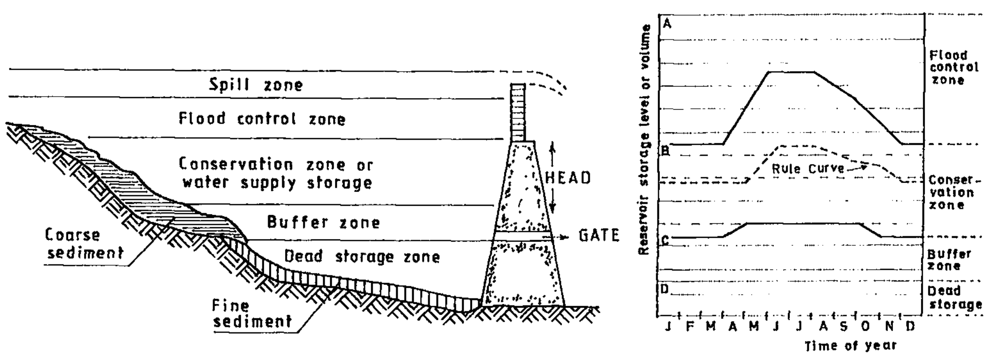


Figure 7.4 *Storage allocation for a multi-purpose reservoir, with associated sedimentation, and operational rule curves*
Sources: Brooks et al., 1990; Mahmood, 1987.

In Chapter 10 one example is given of a reservoir, primarily used for irrigation water supply (in Indonesia) and another example of a reservoir that is used for the supply of drinking water (in Jamaica).

For *hydropower* installation the net head (h = total head minus friction losses) is important as is the quantity of water (Q = streamflow). The minimum flow represents the amount of water that can be used to drive the turbines on a continuous basis, but by increasing streamflow, more power can be generated.

The amount of power that can be practically obtained will be about KW = (0.50)*h*Q/102, taking into account an overall efficiency (of turbine and generator) of 50%. This calculation should be made for the lowest and highest seasonal flows and for the average dependable flow per month. There are two types of hydropower systems: high head systems, which depend largely on the head of the stream, and low head systems which depend mainly on the streamflow (Brooks et al., 1990).

Some attention must also to be paid to *flood control*, since SCWD activities could also have a great impact on flood occurrence and flood damage, in the absence of reservoirs.

For the assessment of the benefits of flood control measures detailed information is required about the occurrence of peak flows in the past (e.g. over 50 years) and about the direct and indirect damage caused by those peak floods. Peak floods are plotted on paper with distorted scales (e.g. Gumbel), to obtain the probability of exceding a certain critical level (percentage per year). Rating curves are then prepared from past hydrometric surveys, to provide a relationship between the river discharge and the river stage at a certain critical point. With the resulting stage-discharge curve and a stage damage curve, the relationship could be established, graphically, between the probability of flood peaks and the corresponding damages. With flood control measures this graph changes. With a dyke system all but the highest peak floods, will be controlled and cause no damage, while a diversion or reservoir in the river system may reduce the damage of all floods (Kuiper, 1971; de Graaff, 1992).

Conclusions

In this chapter an overview is given of the downstream effects of SCWD activities, and an outline is provided for the assessment of the eventual downstream impact of these activities in situations with multiple function reservoirs. For many watersheds insufficient attention is given to erosion control and reservoirs are fast losing their functions through siltation and changes in streamflow. This may eventually lead to much lower irrigation and hydro-electricity capacities, or to very high costs of dredging and other correcting measures.
Since many SCWD projects are initiated to safeguard these reservoirs and other infrastructure, more attention should be paid in project preparation and appraisal to their downstream effects.

APPENDIX 7.1 EXAMPLE OUTPUT KONTO RIVER SPREADSHEET MODEL

Konto **Weather** 4 **Scenario** 1 **Period** 5

Month	Erosion (t/ha) ERw	ERm	SS	Water balance (mm) ETa	SMe	WD	ROs	ROo	SF	GW
jan	3.8	1.8	3.7	134	376	110	55	81	145	55
feb	3.7	1.8	3.4	131	376	119	56	84	140	52
mar	3.2	1.5	3.4	126	376	97	45	70	130	56
apr	0.8	0.1	1.5	121	344	0	0	1	37	25
may	0.8	0.3	0.9	71	360	4	3	6	41	27
jun	0.7	0.3	0.6	60	367	5	4	6	35	24
jul	0.5	0.2	0.4	59	355	3	3	5	29	21
aug	0.4	0.1	0.3	61	329	1	1	2	23	19
sep	0.1	0.0	0.2	75	268	0	0	0	19	17
oct	0.8	0.3	0.4	105	245	4	4	7	28	21
nov	1.8	0.6	1.0	134	279	8	9	15	40	27
dec	3.1	1.4	2.7	175	348	26	17	29	73	43
Total	20	8	18	1252	335	375	198	305	739	387

INPUT VALUES

Transport coefficients

From SWS	Streamflow 1	2	Sed. in stream 1	2
month t	1	1	0.7	0.9
month t-1	0	0	0.2	0.1
month t-2	0	0	0.1	0

Water & sediment from SWS1
Area (ha) 12660 (Pujon)

Month	WD	SS	SF
1	101	4.0	122
2	96	3.2	106
3	103	3.3	108
4	46	1.0	34
5	50	0.7	38
6	44	0.5	29
7	39	0.4	24
8	34	0.3	20
9	31	0.1	18
10	38	0.4	23
11	50	1.2	32
12	78	3.2	69
Total	710	18	623

Water & sediment from SWS2
Area (ha) 10580 (Ngantang)

Month	WD	SS	SF
1	0	2.6	172
2	0	2.6	180
3	0	2.3	156
4	0	0.7	41
5	0	0.6	45
6	0	0.5	41
7	0	0.4	34
8	0	0.3	26
9	0	0.1	21
10	0	0.5	34
11	0	1.2	50
12	0	2.1	77
Total	0	14	878

Figure A7.1 *Aggregated watershed level erosion rates and water balance for Scenario 1 (actual development), weather 4 (average over 1987-1989) and period 5 (1996-2005).*

8 FRAMEWORK FOR PREPARATION AND APPRAISAL OF SCWD ACTIVITIES

You can never plan the future by the past
(E. Burke, 1791). In: Hooff, 1995.

8.1 Introduction

Over the past twentyfive years a considerable number of handbooks and guidelines have been written about project appraisal. These studies deal with project appraisal in general (e.g. UNIDO, 1972; Little and Mirrlees, 1974), focus in particular on economic, social or financial analysis (Squire and van der Tak, 1975; Brown, 1979; FAO, 1991), or discuss practical issues (Ward and Deren, 1991). Some guidelines are written for donor organisations (e.g. ODA, 1988; Kuyvenhoven and Mennes, 1989), and several books deal specifically with sectors: agricultural projects (Gittinger, 1982; Benjamin, 1981; FAO, 1993), irrigation projects (Bergmann and Boussard, 1976) or forestry projects (Gregersen and Contreras, 1992).

The basic principles elaborated in these general guidelines, and discussed in Chapter 4, also apply to the appraisal of soil and water conservation activities. However, the specific features of these projects call for some modifications. First there is the issue of measuring on-site benefits. Since benefits usually do not consist of yield increases but of 'a prevented decline' of yields, much attention needs to be paid to the definition of project options and in particular to that of the 'without-project' situation. This matter formed part of the methodology for economic evaluation of comprehensive watershed management in Korea by Gauchon and Lok (1973). The method was later adapted (Section 6.2) for use in Indonesia (Gauchon, 1976) and Jamaica (de Graaff, 1981). Wiggins (1981) applied a similar method in El Salvador and Anderson (1987) developed a method for afforestation, with an example from Nigeria. A second important issue for SCWD projects is the quantification and valuation of external (i.e. downstream) effects. Sfeir-Younis (1985) was among the first to focus attention on the assessment of downstream benefits. Gregersen et al. (1987) integrated the on-site and downstream elements and implicitly emphasized the need for an interdisciplinary approach in the economic evaluation of SCWD projects.

While further developing the latter approach, special attention is given here to the identification of beneficiaries and the way SCWD activities affect them. Chapter 5 therefore focused on actors and target groups, and Chapters 6 and 7 on methodologies to identify and quantify on-site and downstream effects of SCWD activities.

In this chapter a framework is developed for the appraisal of soil conservation and watershed development activities, in which these special elements are incorporated. The framework is based on the theoretical issues raised in Chapter 2 (land degradation), Chapter 3 (actors) and Chapter 4 (evaluation methods). The special elements concern mainly 'impact assessment', the second of the three main phases in project appraisal: decision-making framework, impact assessment and evaluation (van Pelt, 1993). Since an appraisal very much depends on data made available during identification and preparation, attention is here also paid to these earlier stages of the project cycle.

Table 8.1 shows the various phases and steps in the preparation and appraisal of SCWD activities. Except for the separation between stages and phases, the steps are not necessarily in chronological order, and several issues have to be looked into more or less simultaneously.

Table 8.1 *Framework for the preparation and appraisal of SCWD activities*

Stages, *phases* and steps	
Project Preparation	**Project Appraisal**
1 *Preparatory phase*	2 *Decision making framework*
1.1 Ecological setting	2.1 Alternatives or options
1.2 Socio-econ. situation	2.2 Role of actors
1.3 Project objectives	2.3 Evaluation criteria
1.4 Potential components	
1.5 Project organisation	3 *Impact assessment*
	3.1 Inputs by actors
	3.2 On-site impacts
	3.3 Downstream impacts
	3.4 Other impacts
	3.5 Overall impacts
	4 *Evaluation*
	4.1 Financial analysis
	4.2 Efficiency assessment
	4.3 Equity considerations
	4.4 Sustainability
	4.5 Trade-off analysis

8.2 Problem identification and project preparation

Identifying land degradation problems and setting priorities in SCWD
After analysing the problems encountered by 70 projects during implementation, the FAO Investment Centre concluded that the identification phase of the project cycle is of crucial importance and most in need of improvement. The sources of project ideas are many and so too is the extent of their maturity (FAO, 1993). During identification one should verify the correctness of the diagnosis and the validity of the objectives set for the project. Logical planning frameworks (GTZ, 1989) can be used for this.

For SCWD projects this implies that the type and extent of land degradation problems in the project area should be clearly identified and well-defined, and the perception of the problems by different actors should be fully understood.

On-site effects of erosion are often ignored by land users themselves, since they appear slowly and are masked by annual yield fluctuations, increased fertilizer use and other factors (de Graaff and Wiersum, 1992). Even when land users are aware of the erosion problem, there may be a variety of reasons why they do not call for action (Chapter 3). The 'on-site' land degradation problems are more often raised by local extension officers or by regional authorities, who keep data on land use and production and undertake land evaluation studies. In project identification one should verify whether these 'reports' do not over- or understate the problem and whether and how quantification is possible.

The *downstream effects* of land degradation consist of both gradual changes (in sedimentation and streamflow) that go often unnoticed to the general public, and irregular abrupt effects after special events, such as peak storms (leading to flooding) and severe droughts. These effects are clearly visible to all groups concerned, but they are unpredictable. These latter effects usually receive much attention and are able to mobilize people and funds, that are then often used both for short term relief programmes and for the (long term) 'rehabilitation of watersheds' (e.g. hurricane relief programme in Jamaica). In the project identification phase one should pay attention to both the gradual downstream effects and to the probability of the occurrence of disasters.

In order to be able to establish *priorities in SCWD* activities, the need is increasingly felt to monitor the use of land and water resources. In many countries with humid mountainous zones, a priority list exists of watersheds. Indonesia and Jamaica are clear examples. In Indonesia 36 watersheds were selected in 1976 to receive priority in a nationwide watershed management programme, and 22 of these received super priority status in 1984 on the basis of hydrological, economic and socio-economic status. In Jamaica a so-called Land Authority approach, for rehabilitating watersheds, was already initiated in 1952. Of the 33 watersheds on the island, 25 were later brought under a Protection Act and 11 received priority status in 1983. In 1989 the Water Resources Development Masterplan was prepared, which regrouped the watersheds in ten areas for which water balances were calculated (Chapter 10).

These two countries were the first to receive assistance from FAO and UNEP, in formulating a *national soils policy* (FAO/UNEP, 1994). The Indonesian soils policy suggests among other things the establishment of an Integrated Land-use Plan, independent of all sectoral interests and based on the natural soil potential and future needs. In the suggested soil policy for Jamaica a distinction is made between three major regional units: the steeply sloping upper watershed areas, in particular to be preserved for water production, the hill zones and the coastal and interior lowlands. Apart from the water production objective of the upper watersheds in Jamaica, surprisingly little reference is made to water resources in these national soil policies.

Although less emphasis is given to watershed development in semi-arid zones, the *monitoring of water resources* is extremely important. In Tunisia the watersheds, and the reservoirs within it, formed the basis for a ten-year water resources strategic plan (DGRE, 1990). Like the Jamaican water resources masterplan, the Tunisian plan provides information about availability and present use of all surface and underground water resources. However, no explicit attention is paid to the consequences of soil erosion on water availability.

'Integrated land and water inventories' could form the basis for a regionalized assessment of the land and water resources utilisation space (Chapter 2), on the basis of which new SCWD projects could be screened. Such national inventories require continuous updating and should also consider socio-economic and institutional factors in the use of land and water resources.

Project preparation

In preparing SCWD activities or projects, three major difficulties usually arise:

1. Quantifying the land degradation problem;
2. Identifying the categories and numbers of actors involved; and
3. The delicate choice of the most appropriate organisation(s) for the project, and in particular the lead agency.

These issues should have already been looked into during project identification in order to draw up the project outline and rationale, but they need to be resolved during project preparation. During this stage one has to determine simultaneously the real causes of the land degradation symptoms; the area and actors concerned; the project objectives; the SCWD components; the major project effects and their impact on different groups; and the organisational setup.

This analysis requires first of all detailed understanding of the ecological and socio-economic setting and often requires some additional studies. As Table 8.2 shows, the analysis of the setting is followed by a review of development objectives and aims of land users in order to define the project objectives. Emphasis is then given to the selection of SCWD components that are technically feasible, economically efficient, financially attractive and socially acceptable. Finally institutional aspects and organisational matters are considered.

Table 8.2 *Steps and investigations in the project preparation stage*

	Phase and steps	Issues	Type of analysis
1	**Preparatory phase**		
1.1	Ecological setting	Assessing land degradation	Hydrol/erosion research
1.2	Socio-econ. setting	Identifying actors involved	Socio-economic research
1.3	Project objectives	National & actors objectives	Def. project objectives
1.4	Potential components	Matching activit. & problems	Screening of components
1.5	Project organisation	Entities & responsibilities	Selecting organ. setup

Ecological and socio-economic setting

In the project preparation stage the ecological and socio-economic setting should be analyzed to clarify which land and water resources and which actors are affected by land degradation and what interaction takes place between the ecological and socio-economic systems. For the (renewable) land and water resources, with their respective functions, the 'project area screening' suggested above will have to show the discrepancy between actual and sustainable use levels.

Unless adequate data are already available, both detailed hydrological and erosion research and socio-economic baseline studies are required for SCWD projects prior to project implementation (Table 8.2). These studies should indicate what type of land units (which LUST's) are affected, how the degradation processes take place (effects on water and nutrient balances), which categories of people (farm patterns) accelerate the degradation process, and what other groups are affected by it? On the basis of the socio-economic data, farm patterns (and other actors) are distinguished, along with their actual role in land degradation and their potential role in soil conservation activities, as discussed in Chapter 5. In an early stage of project preparation the attitude of target groups should be known, since 'without a full commitment by borrower and beneficiaries, successful project implementation is not likely' (quote from World Bank, 1992a).

To be able to monitor the use of land and water resources and the changes caused by project activities, indicators of the pre-project conditions should already be established at the project preparation stage (van de Putte, 1991).

As an example Table 8.3 shows two indicators for the present state of the land use systems: gross margins from the forest and farming activities and present erosion rates (from research data). Depending on the criteria selected for the appraisal, indications could also be given about employment (labour inputs) or foreign exchange requirements, etc. As well as the actual erosion rate, information may also be required about remaining soil depth, soil organic matter content or nutrient status, etc., in order to better define the actual erosion problem.

Table 8.3 *Land use systems, environmental stress and actors: the present situation*

Land use systems (LUST's)	Extent (ha)	Present state: Produc. GM in $	Present state: Erosion (mm/yr)	Environmental stress	Actors: Forest Dpt(A)	Actors: Farm patterns P1	P2	P3 etc.
Upstream:					(land managed in ha)			
Protect. For.	x_1	y_1	z_1	-	a_1			
Prod.Forest	x_2	y_2	z_2	excess.cut	a_2			
Shrub								
- steep	x_3	y_3	z_3	uncontroll.	a_3	b_3		
- hilly	x_4	y_4	z_4	cultivation	a_4	b_4	c_4	
Irrigated land	x_5	y_5	z_5	-				d_5
Rainfed annuals:								
- deep soil								
terraced	x_6	y_6	z_6	-				d_6
unterr.	x_7	y_7	z_7	excessive		b_7		
- shallow soil	x_8	y_8	z_8	erosion			c_8	
Perennial crops:								
- steep	x_9	y_9	z_9	erosion			c_9	
- less steep	x_{10}	y_{10}	z_{10}	-				d_{10}
Built-up land	x_{11}	(y_{11})	z_{11}	erosion		b_{11}	c_{11}	d_{11}
Total Sum:	$(x_1..x_i)$	x_i*y_i	$x_i*z_i/(\text{Sum } x_1..x_i)$					

Land use systems (LUST's)	Extent (ha)	Present state: Produc. GM in $	Present state: Erosion (mm/yr)	Environmental stress	Actors: Public works(B)	Actors: Farm patterns Q1	Q2	Q3 etc.
Downstream:					(land managed in ha)			
Irrigated	u_1	v_1	-	water short.		f_1	g_1	h_1
Rainfed land	u_2	v_2	-	-		f_2		
Built-up	u_3	(v_3)	-	occ.flooding		f_3	g_3	h_3
Reservoir	u_4	-	w_4	sedimentat.	e_1			
Total Sum:	$(u_1..u_j)$	u_j*v_j	$u_j*w_j/(\text{Sum } u_1..u_j)$					

For each land use system of the different land users, attainable 'target' erosion rates could then be established with corresponding production levels, to be monitored during project implementation. What levels are 'attainable', depends on the objectives of the actors.

Project objectives

Objectives of SCWD activities and projects are derived from both national objectives with regard to land and water resource management and socio-economic development and from the objectives of the major actors involved. The first set of objectives form the basis for the criteria in economic CBA and the objectives of actors are important for the financial analysis. In multi-criteria analysis different weight sets may be chosen that reflect certain combinations of these two sets of objectives.

The objectives of the major actors (farm patterns) can be derived from the socio-economic baseline studies. In order to assess whether these potentially conflict with objectives of other actors (e.g. government), it is important that these studies also pay some attention to (1) the perception and the attitude of land users and regional/national authorities towards land degradation, and (2) to the solutions these groups consider themselves, including incentives and other government policies.

A major drawback to many SCWD projects is that their objectives are not defined well enough to properly determine the effectiveness and efficiency of these projects. It is thereby argued that lack of data on the actual status of degradation (e.g. erosion rates) does not allow for the establishment of quantitative targets for erosion control activities. This stresses the importance of erosion baseline research that could at least provide some yardsticks in project preparation to assess the extent of erosion and the effects of control measures. Clear proposals can then be made with regard to the monitoring and evaluation of the activities.

Screening of SCWD components
In most countries a considerable number of SCWD components have been developed, that range from simple and more elaborate line interventions, such as stone lines, hedges and terraces, to drastic land use changes, such as reforestation and *mise-en-défense*. For each of these components a range of variations exists. Therefore a screening process may be needed during project preparation in order to select the most appropriate component for each specific situation. In the case studies two examples are given: the choice between different line interventions in Burkina Faso (Section 9.3), and alternative land use options related to land capability in Jamaica (Section 10.7). These two examples show that both CBA and MCA constitute useful methods in such a screening process.

Lead agencies for SCWD activities
Whether gradual on-site and off-site effects are at stake or sudden events, such as floods and droughts, it is often hard to determine which organisation(s) should become the lead agency in the preparation and subsequent implementation of SCWD-projects. Because of the multiple objectives and the diverse group of actors, separated by time and space, several, mostly public, organisations are represented in the decision-making body of SCWD projects. Sometimes semi-autonomous watershed or river basin authorities are considered as alternatives.

In all four case-study areas there have been controversies about the responsibilities for SCWD activities, particularly between the ministries of forestry, agriculture and local government (or planning). However, ministries of public works, water resources and the environment also claim a share in decision-making of SCWD projects. Ideally there is a coordinating body in watershed development which designates the lead agency for every SCWD project.

8.3 Decision-making framework

Options
Once the ecological and socio-economic setting has been analyzed, and the objectives, resource endowments and constraints of major actors are known, various options or alternative scenarios (combining various SCWD components) can be formulated that contribute to the overall objectives. This is the first step in the decision-making framework (Table 8.4).

Options may be distinguished on the basis of different conservation techniques, different agricultural development approaches (e.g. low or high external inputs), different organisation and management features, or varying perspectives of the main social groups.

Table 8.4 *Steps in decision making framework*

Phase and steps	Issues	Type of analysis
2 Decision making framework		
2.1 Options	Alternative solutions	Defining alternatives
2.2 Role of actors	Determining target group(s)	Analysis of participation and conflicts of interest
2.3 Evaluation criteria	Criteria & criteria weights	Selection criteria, attributes & weights

An analysis should be made of whether options are mutually exclusive or whether some could be combined to form a coherent package approach that seems to meet well the divergent objectives of respective categories of actors. The more prominent options have to be developed in scenarios for a one or two generation period (30 or 60 years), depending on the physical lifetime and long term effects of the interventions. This should include (at least) one so-called 'without-case', as normally required in cost-benefit analysis, and several alternative 'with-cases'.

Here the focus is on investment activities in soil conservation and watershed development, where necessary accompanied by support services, etc.

Actor involvement

During the project preparation stage the various groups of actors involved in land degradation are identified, and the possible role of these groups in the SCWD activities are assessed. When the options or combination of components are formulated, attention should also be given to the selection of relevant target groups for these components. For each of the options one needs to spell out which farm pattern or group of actors is likely to participate in one or more components or to be affected otherwise. This could be referred to as 'participation analysis'. Some analysis may be required to assess whether conflicting views could be reconciled, by redistributing costs and/or benefits (Section 5.3). This could be in the form of charges (e.g. for water) or incentives or support services (Chapter 11). A number of special propositions may have to be added for some well-defined groups of actors (e.g. off-farm work for squatters).

Evaluation criteria

The next issue in the decision-making framework is to indicate the main criteria and attributes that will be applied in the appraisal of alternative options or scenarios. As discussed in Chapter 4, the emphasis in SCWD projects is not only on maximizing overall productivity or utility (the efficiency criterion), but also on the optimal distribution of the increased productivity/utility over time (intertemporal equity), in space (upstream, downstream and wider interests) and among social groups (income distribution effects and potential contribution to conservation).

It is proposed here to refer to a feasible or attainable activity or project, when it scores sufficiently high on the three main criteria: efficiency, equity and conservation and when it is financially attractive to the main actors concerned.

Feasible option:

- Economically efficient
- Socio-economically equitable
- Contributing sufficiently to conservation
- Financially attractive for main actor(s)

From the discussion in Chapter 4 about the three main criteria: efficiency, equity and conservation, it has become clear that attributes of these criteria may overlap. In the evaluation a set of attributes of the criteria should be selected that best represents the complex of objectives of the actors involved.

The objectives of the respective actors could be made operational either in the form of specific goals (e.g. maximizing production, minimizing erosion, maximizing cash income or foreign exchange earnings) or as constraints (e.g. food production at least at subsistence level; erosion not exceeding a certain level; incomes above poverty line). To the aggregated set of objectives, weights have to be attached, which may vary for the respective actors.

The conservation criterion may have different attributes for situations with on-site effects only and for situations with important downstream effects. Where good land is scarce a strong sustainability or conservation criterion is likely to be used at the local, LUST or on-site level, with threshold levels for attributes defined as follows: erosion on shallow soils should not exceed the soil formation rate; the soil organic matter should not descend below a certain minimum level, etc. In the latter case (with downstream effects) threshold levels for resource use could be given at watershed level (e.g. the overall watershed erosion rate should not exceed the natural or design level of sedimentation in reservoirs and/or the relationship between the dry and wet season streamflow in a watershed should not decline below a certain level). This may then imply the use of a weak sustainability criterion at LUST or farm pattern level: erosion in some spots may exceed critical levels as long as overall erosion rates remain below threshold value.

Knowing the actual state of land use and degradation (e.g. present soil depth and erosion rate), as presented in Table 8.3, the minimum permissible (sustainable and/or attainable) levels, the land and water utilisation space (LWUS) could be more precisely defined for various land use systems within the watershed (as represented by certain farm patterns) and/or for the watershed as a whole. A continuous quantitative scale could be established for the respective indicators (e.g. on the basis of soil depth and erosion rates: present soil depth is still 300 mm above minimum non-depressive soil depth, with actual and permissible erosion rates at 20 and 4 mm/year respectively).

8.4 Impact assessment

When the decision-making framework has been determined, a start can be made with impact assessment (Table 8.5). This starts with the identification of all direct and indirect effects, which in SCWD projects in particular relate to certain land use systems with their technology (LUST's). For each component the inputs have to be assessed as do the different actors that either incur costs or derive benefits from it. Following their identification, the effects need to be quantified and valued, where possible. For the overall impact assessment, field and actor level data need to aggregated to watershed and project level (upscaling).

Identification of effects and impact

The experiences with (environmental) impact studies have shown that it is often rather difficult to predict the outcome of certain measures on people and the environment (Section 5.1). It is therefore extremely important to investigate the various effects of such measures thoroughly.

Table 8.5 *Steps in impact assessment*

	Phase and steps	Issues	Type of analysis
3	**Impact assessment**		
3.1	Inputs by actors	Investment & recurrent costs	Cost analysis
3.2	On-site impact	Effects on soil and water	Yield response
3.3	Downstream impacts	Effects on sedim. & streamflow	Impact downstream changes
3.4	Other impacts	Other (multiplier) effects	Impact of changes
3.5	Overall impacts	Upscaling of impacts	Aggregation

For soil conservation and watershed development activities the analysis starts with the direct physical effects on the soil and water resources. The setting analysis should indicate what major effects the degradation problem actually has on the production (potential): whether it affects primarily water supply, soil structure or nutrient uptake and whether off-site effects play a major role. For the activities considered in the respective scenarios, one should then determine and quantify the physical effects on the soil water and/or nutrient balances and the yield response of these changes (Chapter 6). Subsequently an assessment must be made of how the different effects together are likely to affect on-site production in physical terms, and thereafter how the changes in on-site erosion may affect sedimentation and water supply downstream and thus the downstream actors (Chapter 7).

For the identification and description of the whole chain of related effects use can be made of the 'tree diagram', as used in decision analysis and in project planning (e.g. problem and objective trees in 'Logical Framework').

Since for each farm pattern the respective parcels and their land use and technology are specified, the analysis of on-site effects can be undertaken parcel by parcel (representing LUST's), depending on the activities considered for each farm pattern in the respective

Table 8.6 *Example of impact assessment by component*

Component: Establishing bunds on LUST A (land with soil x, slope y, erosion rate z; sorghum; contour ploughing by oxen); occurring in farm patterns P1 and P3.

	Year 0				Year 1					Year n					
Actors:	1	2	3	4	1	2	3	4	5	1	2	3	4	5	6
Effects															
Inputs:															
Labour inputs	+x	x				x					x				
Material inputs				-x											
Phys. effects:			*Response*												
Reduced run-off ——>															
Increased infiltration }															
Reduced erosion ——>															
Reduced fertility loss }															
Econ. effects:															
On-site product. increase ——>						+x	x		x		+x	x		x	
Downstream effects ——>														x	x

"x" constitutes amounts and the signs +,- indicate benefits respectively costs, expressed in monetary terms

Actors: 1=landless labour; 2=farm pattern (e.g. P1); 3=traders; 4=Government; 5=urban consumers; 6=downstream farmers.

options (Table 8.6). The off-site effects require an aggregation of all water supply related effects on watershed level, and can only be quantified when detailed hydrological research has been undertaken. If not, the magnitude of these effects may be presented on an ordinal scale (e.g. a very strong/strong/moderate/slight/very slight reduction of sedimentation or improvement of Qmax/Qmin ratio).

Impact quantification

In the impact analysis, the various 'expected' effects of degradation and of conservation measures are spelled out, by parcels (LUST's), farm patterns and (sub-)watershed(s). An effort should be made subsequently to attach a certain probability factor to the effects, and to try to quantify the effects when they occur and for each group of actors.

For certain effects of activities quantification is easy, in particular with regard to cost elements (e.g. increased labour and material inputs). Other effects require detailed calculations (e.g. increased biomass and crop production as a result of improved nutrient and/or soil water balance).

When all effects are known a (flow) table could be drawn up, specifying for a specific component all inputs and their effects, the years in which these effects will occur, and the distribution of these effects among the respective categories of actors (Table 8.6).

Finally an estimate can be made of what changes the various activities within the respective scenarios bring about in output, material and labour inputs, erosion rates, for every year and for all actors, and how they affect the LWUS over the total period at the land use system and watershed level.

8.5 Evaluation

When all impacts of the SCWD activities or project have been assessed the last phase of the appraisal can be undertaken, which is here referred to as the attainability assessment or evaluation (Table 8.7). As in cost-benefit analysis, it starts with a financial analysis to assess the possible results for the actors. It is then followed by an economic analysis for the whole project, with its impact area, which for SCWD projects is usually a watershed.

Actor level financial analysis

For farm patterns and each group of other main actors, a partial (or whole farm), multi-period budget could be prepared. For each option or scenario this should show the stream of effects (costs and benefits in physical terms) they are likely to derive from the component(s) in which they are assumed to participate. Valuation techniques should then be applied to arrive at financial values, using conventional, surrogate or artificial market prices.

If all effects can be valued in monetary units, a financial analysis shows to what extent the activities or packages are financially attractive to the respective groups, and which incentives in financial terms may be required for each alternative activity or scenario.

Where certain effects cannot be valued in monetary terms, these effects can be provided in physical or ordinal terms. In financial analysis break-even analysis may then be applied, to review under which conditions (levels for variables that can not be expressed in monetary terms) the activities are attractive for the respective actors (with and without incentives).

Table 8.7 *Steps in evaluation or attainability assessment*

Phase and steps	Issues	Type of analysis
4 Evaluation		
4.1 Financial analysis	Financial results actors	FCBA
4.2 Efficiency assessment	Nat. econ. (monetary) impacts	ECBA
4.3 Equity considerations	Distributive aspects	SCBA
4.4 Sustainability	Conserv. land & water res.	ECBA or MCA
4.5 Trade-off analysis	Score on all criteria & role of incentives	CBA or MCA

Depending on their occurrence and the likelihood of their participation, a weight can be calculated for the respective groups of actors in order to be able to aggregate the financial results for these groups to arrive at the overall financial results.

Watershed level economic analysis

The actor level financial analysis makes clear which activities may be attractive for the respective groups of actors, and if not, what incentives are needed to make it attractive. The financial values are then transformed into economic values by means of aggregation and inclusion of transfer payments and externalities and by using economic prices. It then becomes apparent to what extent these activities are also important from a national economic point of view and whether they could make certain (levels of) incentives acceptable, from a national economic point of view. Whenever possible an attempt should be made to incorporate the downstream and other external effects of soil erosion and soil conservation in economic cost-benefit analysis, by means of quantification of these effects and their valuation in monetary terms (Chapter 7).

As well as differences in economic efficiency, the scenarios may also have a different impact on intertemporal, intratemporal and spatial *equity* (Section 4.5). Therefore emphasis should be paid to differences in impact: on the present and future generations; on the various social groups; and on the upland and downstream communities. In the differentiation between social groups, attention should also be paid to those groups of which the land use practices have the greatest potential influence on degradation and erosion control.

Since small, poor households and landless labourers often farm on marginal, highly erodible land and cultivate the type of (food)crops that contribute much to erosion, and since they lack the means to control soil erosion, they are often the target group *par excellence*. However, for more or less the same reasons (e.g. insecure land tenure on steep land, need to cultivate food crops and lack of financial and other means) this target group cannot be reached easily, despite copious incentives.

In cost-benefit analysis the benefits of soil conservation may be estimated by taking into account the soil loss and resulting loss in productivity in the 'without-case', and the possible lack of land resources that may push up the cost prices of agricultural produce. Since soil erosion is often heavily concentrated on some pieces of over-used land, the effects of conservation will be higher, when a form of priority listing is applied. If the efficiency criterion cannot take care of this, a similar procedure could be applied as with regard to equity. A special weight should be attached to the prevention of erosion on these land use systems (LUST's), or on the parcels of certain farm patterns, that contribute a relatively large amount to erosion and on-site and downstream productivity losses.

Because of the fact that a high priority may be attached to the participation of farm patterns and other actors on the basis of both the equity and the conservation criteria, attention should be paid, in the classification of farm patterns and other actors, to both the level of income and the extent to which 'conservation is urgent' (e.g. emergency cases first).

The choice between or the combination of cost-benefit analysis and multi-criteria analysis

As long as monetary values can be attached to attributes of the conservation criterion, an economic cost-benefit analysis could incorporate this criterion in a similar manner as it deals with equity considerations. In this case only cost-benefit analysis need be applied. However, when important effects pertaining to sustainability cannot be valued in monetary terms and therefore cannot be adequately included in the cost-benefit analysis, multi-criteria analysis can be used instead. Separate attributes of the conservation criterion should be spelt out and weights should be attached to these attributes. Multi-criteria analysis could then incorporate scores on the efficiency (and equity) criteria obtained by cost-benefit analysis. As suggested in Section 8.2, both methods could also be used in an earlier stage, in the screening of potential SCWD components. Where all scores on screening criteria can be quantified and valued, cost-benefit analysis could be used. Where such analysis would require too much 'hard' data, a qualitative multi-criteria analysis may be preferable for such a preliminary assessment.

8.6 Discussion

Since both the effects and the eventual beneficiaries of SCWD activities and projects are hard to identify and to quantify, special attention should be given in the project preparation phase to the collection of hydrological and erosion data and to socio-economic data from the potential target population. These data will not only benefit project design and appraisal, but will eventually permit the physical and socio-economic monitoring and ex post evaluation of the project activities.

When there are numerous alternative soil and water conservation technologies possible in the project situation, a preliminary screening and/or pilot implementation could be applied.

In the decision-making framework much attention should be paid to the objectives of all major actors and to possible conflicts of interests. This could be achieved by applying MCA with weight sets reflecting different points of view, or, in CBA, by confronting the results of the financial analysis for major actors with those of the economic analysis. This facilitates decision-making with regard to the amount and type of incentives needed to resolve potential conflicts.

The focal point of the appraisal of SCWD projects is formed by an impact analysis, in which various on-site, downstream and other effects may play a role. For the overall impact analysis, the various on-site effects on actors need to be aggregated from LUST's of target farm patterns to watershed level.

The eventual appraisal consists of an attainability assessment, that includes the financial analysis for major actors and an economic analysis for the whole impact area. When scores on the three main criteria efficiency, equity and conservation can be quantified and valued in monetary terms, CBA is the most appropriate evaluation method. If not, MCA should be applied, or a combination of both methods.

PART III

EVALUATING SOIL CONSERVATION AND WATERSHED DEVELOPMENT IN PRACTICE

FARMERS IN BURKINA FASO

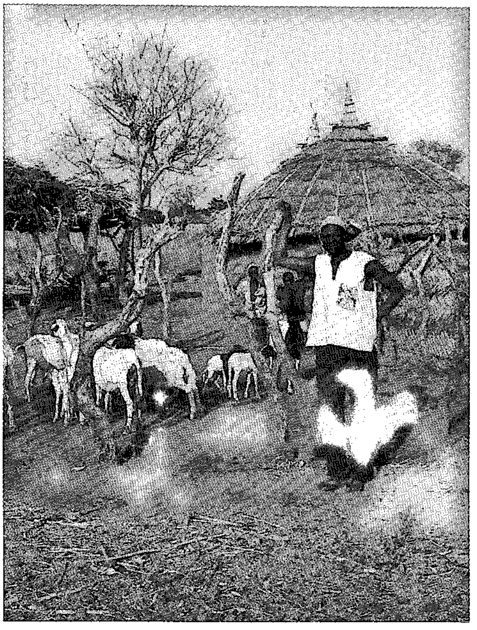


Plate 3 *Mossi farmer, Zoundwéogo*

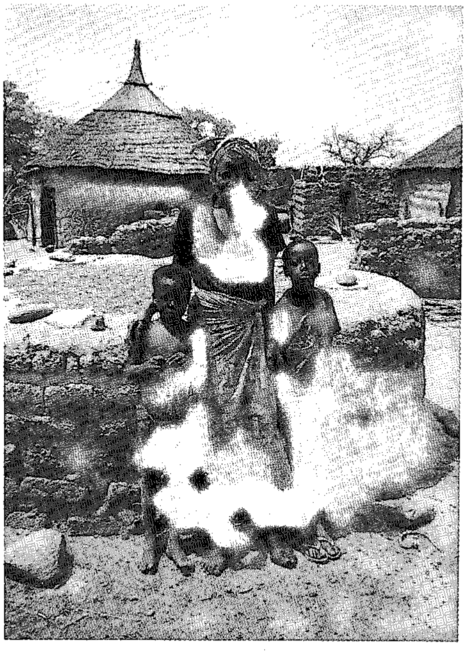


Plate 4 *Mossi woman, Sanmatenga*

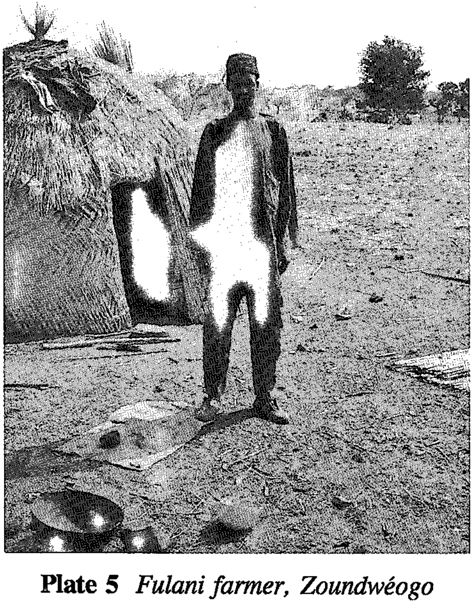


Plate 5 *Fulani farmer, Zoundwéogo*

9 SOIL CONSERVATION MEASURES FOR SUSTAINABLE DEVELOPMENT IN SEMI-ARID ZONES

Koulg san golme, bii yinbga toun golme.
When the river bends, the crocodile has to bend too.
(Mossi proverb)

Introduction

This case study deals with the economic evaluation of soil and water conservation measures in semi-arid zones. It focuses on on-site effects of such measures on soil, water and nutrients to assess the main short- and long-term costs and benefits. Prior to the evaluation emphasis is put on the identification of beneficiaries and the screening of alternative soil and water conservation measures. The Burkina Faso case study is largely based on agro-economic and bio-physical research undertaken in six villages in two research zones of an inter-university research project on Management of Natural Resources in the Sahel (1992-1995). The evaluation concerns primarily two soil and water conservation activities implemented with assistance from bilateral aid projects. A comparison is made with the evaluation of comparable sustainable development activities in a semi-arid zone in Tunisia in the 1970's.

9.1 The setting of the research zones in Burkina Faso

Ecological conditions

The research zones form part of two provinces on the 'Central Plateau' that covers about one quarter of the area of Burkina Faso. The northern zone is located in the province of Sanmatenga, around its chief town Kaya, and the southern zone is situated in Zoundwéogo province, east and west of its chief town Manga. The two zones are located in the upper and lower fringe of the northern Sudan zone (Figure 9.1).

Mean annual rainfall is not very low, not even in Kaya, but the rainfall pattern is not very favourable for various reasons. Temperatures and potential evapotranspiration are high all year around, and 90% of rainfall is concentrated in five months, from May to September. Furthermore, 80% of the rain falls in high intensity showers of 10 mm and more, surpassing infiltration capacity and leading to run-off and erosion. Moreover rainfall patterns fluctuate widely from year to year. As most of the country, the Central Plateau is fairly flat, with altitudes generally around 300 m, except for some hilly ranges that reach 500 m.

Table 9.1 *Mean monthly rainfall (1968-1985) and potential evapotranspiration (1951-1980) for three locations on the Central Plateau of Burkina Faso*

Township	Altitude	J	F	M	A	M	J	J	A	S	O	N	D	Total
Precipitation (in mm)														
Kaya	313 m	0	1	7	7	37	96	159	205	102	24	0	0	638
Ouagadougou	303 m	0	1	6	29	72	109	187	219	127	29	1	0	781
Manga	286 m	0	3	11	30	99	106	167	221	150	49	1	1	839
Potential evapotranspiration (in mm)														
Ouagadougou		196	196	219	191	166	123	108	106	126	170	179	184	1,964

Source: Agrhymet, 1991.

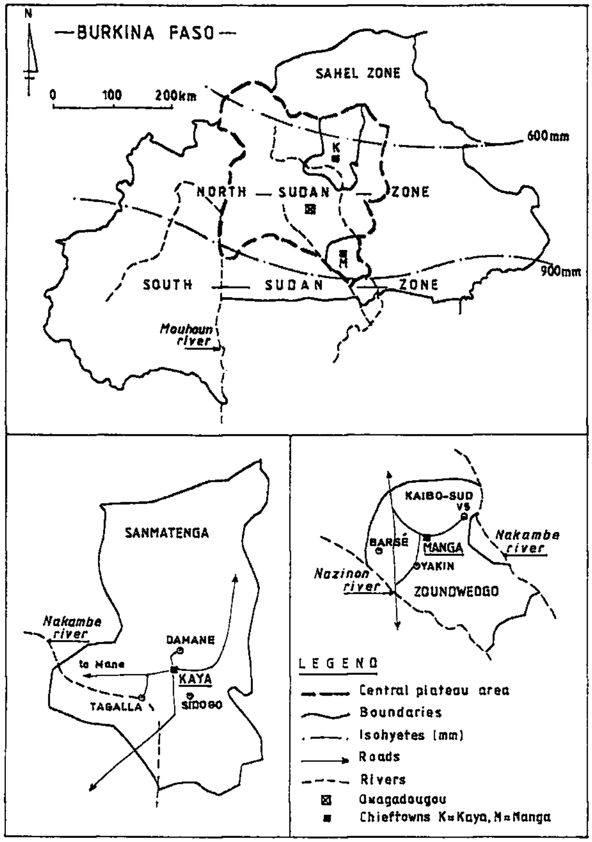


Figure 9.1 *Map of Burkina Faso, showing the case study areas and research villages*

The Central Plateau forms more or less the upper watershed of the two non-permanent Volta rivers, that drain into the Volta Lake in Ghana. The Nakambé (White Volta) and the Nazinon (Red Volta), emerge from the few hilly ranges on the Plateau, and have watershed areas of about 50,000 and 20,000 ha respectively. There are a few permanent lakes in the northern part and recently a large dam with reservoir was built in the Nakambé in the most southern part of the Plateau, along the boundary of Zoundwéogo province. Less than 1% of the land is irrigated, and the scope for expansion is limited.

Most of the Central Plateau forms part of the geological African shield, formed during the Precambrian and consisting of old metamorphic crystalline or volcanic sedimentary formations. In a typical geomorphological profile or toposequence, a descent can be traced from a hilly zone with laterite caps and shallow, stony soils (lithosols) down via the often sandy upper 'glacis' and the sandy loam or clay loam lower 'glacis' to the valley-bottoms, that consist mainly of heavy clays (vertisols). According to the local soil classification system or taxonomy, based on toposequence and soil characteristics, the main soils in the two case study areas are *zegdega*, a very stony loamy soil on the upper part of the slope; *bissiga*, a sandy (loam) soil along the slope, and *bolle*, a heavy clay soil with vertic properties in the valley (Dialla, 1993; Schutjes and van Driel, 1994). Most soils along the slopes have a low organic matter content of less than 1%.

Socio-economic conditions

In 1992 the resident population of Burkina Faso was 9.5 million, of which about half lived on the Central Plateau. This was for centuries the domain of the *Mossi* Kingdoms, which played an important role in the North-South trade in this part of Africa. This probably also explains the relatively high population density of 45 persons per km² in this semi-arid zone. The second largest ethnic group on the Central plateau, next to the *Mossi*, is formed by the *Fulani* (Peul). The southern part of Zoundwéogo province is inhabited by *Bissa*.

The Mossi can be subdivided in several groups, which each held specific functions and social positions within the Kingdoms. Most of them now depend for their livelihood on cultivation of the food crops sorghum (*Sorghum bicolor*) and millet (*Pennisetum americanum* L.) and on remittances from family members who have migrated. Groundnuts and cotton are the major cash crops, but cotton is hardly grown any more in Sanmatenga. Some Mossi own cattle, but small ruminants are more common in their households. In the dry season artisanal activities are undertaken, and in some places people are digging for gold. The Fulani are known as cattle owners and herdsmen. Although sedentarisation has become more common among them, many Fulani still move around with their cattle in search of grazing grounds.

Table 9.2 *Land resources and population density in six villages in Sanmatenga and Zoundwéogo provinces (1993)*

Province Village	Total area (ha)	Cultivated (%)	Population (persons)	P. density (p/km²) Total area	Cultiv. area	Land/person (ha) Total area	Cultiv. area
Sanmatenga	907,625	18	365,001	40	224	2.49	0.45
Damane	590	45	1,108	188	418	0.53	0.24
Tagalla	3,600	14	1,530	42	304	2.35	0.33
Sidogo	800	69	1,427	178	258	0.56	0.39
Zoundwéogo	345,300	22	185,396	54	239	1.86	0.42
Barsé	1,970	20	1,028	52	257	1.92	0.39
Yakin	1,035	57	1,423	137	242	0.73	0.41
Kaibo-Sud V5	630	60	572	91	151	1.10	0.66

Sources: MAE-DEP, 1990; INSD, 1989; de Graaff, 1995.

During the drought periods of the 1970's and 1980's many Fulani were forced to sell part of their herd to Mossi traders and the cattle they herd are no longer entirely their own.

Table 9.2 gives some information about the man-land ratio in the six research villages. It shows that population density differs considerably between the villages, but that the area cultivated per person is more constant, at about 0.4 - 0.5 ha (Vriend, 1993). The three centrally located villages Damane, Sidogo and Yakin are very densely populated. The other three are situated along the (Volta) rivers and still have a more favourable man-land ratio.

In the period 1979-1988 population growth was 1.8% and 2.2% per year for Sanmatenga and Zoundwéogo respectively (INSD, 1989). In Sanmatenga there is a considerable net out-migration, both abroad (to Ivory Coast) and to more southern areas in the country. In Zoundwéogo out-migration is compensated by immigration of people from the north, including migrants from Sanmatenga. As a consequence of both long and short term migration only 47% of the resident population in the two provinces is male and this percentage is much lower for the age group of 20 - 40 years in Sanmatenga. In the six villages seasonal migration made up about 20% of the time spent on farm and non-farm activities of the households. About 10% of the resident villagers are involved and this affects almost half (46%) of the households (de Graaff, 1995). Sanmatenga appears to be one of the provinces with the highest involvement in artisanal activities (Van der Mijl, pers. comm.)

Farming systems and human impact on ecology

In the 1970's and 1980's various farming systems studies were undertaken in different parts of the country (Delgado, 1979; Matlon, 1980; Marchal, 1983; Prudencio, 1983; Broekhuyse and Allen, 1988). These were village level studies, that focused on the spatial arrangements of different types of fields with different cropping systems and fertility management. Important roles in the classification systems of the farming systems are played by the distinction made between 'house fields', 'village fields' and 'bush fields', the local soil taxonomy, the extent of intercropping of grains and legumes (e.g. cowpeas) and the role of livestock. Prudencio (1983), who studied among others two villages around Manga, distinguished five cultivation rings around the compound, for which he found a decreasing land use intensity, in accordance with Von Thünen's location theory. The different soil types on these fields do also play an important role in farmers' strategies (to spread risk). Maize is often found on house plots, sorghum on loamy (*bolle*) village fields and millet on sandy fields (*bissiga*).

In the first half of this century some forms of shifting cultivation systems were still applied, whereby average grain yields on village fields gradually decreased from 900 to 600 kg/ha. Fallow periods followed of up to 25 years, after which the higher yield level was obtained again (Broekhuyse and Allen, 1988). Over the last decennia fallow periods have been reduced considerably, leading to soil mining and other forms of land degradation (Wardman and Salas, 1991). All four forms of land degradation occur: water erosion, wind erosion, physical degradation (e.g. crusting) and chemical degradation (e.g. soil mining). This study only pays attention to the first and last one. In Sanmatenga province average yield levels are now only around 500 kg/ha. Since the 1960's several interventions have been undertaken: large earth bunds were established, cotton and groundnuts were introduced and animal traction was promoted. However, these activities were not very successful in the northern part of the Mossi plateau. And the area around Kaya is now only 90% self-sufficient in food crops in years with a normal amount of rainfall. In the southern part of the Mossi plateau, around Manga, one still finds cotton and groundnuts, animal traction is important, and in a normal rainfall year about 100-110% self-sufficiency in food crops is reached.

Kessler (1994) compared the resource base with the actual population densities in the Sahel and Sudan zones for a relatively dry year. The production limiting factor and the

Table 9.3 *Maximum sustainable exploitation level of the major production limiting factor in three zones in Burkina Faso*

Zone:	North Sahel	In between Sahel and North. Sudan	In between N. and S. Sudan
Province:	Oudalan	Sanmatenga	Zoundwéogo
Annual rainfall	250 mm	638 mm	839 mm
Idem in dry year	150 mm	500 mm	660 mm
Prod. limiting factor	Water	Nitrogen	Nitrogen
Popul. density based on integrated land use (km^{-2})[1]	1	28	43
Actual pop. density (km^{-2})	1	40	54

1. Based on combination and integration of livestock and grain production.
Source: adapted from Kessler, 1994.

population density at the maximum sustainable production of desirable products were determined, based mainly on Breman (1992).

Considering the location of the two provinces within these climatic zones, the resource based population densities in the areas have been extrapolated (Table 9.3). When compared with the actual population densities, it appears that not only in Sanmatenga but also in Zoundwéogo the 'carrying capacity' is already exceeded in relatively dry years, under present technology. In both zones soil fertility is the most limiting factor. Yield measurements have shown yields of almost 2 t/ha on exceptionally well manured small plots in subsequent years 1993-1995 (Loozekoot, 1994b; Haima, 1996; Hamer, 1996). However, where infiltration (capacity) is low, water may still be the most limiting factor (e.g. with crusting).

National economic situation, policies and programmes

In 1990 agriculture employed more than 80% of the country's active population, contributed 32% to (the officially measured) Gross Domestic Product (GDP) and 55% to export value. It is clearly the mainstay of the economy. Since Burkina Faso is a landlocked country, it has high energy costs, and the secondary and tertiary sectors are not yet well developed. Industrial activities are largely confined to the cities of Ouagadougou and Bobo-Dioulasso. Mining activities (iron and gold mainly) take place in several locations, but mostly on a small scale, with simple technologies. Before the large droughts of the 1970's and early 1980's, livestock products formed the most important export commodity, followed by cotton. But in 1989 cotton constituted 35% of exports, followed by gold (20%) and livestock products (only 9%). The country has a large deficit on its foreign trade balance (about 10% of GDP in 1990), and a debt which in 1990 amounted to 26% of GNP (World Bank, 1992). This is lower than that of the other case study countries (Table A1 in Annex 1).

According to the first (1985-1990) and second (1991-1995) national development plans, the main development objectives were: to satisfy the basic needs of the population; and to focus on use of own resources, on own initiative and on participation of the population and their organisations. Apart from these very general objectives more specific targets were set for sectoral growth, which for agriculture was set at 4.5% per year over the period 1991-95. An analysis of Structural Adjustment Programmes in Africa and Asia in the 1980's showed that Burkina Faso has been a successful adjuster (Subramanian, 1994).

The national programme for management of land resources (PNGT) currently plays a very prominent role in agricultural development. Major emphasis in all agricultural development programmes is on controlling erosion and maintaining or improving soil fertility. The 1991-1995 national investment plans proposed to cover another 5,000 ha with erosion control measures and to establish another 2,000 compost pits in Sanmatenga province (CNP, 1990a). The plan for Zoundwéogo was less explicit about agricultural investment, but included large sums for an agricultural and rural development project, pastoral zones and construction activities, including school buildings (CNP, 1990b).

Two integrated development projects (Burkina Faso-Netherlands cooperation) have been operational in the two provinces since the early 1980's. Project PEDI (Programmation et Exécution du Développement Intégré) in Kaya falls under the Ministry of Planning and assists the provincial services in the fields of health, water supply and food production. Project PDI/Z (Projet de Développement Intégré en Zoundwéogo), in Manga, succeeds the former 'Projet d'Aménagement des Vallées du Volta' (AVV), a large settlement programme. The project assists the regional services in promoting sustainable crop and livestock production systems, and is involved in strengthening farmer and government institutions.

9.2 Measures against land degradation

Soil and water conservation in Burkina Faso

Although some indigenous measures were already practised, since the 1960's much attention has been given in Burkina Faso to the implementation of soil and water conservation measures. A first, large scale and partly mechanized attempt with large earth bunds was made in the province of Yatenga, but failed. It had followed a top-down approach and the technology was not adapted to local circumstances. However, the gradual, small-scale and participatory approach by the Oxfam 'Projet Agro-forestier' (PAF) in the same province in the 1980's was considered a success. Although starting out as an agro-forestry project, it eventually focused largely on the establishment of stone rows along the contour lines, one of the indigenous conservation measures. Many other projects, in similar areas, followed this example and added new elements to the conservation approach (Kessler et al., 1995).

Since the 1980's the CRPA's (Regional Centres for Agricultural Production), i.e. extension centres, have followed a strategy by which land is first protected with erosion control measures, then the use of manure, compost and mulching is promoted and finally chemical fertilizers are added (combined with better crop varieties, etc).

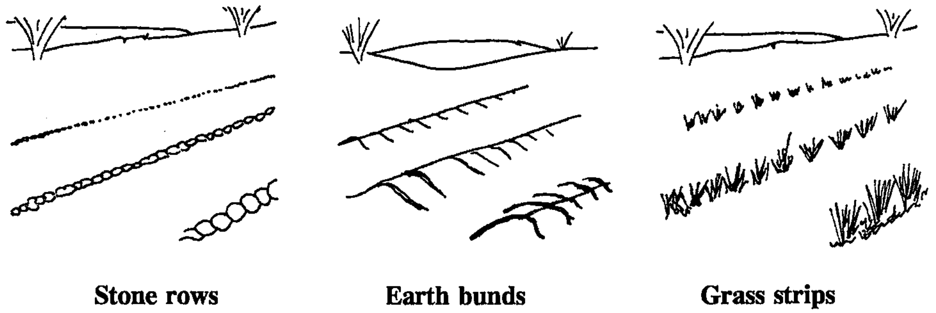


Figure 9.2 *The three main erosion control measures on the Central Plateau, Burkina Faso*

Erosion control measures

In the two research zones one can distinguish three main erosion control measures, all line interventions (Figure 9.2): *earth bunds* (*diguettes en terre*), *stone rows* (*cordons pierreux*) and *grass strips* (*bandes des herbes*). Grass strips (usually consisting of *Andropogon spp.*) can also be planted on or along the bunds (or rows). Much attention is also given to semi-permeable stone dams (*digues filtrantes*), but these are only constructed in valley-bottoms and do not constitute an alternative erosion control measure for most agro-sylvo-pastoral land. The earth bunds and stone rows are normally established in the dry season, while the grass strips have to be planted during the rainy season (Buma, 1992).

All three measures perform more or less the same functions: to reduce soil losses, to reduce nutrient losses and to reduce run-off, thus increasing infiltration. Farmers emphasized their role in maintaining productivity, which has been interpreted as maintaining soil fertility over a long period of time (Table 9.4).

Table 9.4 *Farmers' ideas about the functions of conservation measures (in percent)*

Main effect	Measure(s): Stone rows	Stone r. & grass	Earth bunds	Earth b. & grass	Grass strips	Total
Increasing moisture	13	19	19	0	6	12
Maint. productivity[1)]	47	31	43	55	53	46
Reduced soil losses	23	25	19	27	24	23
Reducing risk	9	19	10	9	18	12
Other effects	8	6	10	9	0	7
Total	100	100	101	100	100	100
No of farmers	47	16	21	11	17	112

1) Or maintaining soil fertility over a long period of time.
Sources: Antenne Sahélienne farm household studies 1992-1994.

Vlaar (1992) classified the various soil and water conservation measures according to their suitability for different agro-ecological zones and different soil types. All three measures are most adapted to the Southern Sudan zone. Under the rainfall patterns in the Northern Sudan zone semi-permeable structures (stone rows and grass strips) are more effective than earth bunds, and less risky in wet years. With a minimum maintenance effort the expected lifetime of stone rows is considerably longer than that of earth bunds, which need to be reshaped every five years. However, earth bunds may last longer when they are planted with grass, and/or have adequate drainage outlets.

One can distinguish between single rows of stones (usually with large stones) and stone rows whereby (smaller) stones are put next to or on top of each other. Since in part of Sanmatenga province the availability of stones is not yet a major problem, earth bunds are no longer constructed very often in this province. In Sanmatenga stone rows were originally built by individual farmers, but for efficient stone transport by lorries the emphasis has gradually shifted towards construction by groups of farmers on sites of at least 10 ha. In the period 1985-1994 a total of 11,093 ha were treated, mostly with stone rows (DRP, Kaya; pers. comm.). In Zoundwéogo stones are not always available within reasonable distance. More than two thirds of the total area treated of 13,596 ha between 1985 and 1994 consisted of earth bunds (SPA, Manga; pers. comm.). However, few of the earth bunds established before 1990 are still intact.

Table 9.5 *Erosion control measures applied in six villages in Burkina Faso (1993)*

Province / Village	Sample households (No)	Area cultiv. (ha)	Cultiv. area protected with: stone rows (percentage of cultiv. area)	earth bunds	grass strips	one or more measures	Population density (pp/km²)
Sanmatenga							
Damane	25	81	38	0	18	53	188
Tagalla	26	129	30	0	22	49	42
Sidogo	31	217	31	14	20	62	178
Zoundwéogo							
Barsé	28	150	1	10	4	13	52
Yakin	25	139	15	19	4	36	137
Kaibo-Sud V5	25	135	15	0	3	17	91
Total/ average	160	851	21	8	12	39	82

Sources: Antenne Sahélienne farm household studies 1992-1994.

Table 9.5 shows which part of the cultivated area in the *six research villages* has been protected with the main erosion control measures. The six villages were selected partly on the basis of the extent of measures taken and are as such not representative for all cultivated land on the Central plateau. It is interesting to compare the situation in the respective villages. There is more emphasis on soil conservation measures in the more densely populated villages. Stone rows are the most common measure, except in Barsé where stones are hardly available. Grass strips are also common, but they are not always planted along the contour lines and thus not always very effective in erosion control.

Fertility maintenance and compost pits

There are several possibilities for maintaining and increasing soil fertility, each having its advantages and disadvantages. The present population density and need for food production in any case no longer allow for long fallow periods.

Soil fertility is sometimes maintained through *agreements* between farmers (Mossi) and *herdsmen* (Fulani). The latter move seasonally with their large herds of cattle from the north to the south in search of grazing land and back (transhumance). They let their cattle graze on the stubble of fields of the Mossi, who in some cases pay them in kind (e.g. bags of millet) for the dung they leave on the land. But this may not be possible on a large scale, since in order to maintain soil fertility with manure only, about 15-20 ha of grazing land are required for 1 ha of crop land (van Keulen and Breman, 1990).

Another traditional way of maintaining soil fertility was the cultivation of food crops under *Acacia albida trees*, which shed their leaves in the rainy season and therefore cause little shade. Under certain soil conditions (depth, water and nutrient availability) these trees may also fix nitrogen: 50 trees per ha provide more than 5 tonnes of organic material, about 70 kg N and 4 kg P, and increase yields of millet and sorghum considerably (Broekhuyse, 1990). While religious beliefs in the past prevented villagers from cutting the trees, these beliefs seem to be less important nowadays and the number of trees per ha is fast decreasing.

Mulching has become a common practice in most villages, since it serves many purposes: to cover the soil against the first heavy rains, to prevent crusting, to reduce soil erosion and to contribute to the organic matter and nutrient content of the soils. It facilitates the role of termites in improving soil structure.

Inorganic fertilizers are seldom used. In Zoundwéogo province application fluctuated in the period 1985-1994 from a mere 1 kg/ha in 1991 to 3 kg/ha of arable land in 1994, when farm prices for cotton had increased following the 100% devaluation in early 1994. About 80% consist of composite fertilizers for cotton (14N-23P-14K-6S-1B) and the remainder of urea and Burkina phosphate (25% P_2O_5). The prices for cotton fertilizer and urea were less than CFAF 110 per kg before and between CFAF 170 and 210 per kg after the devaluation. The price for Burkina phosphate went up in 1994 to CFAF 55 per kg (Bazié, 1995). Because of the high prices of imported fertilizers, attention is now being given to the promotion of Burkina (rock) phosphate as one way of conserving the quality of land resources. This could be done in combination with compost pits.

Since farmers have no cash to pay for fertilizers on their food crops, much emphasis is nowadays given to the use of locally available fertilizing materials, and the preparation of *compost*. There are two types of compost pits (*fosses fumières*): the Manga type and the Gorom type (Leegte, 1994). In the provinces of Sanmatenga and Zoundwéogo the Manga type is more common (Figure 9.3). It consists of a pit of 3 m long, 2.5 m wide and about 1,30 m deep (about 10 m^3), preferably with a roof to reduce evaporation and volatilization.

Normally the pit is filled with ashes of household refuse, farm manure, straw and leaves, and the compost is afterwards put on a pile next to the pit, and mixed with grasses and water to obtain good compost. Such a system produces about 5 ton compost per year, which is the recommended amount for one hectare. Watering (200 l per week) is cumbersome and often not respected. Most compost pits are not reinforced with cement, reducing the effective life from 10-15 to at most 4-5 years.

In Zoundwéogo province compost pits have been established since 1984, and their number increased substantially with the farmers' contest *Restaurons nos sols*, which stimulated farmers to engage in various activities to conserve their soils and to increase fertility. In 1992 there were 4,403 compost pits registered in the whole province (SPA, pers. comm.). However, because of a lack of water and means of transport, not all compost pits are used effectively. A survey on fertility maintenance in this province showed that farmers with compost pits only applied an average 5 cartloads per ha, or 20% of the amount recommended (Compaore and Pilabre, 1993), and they only select one or two fields for the application of compost. In Sanmatenga compost pits have been promoted since 1986. Initially farmers could obtain credit for a donkey cart, once they had constructed a compost pit. Although eager to obtain a donkey cart, they were not (yet) interested in compost pits. In the three departments Kaya, Mané and Boussouma about 1,200 pits were established up to 1994.

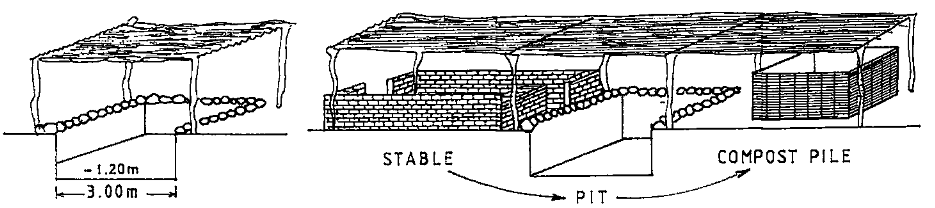


Figure 9.3 *A single compost pit (Manga type) and one combined with stable and pile*

Only 15% of the 160 farm households in the *six research villages* have made much use of cattle manure to fertilize their fields, by letting cattle graze on the stubble. The Fulani themselves and a few Mossi livestock farmers left herds of about 50 animals (herded by Fulani) for 100 nights on fields of about one hectare (estimated production of 7.5 ton dry manure per ha). Some farmers in Yakin keep their own 6 - 10 cattle for about 100 nights on their fields, producing 1.2 ton dry manure on 1 ha. More common is the use of small amounts of farmyard manure, from small ruminants and chickens, applied at sowing time.

In 1994 an inventory was made of the number and type of trees on the farmers' fields. In the three villages in Sanmatenga there were on average about 7 trees per ha of cultivated land, of which a quarter consisted of *Acacia albida*. In the Zoundwéogo villages the average number of trees per ha was about 10, with more than half consisting of sheanut trees and very few *Acacia albida*. Given this limited number of trees and taking into account that these trees are only fully grown after 20 years or more, it is doubtful whether this agroforestry option constitutes a prominent solution for the soil fertility problem. However, because of its positive features it should remain an important long term ingredient in overall soil fertility management.

Table 9.6 *Practices for soil fertility maintenance in six villages in Burkina Faso (1993)*

Province / Village	No. of house-holds	Area cultiv. (ha)	Soil Fertil. % C 1)	Perc. househ. applying: Mulch	Manure/ compost	Fertil. (inorg.)	Households with compost pits (%)	cattle on land
Sanmatenga								
Damane	25	81	0.3 (10)	64	44	8	16	16
Tagalla	26	129	0.8 (11)	27	15	15	12	8
Sidogo	31	217	0.4 (10)	58	48	42	10	3
Zoundwéogo								
Barsé	28	150	0.8 (10)	4	21	0	7	21
Yakin	25	139	0.6 (6)	12	48	32	52	24
Kaibo-Sud V5	25	135	0.8 (6)	-	44	44	44	20
Total/aver.	160	851	0.6 (53)	28	37	24	23	15
Perc. of area cultiv.:				10	17	12	-	6

1) Organic matter content (C-Kurmies) on cultivated land; samples in brackets
Sources: Antenne Sahélienne farm household studies 1992-1994.

Only 38 of the 160 households (24%) applied inorganic fertilizers in 1993, with an average application rate of only 47 kg/ha (mostly cotton fertilizers, and a little Burkina phosphate). This was done mainly by farmers in the densely populated village of Sidogo in Sanmatenga and cotton growers in the Kaibo-Sud settlement village in Zoundwéogo (Table 9.6). Almost the same percentage of the households (23%) had established a compost pit (in four cases two pits). More than half of these also use some inorganic fertilizers. Most compost pits were found in the villages Yakin and Kaibo-Sud V5.

9.3 Options and evaluation criteria

Target group

The evaluation concerns the general strategy that regional authorities and development projects follow in assisting 'farmers' to improve their farming systems, starting with erosion control measures and continuing with soil fertility maintenance activities. The question is whether this is the best strategy for all farmers, or only for certain categories of farmers.

Before presenting and screening various possible activities or components for such a strategy, an assessment is made of the target group for such a general strategy. Much insight can be gained from the situation in the six villages, where several of the activities have already been implemented. Following the outline given in Chapter 5, attention will be paid to the location, resources and resource use of farm households, their attitude with regard to soil and water conservation and to the manner in which priorities are set in implementation.

With regard to the *location* of the villages, there is a clear difference between villages alongside the rivers, previously river forest areas, and villages that are located more centrally on the plateau. In the former population density is relatively low, and much less erosion control and soil fertility measures have been undertaken than in the latter. Within the villages there are also clear differences between quarters, where the farmers live. Some wards have received much more assistance than others, depending on the enthusiasm of farmer groups and village elders and on socio-political factors.

An impression of the *farm household resources* can be derived from the selection of typical farm patterns (Box 5.2 in Chapter 5). Each farm pattern is represented by the actual farm, that most closely resembles the pattern. Selection was based on ethnic descent, gender and age of head of household, family size, man-land ratio and livestock numbers. Barning and Dambré (1994) and Kunze (1994) undertook similar farm 'typology' studies. On the basis of farm pattern resources (Table 9.7), one can comprehend that not all of them will respond in a similar way to a 'standard package' for erosion control and fertility maintenance.

Table 9.7 *Farm households representing the different farm patterns in the two research areas in Burkina Faso*

Code [2]	Ethnic identity	Main feature	Age Head of househ.	Labour Family size	Land Area cult. (ha)	Livestock: Cattle (No)	Goats Sheep (No)	Off-farm income [3]	Conservation measures [1]: SR (-- ha --)	EB	GS	CP (No)
(In villages in Sanmatenga province)												
S1	Fulani	Resident	35	14	3	20	20	-	0.3	-	-	-
S2	Mossi	Widow	55	2	1	-	2	27	-	-	-	-
S3	Mossi	Large fam.	50	22	11	1	5	1,960	5	1	-	-
S4	Mossi	Rich	36	10	16	-	4	1,189	1	-	0.8	1
S5	Mossi	Old	58	12	4.5	-	7	497	0.5	-	-	-
S6	Mossi	Young	31	9	6	1	3	333	1	-	0.5	-
S7	Mossi	Livest. f.	42	19	9	42	17	589	3	-	-	-
(In villages in Zoundwéogo province)												
Z1	Fulani	Transhum.	34	20	0.8	53	-	37	-	-	-	-
Z2	Mossi	Settled.	43	11	9.3	-	-	210	1	-	-	1
Z3	Mossi	Large fam.	48	25	16.6	6	10	2,188	2	0.5	-	1
Z4	Mossi	Rich	40	13	15.2	17	9	1,205	2	-	0.5	1
Z5	Mossi	Old	61	9	3	3	5	187	-	-	0.5	-
Z6	Mossi	Young	35	6	4	2	6	399	2	1	1	-
Weighted average			45	11	6.3	6	6	572	1.3	0.3	0.3	0.2
Sample average (n=160)			47	10	5.4	6	9	490	0.9	0.3	0.4	0.2

1) SR = stone rows; EB = earth bunds; GS = grass strips; CP = compost pit.
2) S1 is resident Fulani household; Z1 still involved in transhumance.
3) Revenues in CFAF 1000 per year; US$ 1 = CFAF 275 (1992/93).
Source: Antenne Sahélienne farm household studies 1992-1994.

Each farm pattern has its own strategy for soil conservation and fertility maintenance. Fulani and Mossi livestock farmers use much manure (farms S1, S7 and Z1), and non-resident Fulani do not invest in erosion control measures. So-called 'rich' farmers, with a favourable man/land ratio (about 1 ha per person) and ample other resources, can afford to apply fallow in their crop rotations and to use inorganic fertilizers, which is the case for farms S3 and Z4. Settlement farmers (Z2) fall more or less in the same category as the 'rich' farmers (having received 10 ha per household), and have received considerable extension and credit support. However, part of their savings are (indirectly) reinvested in their area of origin, with which they still maintain close contacts, twenty years after their departure. Farms with large (extended) families can engage in labour intensive activities, such as stone rows, dung collection, tree planting, mulching, and compost pits. Farm S3 already has more than half of its land protected with conservation measures and is one of the few engaged in tree planting. Farm Z3 is making quite good use of its compost pit.

However, the majority of farmers (56% of entire sample) fall in the category of 'common' households with insufficient land and other resources, who require help to obtain resources for erosion control and fertility maintenance. This group has been sub-divided by age of heads of households into old (above 55 years) and young farmers, because of small differences in resources and resource use. The young are more involved in soil conservation measures than the old.

During the farm household surveys attention was also paid to the opinion and *attitude of farm households* about the soil conservation measures (Schaper, 1993; den Boef, 1993). Most heads of households had recognized erosion symptoms (sheet and rill erosion, reduced vegetation, etc.) and the effects on their fields, and said that they were interested in erosion control measures. The reasons why farmers were not yet engaged in such measures could be classified according to the steps in the scheme of Figure 3.1 (Chapter 3), as follows:

Step 3 (No interest)	:	9%	did not take erosion seriously; mostly in southern area
		11%	had no parcels of their own / are often away (e.g. Fulani)
Step 4 (No knowledge)	:	11%	had no idea how to tackle the erosion
Step 5 (No ability)	:	13%	found themselves incapable of tackling it (e.g. old age)
		6%	had insufficient labour resources
		21%	had insufficient material resources (e.g. donkey carts)
		2%	had only recently obtained a parcel of their own
Step 6 (No willingness)	:	4%	had other, more urgent, priorities
Step 7 (No readiness)	:	4%	found that stone deposits were too far away
		19%	said that it was not yet their turn (awaiting lorry)

There appeared to be not much difference between farm patterns with regard to the attitude towards erosion and control measures. Four of the selected 'Sanmatenga' farm households (widow, old, young and livestock farmer) and two of the 'Zoundwéogo' households (large household and young farmer) considered erosion to be a major problem in their life. However, as in the adoption study of Dialla (1992), it was difficult to find variables that had any significant effect on the Mossi farmers' conservation behaviour. There is a general interest in stone rows, but farmers need assistance with the transport of stones and have to await their turn. Grass strips are also appreciated, particularly in densely populated villages, where these strips are a major source of supply for thatching and mulching. Interest in fertilization is less pronounced, although farmers realise its importance. Compost pits are only common practice in two of the six villages, whereby the need for watering is the main reason why farmers in other areas are not very keen on them.

There are several factors that determine the *priority setting* for soil and water conservation. General observations, soil samples (about 10 per village) and data on yields (Loozekoot, 1994a; Haima, 1996; Hamer, 1996) suggest that villages and hamlets with a less favourable man/land ratio (e.g. Damané, Sidogo, Yakin) appear to have more problems with land degradation than the others. Each of the selected villages shows a certain mixture of landforms and soils, and only around Damané do large tracts of completely degraded land occur. The projects and agricultural services (CRPA) have recently chosen for a concerted approach aiming at selected villages, but continue to assist other villages on request. Priority setting of sites to be treated is undertaken by leaders of farmer groups and extension officers. In the 10 ha block approach, families that have large fields close together have more chance to participate.

On the basis of the above analysis it is assumed that a priority conservation strategy will focus on the target farm patterns S5, S6, Z5 and Z6 in the more densely populated villages.

Despite agro-climatic differences between the two provinces and age differences of heads of households, the resource availability for these farm patterns is about 8 family members, 4 ha cultivable land, 1 head of cattle (2 in Zoundwéogo), 1 donkey, 5 goats and annual cash earnings from off-farm activities (including migration) of CFAF 500,000. These farm patterns represent in particular many farm households in villages such as Sidogo and Yakin.

The target group can therefore be defined as: farm households with relatively modest land and livestock resources in the more densely populated, centrally located villages in zones where land degradation is apparent.

Evaluation method and evaluation criteria

CBA requires a detailed quantification and valuation of all effects on the efficiency criterion, and the most relevant ('with') options are compared with the 'without situation'. MCA is better equipped to deal with more objectives (criteria) and non-monetary and qualitative effects. In this case there are two types of possible activities: erosion control and fertilizing measures. The erosion control measures (stone rows and earth bunds) are mutually exclusive, while fertilizing measures are often complementary. Some measures have a considerable investment component (e.g. stone rows), while others only constitute annual costs (e.g. inorganic fertilizers).

There are two main actors involved: the target farm households and the government, acting among others on behalf of future farmers. The main objectives of farm households relate to short-term self-sufficiency in food production. In the Sanmatenga villages, facing food production deficits in two out of three years, all other objectives are more or less subordinate to that. The Government is in its agricultural development efforts much concerned about long-term soil fertility maintenance. Both groups consider few other criteria in their conservation approach. Considering these objectives and three key criteria the following attributes (the more prominent in bold print) could be defined:

Key criteria:	**Attributes:**	**Actor(s) concerned:**
Efficiency:	**Local food production (for self-suffiency)**	Farmer
	Investment costs	Gov't/Farmer
	Production and maintenance costs	Farmer
	Local input use to save foreign exchange	Gov't
	Future productivity losses through degradation	Gov't
Equity:	**Intergenerational equity**	Gov't
Conservation:	Erosion control	Gov't/Farmer
	Water conservation (short term)	Gov't/Farmer
	Fertility maintenance (long term)	Gov't/Farmer

Interregional and intragenerational equity considerations (Chapter 4) are not emphasized in national objectives and are not included here, although they play a certain role in the selection of the target groups, as undertaken above.

Since no detailed (quantitative) data on the attribute score are available for the various erosion control measures, a screening of these activities will be undertaken first, with the use of a qualitative MCA method. This will then be followed by a cost-benefit analysis for the 'best' erosion control measure, in combination with the most promising fertilizer activities.

For the detailed evaluation of these 'best options' an attempt is made to express the attributes of the three conservation criteria in terms of production and income. A shadow price for foreign exchange would deal with import substitution. The intergenerational equity criterion could be dealt with separately, by attaching a premium to a favourable production situation at the end of the physical life of the measures (15 years).

Options

Options should be looked at from field, farm, watershed, regional and national level. The best options at local level may not be relevant or appropriate at regional or national levels. In this case study emphasis is given to local level options for rainfed farming by the resident population, realizing that the scope for irrigated farming, for land use changes, for further emigration and for artisanal activities is quite limited. In defining the options the following categories could be considered for the two main conservation objectives:

For erosion control	For fertility maintenance
A : No control measures	**0 : No fertilization**
B : Stone rows (alone)	**1 : Compost pits**
C : Earth bunds	**2 : Mulching & fertilizers**
D : Grass strips	3 : Livestock manure
E : Bunds with grass strips	4 : Leguminous trees

The three erosion control measures, stone rows, earth bunds and grass strips (or vegetative barriers), are alternatives that have each their advantages and disadvantages under different circumstances, and from different viewpoints. In Bam province farmers often combine stone rows with grass strips, but this is not often practised in the two research zones.

Vlaar (1992) compares these and other erosion control measures in the Sahel countries on the basis of several criteria. These criteria relate to costs and impact (efficiency and conservation), but also to organisational aspects ('bottlenecks'), such as provision of transport and know-how. Equity is not considered. Apart from a few quantitative criteria scores (e.g. costs), the comparisons made are mainly concerning qualitative scores. All measures involve some loss of cultivable area, and bunds may cause waterlogging in case of floods (Kempkes, 1994). These latter effects will not be included here.

With a qualitative MCA method a screening of these measures is undertaken on the basis of ten criteria (Box 9.1). Table 9.9 shows that stone rows are considered the best erosion control alternative, followed by grass strips. When stone quarries are too far away, grass barriers could be considered or a combination of earth bunds planted with grass.

For *fertility maintenance* one does not deal with mutually exclusive options. Inorganic fertilizers could be an alternative to compost, as far as the supply of nutrients is concerned, but organic matter is also of crucial importance and fertilizers should at least be accompanied by mulching. In view of the national objectives, which focus on the use of local resources, compost and Burkina (rock) phosphate are better suited than other fertilizers for which foreign exchange is required (World Bank, 1994; Gerner and Mokwunye, 1995).

The planting of leguminous trees such as *Acacia albida* is an unlikely single option for most farm patterns. Farm pattern S3 has planted a considerable number of trees in the past two years, but as no fencing was erected, part of the plantation was damaged by livestock.

Box 9.1 *Multi-criteria analysis for the screening of erosion control alternatives*

Table 9.8 shows the ten different criteria on the basis of which the three erosion control measures are screened. Two weight sets are considered, representing the point of view of the Government or general public and that of the farmer (target farm pattern) respectively. It further represents a situation on the Central Plateau, that is close to average with regard to type of field, soil type, climate, availability of stones, etc.

Table 9.8 *Ranking of alternative soil and water conservation measures, and weight sets from public and farmer point of view, Burkina Faso*

Criteria	Alternative measures: Stone rows (a)	Earth bunds (b)	Grass strips (c)	Weight sets: Public	Farmer
Cost aspects	**Scores (ranks)**				
Investment:					
labour inputs	1	2	3	0.05	0.20
machine inputs	1	2	3	0.20	0.00
Maintenance needs	3	1	2	0.10	0.10
Impact					
Erosion control	3	2	1	0.10	0.05
Water conservation	2	3	1	0.05	0.10
Fertility maintenance	3	1	2	0.20	0.25
Other benefits	2	1	3	0.00	0.10
Organisational preconditions					
Transport/tractor depend.	1	2	3	0.10	0.10
Time of implementation	3	2	1	0.05	0.05
Know-how	2	1	3	0.15	0.05

Note: ranking from 1 (least desirable) to 3 (most desirable).

All scores on criteria are expressed in qualitative terms, in the form of a ranking. Other benefits comprise in particular the use of *Andropogon* grass for thatching and mulching and the use of stone rows to delimit parcels. The organisational preconditions concern the dependence of farmers on lorries and tractors, the seasonality of implementation and the knowledge and extension required for execution.

For this screening of alternatives use is made of Regime analysis, whereby first a pairwise comparison is made of the scores (ranks) on the criteria (-1 for lower and +1 for higher rank), and thereafter these scores are multiplied by the weights in order to obtain the weighted score. A positively weighted score indicates that the first measure of the pair (a in ab) is preferred. Such a relatively simple analysis can be easily performed within a spreadsheet, as shown in Table 9.9.

From the point of view of the Government or general public, stone rows and grass strips have a similar aggregate score (Pac = 0.00), with earth bunds coming in third place. From the farmer's point of view stone rows score slightly better than grass strips (Pac = 0.10), and earth bunds are again clearly the least attractive. Each of the respective farm patterns and agencies concerned will have different preferences and thus other weight sets, and this may alter the result.

Box 9.1 *Continued*

Table 9.9 *Regime analysis for choice between stone rows, earth bunds and grass strips, on the basis of 10 criteria and 2 weight sets*

Criteria:	(Cost)			(Impact)				(Organisation)			Score
	Labour input	Mach. input	Main-tenance	Ero-sion	Water cons.	Produc-tion	Other benef.	Trans port	Sea-son	Know-how	
Pairwise comparison of scores on criteria:											
Rab	-1	-1	1	1	-1	1	1	-1	1	1	
Rac	-1	-1	1	1	1	1	-1	-1	1	-1	
Rbc	-1	-1	-1	1	1	-1	-1	-1	1	-1	
Scores for each pair of measures with first (public) weight set (W1):											
W1	0.05	0.20	0.10	0.10	0.05	0.20	0.00	0.10	0.05	0.15	1.00
Pab	-0.05	-0.20	0.10	0.10	-0.05	0.20	0.00	-0.10	0.05	0.15	0.20
Pac	-0.05	-0.20	0.10	0.10	0.05	0.20	0.00	-0.10	0.05	-0.15	0.00
Pbc	-0.05	-0.20	-0.10	0.10	0.05	-0.20	0.00	-0.10	0.05	-0.15	-0.60
Scores for each pair of measures with second (farmer) weight set (W2):											
W2	0.20	0.00	0.10	0.05	0.10	0.25	0.10	0.10	0.05	0.05	1.00
Pab	-0.20	0.00	0.10	0.05	-0.10	0.25	0.10	-0.10	0.05	0.05	0.20
Pac	-0.20	0.00	0.10	0.05	0.10	0.25	-0.10	-0.10	0.05	-0.05	0.10
Pbc	-0.20	0.00	-0.10	0.05	0.10	-0.25	-0.10	-0.10	0.05	-0.05	-0.60

R = regime vector; P = score; a = stone rows; b = earth bunds; c = grass strips.

The two options of planting leguminous trees and using large amounts of cattle dung can only be implemented by a few farm households, and are thus not considered in this analysis.

The remaining options for the evaluation therefore consist of stone rows only (B0), stone rows and compost (B1), stone rows with inorganic fertilizers and mulch (B2), no action at all (A0), compost only (A1) and fertilizers with mulch only (A2).

9.4 Costs of establishing stone rows and compost pits

Costs of stone rows

In several studies estimates have been made of the costs of establishing stone rows, but these estimates vary considerably because of different circumstances and techniques involved. Rochette (1989) arrives at an average workload of 219 mandays per ha, but in his case farmers dig trenches before placing the stones. Matlon (1980) arrives at a total of 181 mandays per ha, of which most is spent on collection of stones, which may have to be cut from the rocks. The exact conditions were not known. For this reason a 'time and motion' study was undertaken in the village of Tagalla, whereby the whole operation of procuring stones and constituting the rows was monitored (Kempkes, 1994). In this case the distance to the stone collection site was 2 km, and stones were obtained relatively easily from loose laterite rocks and outcrops. Transport was by lorry. Per trip an average of 464 stones, with an average diameter of 30 cm, were transported. The loading and the return trip (including unloading) took on average 11 and 19 minutes respectively, which allowed the driver to perform the 10 trips per day that are prescribed. The operation was undertaken for an area of 10 ha, where stone rows were placed at a (quite large) average distance of 50 m.

With a total of 2784 stones per ha and a group of 30 adults and 10 children involved in stone collection, the operation was completed in six days. In this particular case, with a slope of about 1-2 %, only about 50 mandays (equivalent) were needed per ha. In case of steeper slopes of 3 % and more, stone rows should be placed at a distance of 20 m or less.

The most important factors that determine the costs are the following:

- Means of transport: by lorry, donkey cart, wheelbarrow or head-load. The farm household studies showed that lorries were most often used (74%), followed by head-load (10%), donkey cart (8%); wheelbarrow (6%) and other mode of transport (2%).
- 'Concentrated group effort', whereby areas of about 10 ha are treated;
- Slope of the terrain, determining the average distance between rows. Together with the choice of simple or double rows this determines the number of stones needed per ha;
- Distance from which stones have to be hauled, and the ease with which they can be obtained at the collection site, which determines the collection time;
- Assumptions about the opportunity costs of the labour involved. Because of the arduous work, labour costs are here fixed at CFAF 500 per manday (person-equivalent). The 1993 farm survey showed (prior to the devaluation) average earnings per manday in alternative employment during the dry season of about CFAF 320 per manday.
- Assumptions about fixed and variable costs of means of transport, and number of days in use (here fixed at 150). A new lorry is assumed to cost CFAF 40 million and a donkey and cart CFAF 240,000. The capacity of lorry and donkey cart per trip are 500 stones (4.5 m^3 or 5 ton) and 50 stones (0.4 m^3 or 0.5 ton) respectively. Because of the duration of the return trip the donkey makes only 5 trips of 2 km and 2.5 trips of 4 km a day.

Table 9.10 shows the cost of establishing 1 ha of stone rows for two modes of transport and different circumstances.

Table 9.10 *Costs of establishing 1 ha of stone rows, in Burkina Faso (1995)*

	Workload (persondays)				Costs in CFAF 1000			
Length of rows:	200 m/ha		400 m/ha		200 m/ha		400 m/ha	
Distance site:	2 km		4 km		2 km		4 km	
Collection effort:	easy		arduous		easy		arduous	
Transport means:	Lorry	Cart	Lorry	Cart	Lorry	Cart	Lorry	Cart
Activities:								
Transport (means)	-	-	-	-	34.0	6.0	110.0	24.0
(labour)	-	12	-	48	-	6.0	-	24.0
Collection/loading	37	37	90	90	18.5	18.5	45.0	45.0
Outlining	4	4	8	8	2.0	2.0	4.0	4.0
Placing stones	10	10	20	20	5.0	5.0	10.0	10.0
Materials	-	-	-	-	4.0	4.0	8.0	8.0
Total	51	63	118	166	63.5	41.5	177.0	115.0
Farmer contribution	51	63	118	166	29.5	41.5	67.0	115.0
Annual maintenance	3	3	6	6	1.5	1.5	3.0	3.0

Costs of compost pits

The compost production costs consist of the establishment and maintenance of a pit, the cost of material inputs such as manure, straw, litter, ashes, refuse, fertilizers (Burkina Phosphate) and water, and the labour cost of filling, watering and emptying the pit and transporting and spreading the compost. The quality of compost depends in particular on the composition of inputs and the extent of watering. A detailed survey was undertaken on the use of manure and the contents of compost pits of several farmers in Yakin (Miedema, 1994).

Table 9.11 *Average organic matter and nutrient status of soil samples, compost and manure in research villages, Burkina Faso*

	Organic matter % C (Kurmies)	**Nitrogen** % N	**C/N ratio**	**Phosphorus** mg/kg
Soil samples (n=53)	0.6	0.05	11	153
Range of values	0.2 - 1.3	0.01 - 0.11	7 - 20	42 - 485
Compost in Yakin (n=6)	8.6	0.49	18	1389
Range of values	3.6 - 16.1	0.19 - 0.77	13 - 26	867 - 2992[1)]
Livestock **manure** (n=8)	23.5	0.92	27	1894
Range of values	10.3 - 39.8	0.63 - 1.52	15 - 40	1144 - 2904

1) Enriched with Burkina Phosphate.
Source: (soil) Hamer, 1996; (compost and manure) Miedema, 1994.

Table 9.12 *Costs of establishing and operating a (5 t) compost pit, in Burkina Faso (1995)*

	Workload (persondays)		Costs in CFAF 1000	
Type of compost pit:	Simple	Reinforced	Simple	Reinforced
Av. life time (yrs):	4	10	4	10
Establishment cost				
Digging pit	10	10	5.0	5.0
Reinforcing pit	-	3	-	1.5
Cement (2 bags)			-	12.0
Depreciation & interest			1.4	3.0
Annual maintenance	2	2	1.0	1.0
Operational cost				
Filling pit	6	7	3.0	3.5
Materials			1.5	1.5
Phosphate (2 bags)			-	5.5
Watering	5	5	2.5	2.5
Emptying/piling	7	7	3.5	3.5
Transport/spreading	9	9	4.5	4.5
Total annual cost	29	30	17.4	25.0

The average amount of compost produced per pit was 3.7 tons. The contents included ashes (about 30%), straw, leaves, manure from different animals and household refuse. One farmer with two pits had added respectively 4 and 2 bags (50 kg each) of Burkina Phosphate. Table 9.11 shows the average nutrient status of this compost, in comparison with that of the soil and of cattle manure. Another detailed time and motion study was undertaken to assess the labour inputs in filling and emptying compost pits, for a financial analysis (Bazié, 1995). Table 9.12 is based on data from this study.

9.5 Impact of stone rows and compost on production

Several research efforts have been made to estimate directly, in an empirical manner, the effects of stone rows on crop yields. The most elaborate research was done by the PAF project in Yatenga, over the period 1981-1986 (Reij, 1988). Over this five year period yields were measured for about 400 fields. The difference in yields for plots with and without stone rows was about 100 kg/ha (35%) in dry years, with an average of 406 mm rainfall and about 360 kg/ha (65%) in wet years, with 642 mm rainfall. In other studies the differences were more pronounced in dry years (e.g. Wardman and Salas, 1991). From the available data it cannot be ascertained whether such an increase could be solely attributed to stone rows, or also to complementary measures (e.g. fertilization). In a World Bank study (1990) it has been assumed that on the Central Plateau stone rows alone would increase yields on very degraded land from 350 kg/ha to 515 kg/ha, and that yields could be further increased to 630 kg/ha by adding 1.7 t organic fertilizers, to 700 kg/ha by adding 150 kg inorganic fertilizers and to 805 kg/ha by adding both. The duration of these yield increases is not mentioned.

Within the framework of this research a dual strategy was followed: empirical field research was undertaken in the research villages and an attempt was made to assess the impact of the measures in a theoretical way, by applying the methods outlined in Chapter 6.

Empirical field research

In three subsequent seasons (1993-1995) field size was measured and 'harvest samples' were taken, to estimate yields and to obtain an idea about the reliability of farmer estimates (Nibbering, 1994). It appeared that farmers generally indicate larger field sizes and underestimate yields (per ha). The resulting measured production figures matched farmer estimated production reasonably well. In 1994 and 1995 field size and yields were measured on a total of 50 fields, 32 of which formed 16 (more or less uniform) pairs of fields of the same farmers, one of which with stone rows and the other without. This small study produced interesting data, although the floods, caused by exceptionally high rainfall around Manga in 1994, affected the results. In 1994 average yields on fields with stone rows were only 14% higher than on those without rows, and this difference could also be attributed to the higher input of fertilizers, manure, compost, etc. Thirteen fields with rows received fertilizers (about 49 kg N per ha), against only seven fields without rows (a mere 7 kg N/ha).

This would confirm that farmers see the stone rows as a prerequisite to intensify land use, and that they see fertilizer use as the next step, whether with manure, compost or inorganic fertilizers. However, apart from the Fulani and the Mossi livestock farmer, few farmers have advanced much with fertilization. The six fields of this exceptional group received very large amounts of manure (providing 89 kg N/ha), resulting in average yields of 1,800 kg/ha (based on harvest samples), whereas the average yields on the 26 fields of all other farmers was only 703 kg/ha, with an average calculated input of only 14 kg N/ha.

In 1995 rainfall was close to average, with reasonably good yields of sorghum on the better soils and lower yields of millet. Average yields on fields with stone rows were again only slightly higher than on those without stone rows. During this season soil samples were analyzed from 43 of the 50 fields. There appeared to be clear differences in soil fertility of fields in the more densely populated villages (0.4% C(Kurmies); 0.04% N and 0.02% P) than in less densely populated villages (0.8% C(K.); 0.07% N and 0.01% P), and average yields were 35% higher in the latter. The influence of soil fertility on yields was for this year more evident than the relationship between fertilizer use and yields (Hamer, 1996).

Impact of soil-, water- and nutrient-losses on production: a theoretical approach.
The field research did not provide a clear picture of the effects of stone rows. To obtain theoretical estimates of benefits of erosion control and soil fertility measures, the effects thereof on soil erosion and water and nutrient balances were analyzed. Although plant production is highly variable in time and space, owing to unpredictable rainfall and small-scale variation in soil fertility (Kessler, 1994), the analysis below focuses on an 'average' situation for a 1 ha 'village' field over a one year period.

Impact on soil erosion
Making use of the (R)USLE formula and of erosion research data for the dominant soil types and slopes on the Central plateau, one may assume that soil erosion on most of the degraded agricultural land is about 12 t/ha in the northern area around Kaya (Chleq and Dupriez, 1984) and about 16 t/ha in the area around Manga (Table 9.13). This is based on an average annual rainfall of 628 mm in Kaya and 839 mm in Manga, and on the empirical data from Roose (1977) showing that the value for the R-factor in the USLE formula in West Africa is about half of the annual precipitation (in mm). The dominant soils are sandy loam, with a soil depth of about 70 cm and a topsoil of 30 cm (van der Hoek et al., 1993). With such soil depth and erosion rates it will be more than a hundred years before no soil is left. So rooting depth appears not to be the limiting factor, unless an advanced stage of denudation has already been reached. The main form of physical degradation, crusting, is not dealt with here. With stone rows the P-factor changes and erosion rates on such land will be reduced to about 4 t/ha around Kaya and about 6 t/ha around Manga. But since erosion affects in particular the nutrient rich top soil layer, stone rows will reduce erosion of nutrients (e.g. nitrogen) somewhat less.

Table 9.13 *Erosion factors and erosion rates in research areas in Burkina Faso, with and without stone rows (SR), under average annual rainfall and on sandy loam soils*

Location and conditions	USLE - factors: Erosi -vity R	Erodi- bility K	Slope (m) L	Slope (%) S	Crop factor C	Manage -ment P	Erosion (t/ha)
Near Kaya, without SR	314	0.2	100	2	0.5	1.0	12
Near Kaya, with SR	314	0.2	100	2	0.5	0.3	4
Near Manga, without SR	420	0.2	100	2	0.5	1.0	16
Near Manga, with SR	420	0.2	100	2	0.5	0.3	6

Source: Glaêtzer and Grierson, 1987 (USLE software).

Impact on water balance
Effects of measures on the water balance depend on the actual precipitation in the growing season, which fluctuates widely per year. Annual rainfall in Kaya ranged from 1971 to 1995 between 454 mm (in 1985) and 935 mm (in 1976). For crop development, water supply in May and June is critical: this fluctuated from a low of 63 mm in 1985 to an excessive amount of 231 mm in 1976. The 25 years were divided into low, medium and high rainfall years and the years 1978, 1980 and 1994 year were selected to represent these years.

For these three years water balances were drawn up, and by using the water balance spreadsheet module, an assessment was made of likely yield reductions with and without stone rows in these years (Table 9.14). The run-off as percentage of rainfall, was based on indications from field research in similar areas on sandy loam soils (Roose and Piot, 1984; Tammes et al, 1994). Only in dry years in areas around Kaya, may water availability reduce yields by a considerable amount. According to Table 9.14 stone rows would have been able to reduce water stress on sorghum fields in the villages around Kaya by about 15% in these three years, where water would have been the most limiting factor. In the areas around Manga the water retention effect of stone rows on crop yields is less pronounced. In the past average yields of sorghum of 900 kg/ha have been recorded on the Central Plateau, under similar rainfall conditions. Present low average yields of 400-700 kg/ha can not be ascribed to water shortages (alone). Such a conclusion was also obtained for biomass production on silvopastoral land (Stroosnijder, 1982).

Table 9.14 *Water balances and crop yield reductions for relatively dry, average and wet years in areas near Kaya and Manga (Burkina Faso), with and without stone rows*

Type of year and measures	Run-off (%)	P (mm)	Pef (mm)	ETa (mm)	D (mm)	Yred (%)
KAYA						
Dry year, 1978						
without rows	40	539	332	332	0	32
with rows	20	539	436	415	21	18
Average year, 1980						
without rows	44	628	368	368	0	26
with rows	27	628	465	465	0	9
Wet year, 1994						
without rows	50	812	406	393	13	21
with rows	30	812	568	475	93	7
MANGA						
Dry year, 1990						
without rows	44	647	362	362	0	27
with rows	27	647	517	441	77	13
Average year, 1992						
without rows	50	873	437	425	11	17
with rows	30	873	611	454	157	11
Wet year, 1994						
without rows	50	1191	596	456	140	10
with rows	30	1191	834	480	354	6

Note: P and Pef = total and effective annual precipitation; ETa = Actual Evapotranspiration; D = Deep percolation and Yred = Yield reduction as a result of water shortages (Chapter 6).

Impact on nutrient balances and organic matter content

In most of the Sahelo-Sudanian zone in Africa soil depletion has reached the point that not water supply but the availability of soil nutrients is the most limiting factor in plant or biomass production (Penning de Vries and Djitèye, 1982; Breman and de Ridder, 1991). Fallow periods have become very short, and most agricultural production involves the cultivation of food crops that receive very little fertilizers. Only some cash crops and food grown near the homestead receive greater amounts. The gradual depletion of soil nutrients may continue imperceptibly, followed by a sudden dramatic fall in plant production when soil fertility or organic matter content has dropped below a minimum level.

By reducing run-off through stone rows, nutrient losses are also reduced, depending on whether the retained nutrients form part of pool A (comprising free nutrients), pool B (nutrients in organic matter) or pool C (nutrients in mineral reserve). In the last two cases nutrients only become available after the slow process of mineralization. In the first case (pool A) the response of yields to one kg added or retained (fertilizer) nutrient is equal to the product of yield uptake ratio and recovery fraction (Section 6.5). On poor soils in Burkina Faso the recovery fraction of N is about 0.25 kg/kg, but this might increase to 0.40 kg/kg, after implementing soil conservation measures (Centre for World Food Studies, 1985). With a grain/stover ratio for sorghum of 0.33 and minimum nutrient concentrations in grain and stover of 10 and 3 g N/kg respectively, the yield nutrient uptake ratio amounts to 53 (may increase through improved water availability). The increase in sorghum yield (dry grain weight) per kg N would then initially be 0.25 * 53 = 13 kg. Tables 9.15 and 9.16 show that the nutrient balance saldo for the 'with-case' shows a saving of 8 kg N (24 - 16). This saving would then contribute to a yield increase of 13 * 8 = 104 kg sorghum per year.

However, under conditions of 'soil mining', as often found in the Kaya case study area, it is more likely that the nitrogen in retained soil or sediment, only becomes available after mineralization, at a rate of about 2% per year (Pieri, 1989). The grain containing 1.5% nitrogen will benefit mostly. In this case the yield response (due to stone rows) is very low initially, but because of the continuous mineralization and continuing savings on soil loss, increases slowly over the years (de Graaff and Stroosnijder, 1995).

Table 9.15 *Nutrient (nitrogen) balance and crop yield development without stone rows*

```
Calculations with nutrient balances and response (N)  WITHOUT STONE ROWS
------------------------------------------------------------------------
Country : Burkina Faso   Farm type:  3  Rainfall:  628 mm   Slope:   2 %
Reg/site  Kaya                          Pattern:  Aver      Length  100m
------------------------------------------------------------------------
Top soil charact:      Crops 1     2          Erosion    I n p u t s :
Soiltype: S.loam       Sorghum    n.a.         12 t/ha FertN      Manu Compost
Fert.    1 class       Biom   5.3 Biom    0            Urea A/sul An.     Mix
pH      6.0            Pr/Re 0.3 Pr/Re    0              3        400     100
Depth   30 cm          Prod Resi Prod Resi              1.4      0 2.0     1.0
Bulkd 1.5        Q kg   500 1500
OrgM% 1.0        AvN%   1.5   0.4              Fert 0.05   (For Pool A:)
Ncont 5.0        MinN% 1.0   0.3               Enr    2.0 INE1 52.6  INE2   0
Min%  2.0                                                 Recov 0.25 Reco   0
TotN    45 kg    Leg       0                   Base   4.0 Yresp   13  Yres   0
------------------------------------------------------------------------
Mineralisation of N from organic matter (Pool B):                   Future
                       Nutrient balance:     - OUT  +  IN    =   Saldo prod
  Recov:   0.75 Oth.  Prod Resi Leac Gase Eros Fert Manu Depo Fixa
StockN(OM) Min biom.                                                  (kg)
Year 2250 45.0 20.0  7.7  6.0  4.0  6.4 12.0  1.4  3.0  3.5 4.0 -24
------------------------------------------------------------------------
   1 2226 44.5 20.0  7.3  6.0  4.0  6.5 12.0  1.4  3.0  3.5 4.0 -24 476
   2 2202 44.0 20.0  7.0  6.0  4.1  6.5 12.0  1.4  3.0  3.5 4.0 -24 453
   3 2178 43.6 20.0  6.6  6.0  4.1  6.6 12.0  1.4  3.0  3.5 4.0 -23 430
   4 2155 43.1 20.0  6.3  6.0  4.1  6.6 12.0  1.4  3.0  3.5 4.0 -23 407
   5 2132 42.6 20.0  5.9  6.0  4.2  6.6 12.0  1.4  3.0  3.5 4.0 -23 385
   6 2109 42.2 20.0  5.6  6.0  4.2  6.7 12.0  1.4  3.0  3.5 4.0 -23 362
   7 2086 41.7 20.0  5.2  6.0  4.2  6.7 12.0  1.4  3.0  3.5 4.0 -22 340
   8 2064 41.3 20.0  4.9  6.0  4.3  6.7 12.0  1.4  3.0  3.5 4.0 -22 319
   9 2042 40.8 20.0  4.6  6.0  4.3  6.8 12.0  1.4  3.0  3.5 4.0 -22 297
  10 2020 40.4 20.0  4.3  6.0  4.3  6.8 12.0  1.4  3.0  3.5 4.0 -21 276
  11 1999 40.0 20.0  3.9  6.0  4.4  6.8 12.0  1.4  3.0  3.5 4.0 -21 255
  12 1977 39.5 20.0  3.6  6.0  4.4  6.9 12.0  1.4  3.0  3.5 4.0 -21 234
  13 1956 39.1 20.0  3.3  6.0  4.4  6.9 12.0  1.4  3.0  3.5 4.0 -21 214
  14 1936 38.7 20.0  3.0  6.0  4.5  6.9 12.0  1.4  3.0  3.5 4.0 -20 194
  15 1915 38.3 20.0  2.7  6.0  4.5  6.9 12.0  1.4  3.0  3.5 4.0 -20 174
```

Table 9.16 *Nutrient (nitrogen) balance and crop yield development with stone rows*

```
Calculations with nutrient balances and response (N)    WITH STONE ROWS
--------------------------------------------------------------------------
Country : Burkina Faso   Farm type:  3  Rainfall:  628 mm    Slope:   2 %
Reg/site  Kaya                          Pattern:  Aver      Length  100m
--------------------------------------------------------------------------
Top soil charact:    Crops 1     2         Erosion     I n p u t s :
Soiltype: S.loam     Sorghum    n.a.        4 t/ha FertN       Manu Compost
Fert.    1 class     Biom   5.3 Biom     0         Urea A/sul An.      Mix
pH     6.0           Pr/Re 0.3  Pr/Re    0           3        400      100
Depth   30 cm        Prod Resi  Prod Resi           1.4     0 2.0      1.0
Bulkd 1.5       Q kg  500 1500
OrgM% 1.0       AvN%  1.5   0.4            Fert 0.05  (For Pool A:)
Ncont 5.0       MinN% 1.0   0.3            Enr    2.0 INE1 52.6  INE2  0
Min%  2.0                                             Recov 0.25 Reco  0
TotN   45 kg    Leg      0                 Base  4.0  Yresp  13  Yres  0
--------------------------------------------------------------------------
Mineralisation of N from organic matter (Pool B):                   Future
                   Nutrient balance:    - OUT  +  IN   =   Saldo   prod
```

Year	StockN (OM)	Min	Oth. biom.	Prod	Resi	Leac	Gase	Eros	Fert	Manu	Depo	Fixa	Saldo	Future prod (kg)
Recov: 0.75														
Year	2250	45.0	20.0	7.7	6.0	4.0	6.4	4.0	1.4	3.0	3.5	4.0	-16	
1	2234	44.7	20.0	7.5	6.0	4.0	6.5	4.0	1.4	3.0	3.5	4.0	-16	484
2	2218	44.4	20.0	7.2	6.0	4.1	6.5	4.0	1.4	3.0	3.5	4.0	-16	469
3	2202	44.0	20.0	7.0	6.0	4.1	6.5	4.0	1.4	3.0	3.5	4.0	-16	453
4	2186	43.7	20.0	6.7	6.0	4.1	6.5	4.0	1.4	3.0	3.5	4.0	-15	438
5	2171	43.4	20.0	6.5	6.0	4.1	6.6	4.0	1.4	3.0	3.5	4.0	-15	423
6	2155	43.1	20.0	6.3	6.0	4.1	6.6	4.0	1.4	3.0	3.5	4.0	-15	408
7	2140	42.8	20.0	6.1	6.0	4.2	6.6	4.0	1.4	3.0	3.5	4.0	-15	393
8	2125	42.5	20.0	5.8	6.0	4.2	6.6	4.0	1.4	3.0	3.5	4.0	-15	379
9	2111	42.2	20.0	5.6	6.0	4.2	6.7	4.0	1.4	3.0	3.5	4.0	-15	364
10	2096	41.9	20.0	5.4	6.0	4.2	6.7	4.0	1.4	3.0	3.5	4.0	-14	350
11	2082	41.6	20.0	5.2	6.0	4.3	6.7	4.0	1.4	3.0	3.5	4.0	-14	336
12	2067	41.3	20.0	5.0	6.0	4.3	6.7	4.0	1.4	3.0	3.5	4.0	-14	322
13	2053	41.1	20.0	4.7	6.0	4.3	6.7	4.0	1.4	3.0	3.5	4.0	-14	308
14	2039	40.8	20.0	4.5	6.0	4.3	6.8	4.0	1.4	3.0	3.5	4.0	-14	295
15	2026	40.5	20.0	4.3	6.0	4.3	6.8	4.0	1.4	3.0	3.5	4.0	-14	281

The 'spreadsheet' tables 9.15 and 9.16 provide nitrogen balances for the situation with and without stone rows. On the basis of these nitrogen balances and under the assumptions that nitrogen only becomes available after mineralization of soil organic matter and that of all biomass the grains are most affected by nitrogen deficiency, the crop yield development is calculated over 15 years (column on right hand side).

With the spreadsheet module nitrogen balances and crop yield development can also be calculated for the other four options: compost with and without stone rows, and inorganic fertilizers with and without stone rows. Table 9.17 shows the results of these calculations. Application of compost increases both freely available nutrients and the amount of organic matter from which nitrogen can be mineralized. Application of inorganic fertilizers only increases the nitrogen available in Pool A, where it is easily available to the plant.

Similar nutrient balances could also be drawn up for phosphorus and potassium, with their crop yield response, where these two macro nutrients would be the most limiting factor in crop production. The entire analysis could also be repeated for the Manga area.

Table 9.17 *Calculated nitrogen balances for area near Kaya (Burkina Faso) with and without stone rows, compost and fertilizers (applied at non-sustainable and sustainable levels)*

Options	Yield Year1 kg/ha	Inputs Fert kg/ha	Comp. t/ha	Nitrogen balance (kg N/ha) Fer +	Man +	Dep +	Fix +	Pro -	Res -	Lea -	Gas -	Ero -	Saldo	Yield Year15 kg/ha
A0 No rows	476	3	0.5	1	3	4	4	8	6	4	7	12	**- 24**	174
B0 With rows	484	3	0.5	1	3	4	4	8	6	4	7	4	**- 16**	281
A1 Compost only	614	3	5.0	1	27	4	4	10	7	11	13	12	**- 17**	406
Idem; sust.	630	3	13.3	1	69	4	4	10	7	23	26	12	**0**	629
B1 Compost,rows	736	3	5.0	1	27	4	4	11	8	11	13	4	**- 11**	600
Idem; sust.	747	3	10.5	1	54	4	4	11	8	19	21	4	**0**	745
A2 Fertil. only	796	140	0.5	64	5	4	4	12	9	23	25	12	**- 5**	733
Idem; sust.	800	167	0.5	77	5	4	4	12	9	26	29	12	**0**	800
B2 Fertil.,rows	943	100	0.5	46	5	4	4	15	11	17	19	4	**- 7**	851
Idem; sust.	950	140	0.5	64	5	4	4	15	11	22	25	4	**0**	950

Note: All options include input of 0.5 t/ha manure; compost without phosphate. Amounts of nitrogen are rounded off.

9.6 Evaluation of the selected soil conservation options

After impact assessment an economic evaluation can be undertaken, which in this case concerns the comparison between six different options, comprising combinations of erosion control and fertilizing components (A0-B2). Most attention is here given to the financial analysis of the stone row component (de Graaff, 1993a). Tables 9.15 and 9.16 show how much nitrogen is retained by stone rows, and what crop yield response can be expected from this amount of nitrogen. Table 9.18 provides a cash flow table over 15 years for the stone rows, constructed with stones transported by lorry from a nearby site.

Two cases are considered. When the retained sediment (still) includes nitrogen in Pool A the yield increase would at first be 104 kg/ha, and decline gradually to 78 kg/ha by year 15. In the second, more likely, case nitrogen only becomes available after mineralization, and would initially result in a yield response of only 8 kg/ha, but this would increase to about 107 kg/ha by year 15. In the first case, the internal rate of return is a mere 2%, and in the second case it is even negative. Table 9.16 illustrates that with stone rows alone the nitrogen balance remains negative. 'Soil mining' is continuing. How long some grain could still be harvested depends on the remaining organic matter content of the soil. The calculation confirms that one cannot expect 'sustainable land use' from implementing soil conservation measures, such as stone rows, alone. If the measures are to be efficient, they have to be accompanied by complementary measures that increase soil fertility, as indeed is advocated by development organisations in Sahelian countries.

The second case in the example shows that the effects of erosion control measures on productivity, through the reduction of nutrient losses, only appear in the long run. This is in contrast to the effects that result from water retention.

Table 9.19 gives the internal rates of return on investment in the alternative measures, under different conditions, based on crop yield response to changes in nutrient supply, shown in Table 9.17. The table confirms that stone rows alone without fertilizer use are not efficient, and that the use of compost or fertilizers without stone rows is only efficient at high levels of inputs (of which part is lost through erosion). From a public point of view the establishment of stone rows with donkey carts, combined with use of fertilizers would be the best option. As long as farmers do not pay for the costs of the lorry, the option with lorries

Table 9.18 *Cash flow table for the establishment of 1 ha stone rows, with productivity changes based on the nitrogen balance situation*

Costs and benefits	Year 0	1	2	3	4	15
Establishment costs (CFAF 1000)	64					
Labour for maintenance (CFAF 1000)		2	2	2	2	2
Amount of nitrogen retained (kg N)		*8*	*8*	*8*	7	*6*
- <u>If N readily available (from Pool A):</u>						
Yield response (kg/ha)		104	104	104	91	78
Value yield increases (CFAF 1000)	-	8	8	8	7	6
Cash flow 1 (CFAF 1000)	- 64	6	6	6	5	4
(IRR = 2 %)						
- <u>If N only available after gradual mineralization:</u>						
Yield without stone rows		476	453	430	407	174
Yield with stone rows		484	469	453	438	281
Yield response (kg/ha)		8	16	23	31	107
Value yield increases (CFAF 1000)	-	1	2	2	3	9
Cash flow 2 (CFAF 1000)	- 64	- 1	0	0	1	7
(IRR = negative)						

is more attractive to them than the option with ox-carts where they pay all costs. This is shown in the lower part of Table 9.19. When the use of lorries is free of charge, farmers have only to wait their turn, although some realise that their turn may never come.

By applying 10 ton of compost per ha a sustainable production level is reached. This is

Table 9.19 *Internal rates of return on investment (%) for the different options over 15 years, from public and farmer's point of view (on per ha basis)*

Conservation measures		Fertilization alternatives (0 - 2): 0	1			2			
Stone bunds (A/B)	**PUBLIC point of view**	**Not any** fertiliz.	**Compost pits** (contents in t)			**Fertiliz.** (Urea in kg) (CFAF 170)		(CFAF 255)	
	Amount:	0	5	10	13	100	140	100	140
A	No stone rows:	-	-	neg.	17	-	29	-	neg
B	Stone rows:								
	-lorry; site nearby	neg.	6	12		15	28	neg.	17
	-lorry; site far	neg.	neg.	1		1	8	neg.	3
	-cart; site nearby	0	9	16		23	41	neg.	24
	-cart; site far	neg.	neg.	5		5	15	neg.	7
		0	**1**			**2**			
	FARMER's point of view	**Not any** fertiliz.	**Compost pits** (contents in t)			**Fertiliz.** (Urea in kg) (CFAF 170)		(CFAF 255)	
	Amount:	0	5	10	13	100	140	100	140
A	No stone rows:	-	-	neg.	17	-	29	-	neg
B	Stone rows:								
	-lorry; site nearby	3	12	20		30	54	0	32
	-lorry; site far	neg.	3	10		12	25	0	14
	-cart; site nearby	0	9	16		23	41	neg.	24
	-cart; site far	neg.	neg.	5		5	15	neg.	7

more efficient than using 5 t only, but when combined with stone rows it is only attractive when stone collection sites are nearby. Whether farmers can indeed reach sustainable production with compost production, depends on the amount of material the household has available for composting. The studies in Yakin village showed that farmers produce on average only about 3.7 t compost per year.

Since farmers consume most of their food crops, cultivate few cash crops and tend to invest cash from non-farm and migration activities in livestock, housing, bicycles, 'mobylettes', radios, etc. (de Graaff, 1995), increasing fertilizer use to sustainable levels will be hard to achieve.

The right hand side of Table 9.19 indicates that a 50% increase of farm level fertilizer prices sharply reduces the efficiency of lower, non-sustainable fertilizer application levels, making composting relatively more interesting. In the recent past prices increased twice: in 1988 the fertilizer subsidies were abolished and in 1994 the exchange rate of the CFA was drastically devalued, from CFAF 50 to CFAF 100 for 1 French Franc. These policy measures have halted the slow rise of fertilizer consumption.

Although most grain production is consumed domestically, a sorghum price of CFAF 80 per kg is applied in the analysis. When lowered to CFAF 60 per kg, the IRR for investment in stone bunds decreases considerably, to at most 5% when combined with compost and 19% when combined with fertilizers (donkey carts and nearby collection sites).

Discussion

The analysis shows that farmers only reach sustainable land use with conservation measures, when they combine them with intensive fertilizer use. Fertilizers should preferably not be spread thinly over all plots. So far farmers have mainly concentrated on improving their house-plots and 'village' fields. Some have also established stone rows on 'bush fields' (*champs de brousse*). They have done this for different reasons including: much nearer stone collection sites; the only (non-degraded) fields they have, of their own or rented; to make a firmer claim on the land; to arrive at a large enough scheme of 10 ha for collective action, etc. A major constraint to intensifying land use in densely populated villages is the institutional structure of land tenure. Uncultivated land is normally loaned or assigned to those requesting it. This works well in sparsely populated areas, but at high population densities it hastens land degradation by pushing those currently cultivating land to postpone fallow from fear of being pressured into 'lending' it (Ramaswamy and Sanders, 1992). This situation was found in Yakin village, where farmers used more land than they were able to properly cultivate and weed, resulting in low yields (Loozekoot, 1994a).

The conventional wisdom of agricultural development in sub-Saharan Africa has been that the most critical constraint is seasonal labour shortage and that land is abundant (Sanders et al., 1990), hence the recommendation to put a premium on increasing labour rather than land productivity. However, since the fallow system of land rotation is breaking down, and depletion of soil, water and wood resources has become widespread, there is a need to break the vicious circle and to accelerate technological change towards more intensive cropping systems, at least in more densely populated areas. There would then be scope for less degradation (Tiffen et al., 1993). If the target group of households (with 8 members and 4 ha land) could increase average yields from 500 to 800 kg/ha (through stone rows and fertilizers), they would only need 2 ha for self-suffiency, and the other 2 ha could be used for sylvo-pastoral purposes, which would also increase the supply of animal and green manure.

For this intensification cash income (or access to credit) is a prerequisite. However, at present, the meagre income from cash crops, livestock, artisanal activities and migration is mostly used to buy food in the food deficit years (two out of three years) and to improve housing. More emphasis should probably be given to cash income generating activities, particularly in the more densely populated villages. The focus on collective activities on family fields with food crops may form a constraint to this.

9.7 Soil conservation and sustainable development activities in a semi-arid zone in central-west Tunisia (1969-1981); an ex post evaluation

Similarities

In this last section the evaluation of the measures promoted in Burkina Faso is compared with that of sustainable development activities in another semi-arid zone. This concerns the World Food Programme (WFP 482) supported development activities in Kasserine province in the central western part of Tunisia in the period 1969-1981.

This project area has much in common with the case study area in Burkina Faso as far as agro-ecological conditions are concerned: rainfall is low and unreliable; soils are rather poor with a low organic matter content; slopes are not steep but very long; forest has largely disappeared and vegetation cover is rapidly diminishing. Traditionally people have made their living from cereal growing and semi-nomadic livestock keeping. Both areas constitute relatively disadvantaged zones in their countries as far as climate and resources are concerned. Despite this the population density has been relatively high and migration and remittances from relatives abroad have become essential for survival. In both areas soil and water conservation measures were already undertaken traditionally, but they have received special attention since the 1960's. The first large scale top-down approaches failed, but since the 1980's measures have been better integrated into the agricultural systems and are now successfully implemented, as long as incentives are provided. Crop-livestock integration has been a crucial issue in the development plans of both areas.

Differences

There are however also distinct agro-ecological and socio-economic differences between the two areas, that have resulted in a different approach to and choice of SCWD activities.

In the Burkina Faso case study area annual rainfall in most years still exceeds 500 mm, which is usually sufficient for the staple food crops sorghum and millet. In central-west Tunisia average annual rainfall is only 300 mm (winter rain), and in many years less than 200 mm, and reasonable grain yields are only obtained once every three years. Therefore, one radical aim of the Tunisian project was to promote tree crops and fodder crops for livestock instead, also with a view to promoting permanent settlement and stabilizing income. Whereas in Burkina Faso line interventions (stone rows) are emphasized, in Tunisia a choice was made in the 1970's for land use conversion as the main answer to land degradation. In terms of the USLE equation, the focus was on the C-factor and not on the P-factor, as with stone rows in Burkina Faso. While transport facilities form an essential incentive for establishing stone rows, tree and fodder crops were promoted with food aid, credit and subsidies.

Since nutrients have become the most limiting factor in crop production in Burkina Faso, development activities focus on fertility maintenance. In Tunisia there is more emphasis on water conservation and the soil mining problem receives less attention. The more hilly terrain in central-west Tunisia faces a serious erosion hazard, but also offers opportunities for establishing dams and reservoirs to retain water. There are downstream interests and public dams are now built with the sole purpose of raising ground water levels.

Considering these differences, the Tunisian case study concentrates on methods of evaluating land use conversions and on ways of dealing with low and highly fluctuating rainfall levels. The differences in incentive structure are discussed in Chapter 11.

Central Tunisia agricultural development project in Kasserine province (1969-1981)

Following the recommendations of FAO, a joint Government of Tunisia/WFP/FAO project was initiated in 1968 to engage in large scale tree and fodder crop plantations and in soil conservation measures in the whole of Central and South Tunisia. This evaluation focuses only on the project activities in Kasserine Province. Appendix 9.1 provides details of the project and the project area. The project aims were to:

- stabilize and increase agricultural production;
- conserve land resources by reducing low input cereal production and overgrazing;
- encourage semi-nomadic farmers to settle more permanently.

The Tunisian Government provided large sums of (subsidized) credit, the World Food Programme (WFP) provided food rations and FAO provided technical assistance. In Kasserine province about 30,000 ha tree crops (mainly olives and almonds) and some 25,000 ha of fodder crops (mainly spineless cactus) were planted in the period 1969-1976. Except for the first few years not much attention was given to the establishment of earth bunds.

Evaluation criteria

The first two project objectives were directed to crop and livestock production and soil and water conservation. The third socio-political objective of settling the semi-nomadic population was based on interregional equity considerations. The main attributes of the economic efficiency criterion are the increased agricultural production and the direct costs. Attributes of the conservation criterion should relate to safeguarding the functions of the land resources. Because of a lack of data on soil nutrient status and organic matter content, and their changes under different land use, soil depletion as major form of land degradation cannot be analyzed. Loss of land as a result of sheet and gully erosion is therefore used as an attribute of the conservation criterion. In this case the effects on both the production and conservation criteria relate first of all to the two types of land use changes brought about by the project: the change from cereals to tree crops and the change from natural grassland to grassland with cactus. Before the impact assessment, attention is given to the overall land use changes over the period 1969-1981, based on an analysis by farm pattern. Subsequently the effects of the changes are analyzed in terms of production and conservation.

The effects on land use and on target groups

On the basis of statistical data from various sources (FAO, 1968; FAO, 1972; de Graaff, 1976; ITC, 1983; Ministère de l'Agriculture, 1991), changes in land use and livestock numbers were calculated over the period 1969 to 1981, and disaggregated over six typical farm patterns in the province (Tables A 9.3 and A 9.4 in Appendix). This analysis showed that the planting of 30,000 ha of tree crops (excluding 5,000 ha planted on own initiative) and 25,000 ha of fodder crops (not all successful) was done at the expense of the area under cereals (12,000 ha), fallow (19,000 ha), and farm operated natural grassland (18,000 ha). The area farmed also increased, at the expense of forest and natural (alfa) grass land.

The farm pattern analysis also showed that the project plantation activities were most successful among farm patterns D and E in the districts: Sbeitla, Foussana (cactus), Kasserine and Fériana. For many of these farms, representing 36% of the total, tree crops became the main enterprise, while the cactus reduced the pressure on pasture land.

Impact on production and income

Table 9.20 shows how the production of cereals and the main tree crops (olives and almonds) has developed over the years. Cereal production was low in the early 1980's because of successive dry years, but increased again in the early 1990's. Olive oil and almond production has increased considerably, and can be ascribed to a large extent to tree maintenance and new plantings by project WFP 482. Also important is the fact that the yield fluctuations (around an upward trend) of olive production over the years 1980-1992 have been less dramatic than those for cereals, as indicated by the coefficient of variation (C.V.).

Table 9.20 *Development of crop production in Kasserine province, Tunisia*

	Production (1000 t/yr)					
	1964/68	1980/84	1988/92	Period 1980-92		
Product	(5 year averages)			Average	St.Dev.	C.V.(%)
Cereals (wheat/barley)	68	39	69	60	47.7	80
Olive oil	2	7	14	10	5.5	55
Almonds	0	1	5	-	-	-

Sources: FAO, 1968; CRDA Kasserine, 1994 (pers. comm.).

On the less heavy soils in the central zone average cereal yields are only 300 kg/ha, against a provincial average of about 420 kg/ha. Average yields of mature olives trees were 40 kg per tree, and oil content was about 22%. Almond trees produced about 5 kg green almonds or 2 kg dried almonds. Table 9.21 shows that the production value for both cereals and tree crops hardly exceeded the annual costs. The tree crops provided more employment and the

Table 9.21 *Yields and margins per ha of cereals, olive oil, dried almonds and cactus (1981 prices; 1 Tunisian Dinar (DT) = US$ 2.04)*

		Cereals	Olives & Almond		Cactus
Yield	kg	300	220	140	600 UF
Production value	DT	30	22	35	18
Value by-products	DT	12	-	-	6
Material inputs	DT	10	5	7	2
Power inputs	DT	24	12		-
Labour inputs	DT	10	30		12
Net margin/ha	DT	- 2	3		10
Return per manday	DT	0.8	1.1		1.8
Productive period	years	2 out of 3	10-50	4-20	4-15
Annuity estab. costs (5%)	DT	-	11		8

Sources: Derived from: ITC, 1983; Polman, 1978.

annual net margin per ha was slightly higher, when establishment costs are ignored. Cactus was planted mostly on degraded pasture land, which without cactus produced at most 240 UF per ha (UF is unit of energy from fodder, equal to 1 kg barley). Cactus plantations raise feed production on pasture land threefold: 600 UF from the cactus and 120 UF from vegetation between the rows.

Effects on actors

In 1975 an agro-economic survey was undertaken of all members of two active service cooperatives in Sbeitla and Fériana districts. The average resource availability of these members is reflected in the farm patterns D and E. In 1994 a return visit was paid to a small sample of cooperative members (23 households), in order to assess the results of the planting activities (Oostermeijer and van der Kolk, 1994).

Table 9.22 shows land use changes for both the average farm household and for the sample of households. The households in the sample had abandoned cereal growing and now depended heavily on income from their tree crops (and their small flock of sheep). For the farmers in Sbeitla the income was still reasonable, but the plantations of many farmers in Fériana had been affected by successive droughts. Some of the latter farmers were fortunate in having a plot in the irrigation scheme, and neglected their rainfed tree crop plantations once the (generous) subsidies ended.

Table 9.22 *Changes in land use, income and employment at farm level*

Land use (in ha per farm) — Year:	Farm pattern D; Sbeitla 1972 Average	1994 Average	1994 Sample	Farm pattern E; Fériana 1972 Average	1994 Average	1994 Sample
Cereals	7.4	5.5	0.5	8.2	6.4	0.0
Horticulture (irrig.)	0.0	0.0	0.2	0.5	0.6	0.6
Tree crops	**1.8**	**3.8**	**9.4**	**3.0**	**6.3**	**15.3**
Fodder crops	**0.2**	**1.7**	**2.5**	**0.5**	**2.8**	**3.8**
Fallow	2.8	1.8	2.0	8.0	6.0	0.0
Nat. grassland	2.8	2.2	3.0	9.8	7.9	2.6
Total, of which	15.0	15.0	17.6	30.0	30.0	22.3
planted/maintained with project:		3.5	7.5		5.6	13.8
Costs and effects of WFP-482 plantations (DT):						
Value incentives 1st year (1972)		180	265		290	672
Value incentives year 2/3 (73/74)		48	99		78	191
Value incentives year 4/7 (75-78)		30	89		50	149
Additional income in 1994 (DT)			106			71
Addit. employment in 1994 (m/days)			66			54

Sources: de Graaff, 1975; Oostermeijer and van der Kolk, 1994.

Considering the value of the incentives (for labour and other inputs) as the investment costs and the additional income the farmers now derive from their plantations as the eventual benefits (from year 8 to year 25), the internal rate of return on the investments in the Sbeitla situation was still 4%, while it was negative in Fériana.

Impact on conservation

Effects on soil erosion

The change from cereals to tree crops such as olives, does not necessarily reduce soil erosion. Annual crop land is more or less bare for several months, but so is the land under (low density) tree crops when clean weeding is practised. In order to reduce erosion and conserve water, eyebrow terraces are a prerequisite for tree crops. Pasture land does not contribute much to erosion, unless it becomes bare. However, in Kasserine province most natural grassland is severely degraded and soil erosion is relatively high. Planting rows of spineless cactus along the contour lines reduces erosion considerably. Table 9.23 provides estimated rates for soil erosion for these land use categories, but it only includes sheet erosion, whereas gully erosion is also very serious. It is assumed here that eyebrow terraces and cactus rows have a similar effect on reducing gully erosion as on sheet erosion. Both forms of erosion in semi-arid zones are largely related to the intensity of a few 'rain storms'. The three years 1991 to 1993 all had about 300 - 350 mm rainfall in about 50 days, but in 1993 there were 5 and in 1991 only 2 days with more than 25 mm. Camus et al. (1994) showed that within the Tebaga micro-catchments, sediment transport varied from 0.2 to 5 t/ha/yr in years with similar total rainfall. To assess whether tree crops and cactuses reduce the variability of erosion and its consequences on yields, effects on the water balances have to be analyzed.

Table 9.23 *Erosion factors and erosion rates in Kasserine, for an average rainfall year and for different land use*

	USLE-factors						
Land use and conditions	**Erosi -vity** R	**Erodi- bility** K	**Slope length** L(m)	**Slope** S(%)	**Crop factor** C	**Manage -ment** P	**Sheet erosion** (t/ha)
Cereals	160	0.3	100	6	0.55	1.0	8
Tree crops (olives)	160	0.3	100	6	0.70	1.0	10
Id. with eyebrow terr.	160	0.3	50	6	0.70	0.5	4
Pasture, partly bare	160	0.3	100	6	0.2	1.0	3
Pasture with cactus	160	0.3	50	6	0.2	0.4	1

Sources: USLE software (Glaëtzer and Grierson, 1987); Voetberg, 1970.

Effects on the field level water balance

Table A 9.1 in the appendix shows that average annual rainfall is only 20% of potential evapotranspiration. Therefore rainfall strongly limits production and most rainfall contributes directly to actual evapotranspiration. However, rainfall fluctuates considerably and the rainfall intensity is at times very high. Making use of Gumbel probability calculations of rainfall over 66 years, Bouzaien and Lafforgue (1986) found the return periods for certain levels of rainfall. On the basis of these figures certain rainfall patterns can be distinguished over a period of 10 years (Table 9.24).

For the right part this table use is made of the spreadsheet water balance module, with a 10 day interval. The results show that under 'average' rainfall conditions (320 mm/year) yields are likely to be reduced by about 50% for wheat and 56% for olives due to water shortage. Looking at the different rain patterns over the years, together with probability, one obtains a better picture of effects on production and on downstream water flows. The table shows that yield reductions range from about 20-30% in wet years (when distribution remains

Table 9.24 *Annual rainfall according to probability, and the resulting run-off (mm), deep percolation (mm) and yield reductions (%) for wheat and olives (with eyebrow terraces)*

Annual rainfall (mm)	No of years	Wheat Run-off (mm)	Wheat Deep percol.	Wheat Yield reduc.	Olives Run-off (mm)	Olives Deep percol.	Olives Yield reduc.
160	1	29	0	85	19	0	78
220	2	49	0	67	33	1	71
300	4	88	0	53	71	0	60
400	2	137	0	44	108	0	54
600	1	282	39	24	226	22	35
Average rainfall year:							
320	1	104	4	54	81	2	60

Note: Average run-off rates for wheat and olives (with eyebrow terraces)

a problem) to over 80% annual rainfall when annual rainfall is only 160 mm.

On olive fields with eyebrow terraces infiltration will be higher than on wheat fields, the latter still being bare during the period of highest rainfall. In fact it is difficult to compare these water balances. Tree crops with their extensive rooting system have better access to water and can adapt their growing cycle more easily, including their biennial bearing system. Once in ten years there is sudden high rainfall in one or two months (e.g. in 1969), causing heavy floods, but also contributing to deep percolation, of importance for refilling groundwater for multiple use downstream. This is reflected in the 600 mm rainfall pattern.

As well as a regular sequence of these rainfall years over 30 years, a sensitivity analysis is carried out whereby the three decades begin with the driest, respectively wettest years (e.g 600 mm, 400 (2x), 300 (4x), 220 (2x) and 160 mm).

The evaluation

Of four possible rural development options (industrialisation, adapted cereal varieties, more conservation, no action at all) only the conservation option would have been realistic, but for several reasons was not considered seriously after the political changes in 1969. Due to this lack of real options, the activities of project WFP 482 are here evaluated using CBA, whereby the major effects for the 'with-' and 'without-case' are expressed in monetary terms.

The main issue in the evaluation of the WFP 482 activities in Kasserine province, is then, whether it was worthwhile spending about DT 5.8 million (US$ 12 million) on food aid, subsidies, partly unrecovered loans and operational expenses to help about 8,000 farm households to establish tree and fodder crops in order to settle them more permanently, to increase production and to reduce land degradation. The present value of the 'with-case' consists of the total gross margin of olives and almonds (30,000 ha) and cactus (21,000 ha) production. That of the 'without-case' consists of the gross margin of cereals (15,000 ha), fallow (15,000 ha) and natural grassland (21,000 ha). Table 9.25 shows that the NPV is negative for discount rates of 4% and higher. The internal rate of return is only 2.1%, and ranges from 1.2% to 2.7%, depending on whether the three decades (1970 - 2000) started with dry years or with wet years. If the food aid is not considered as a cost to the country (although it here represents labour inputs) the internal rate of return increases to 7.1% (ranging from 5.4% - 8.5%). The role of food aid will be discussed in Section 11.2.

The loss of productive land due to sheet and gully erosion is reduced from about 3,300 ha (6% of area concerned) to about 2,000 ha (3.9%), but still continues. In Appendix 10.3 some attention is paid to the downstream effects.

Table 9.25 *Costs and benefits of tree and fodder crop plantations, under different rainfall regimes (in million Tunisian Dinar (DT) of 1976; P.V. is Present Value)*

Discount rate	P.V. Benefits With case N	D	W	P.V. Benefits Without case N	D	W	P.V. Costs Food aid	Other costs	Total costs	Net Present Value N	D	W
10 %	3.9	4.0	3.8	2.6	2.3	3.0	1.6	1.9	3.5	-2.2	-1.8	-2.7
7 %	5.7	5.8	5.5	3.4	3.1	3.8	1.9	2.1	4.0	-1.8	-1.4	-2.3
4 %	8.5	8.6	8.2	4.7	4.5	5.1	2.2	2.4	4.6	-0.9	-0.5	-1.5
0 %	15.6	16.0	15.1	8.3	8.2	8.3	2.7	3.1	5.8	1.6	2.0	1.0

N=normal sequence of dry and wet years; D=dry years first; W=wet years first.

Discussion

Looking back at the original objectives of the project and the eventual results in terms of land use changes, one can conclude that tree crop plantations have not really pushed back cereal cultivation. This is understandable, since per capita wheat consumption in Tunisia rose from 175 kg in 1975 to no less than 238 kg in 1981 (Doolette, 1986). The tree crops have become an important resource for middle-sized farms, and have helped to settle this farm population more permanently. The spineless cactus plantations have contributed to a more stable feed balance, and this has fortunately not been accompanied by increasing livestock numbers. While the number of cattle and camels has fast decreased, the herds of sheep (and goats) have only slightly decreased. For the main target groups the results have been mixed: the financial results were still acceptable in the central zone, but in the drier southern zone the survival rate of trees and total production levels were low. The generous incentives received during the tree and fodder establishment period provided a fairly stable income to these farmers for several years, and this contributed to permanent settlement.

Apart from the reduced loss of land, the effects of the activities on land degradation are far from clear, and a lack of data on soil erosion and water and nutrient flows is felt.

In 1991 an evaluation was undertaken of soil and water conservation techniques used in Tunisia. The mission concluded that the techniques used on public (forest) land were appropriate, but that it was not yet possible to properly evaluate the measures on private farm land. The measures did not always seem well adapted to the local circumstances. Since not enough data were available for such an evaluation, the mission recommended that priority should be given to monitoring, on-field experiments and farming systems research and development (Fauck et al., 1991). The mission stressed the importance of the structures that are established for refilling of groundwater. However, no monitoring results are yet available to confirm this.

9.8 Comparison and lessons for project preparation and appraisal.

The low and strongly fluctuating rainfall in semi-arid zones lowers production potential and increases production uncertainty to such an extent that farmers do not venture to engage in land improvement, an activity for which they lack the means to embark upon. The main dilemma is to find activities that are attractive enough for the present farmers, and that lead to more sustainable land use for the benefit of future farmers. Since these regions often have very gentle slopes, on-site effects of land degradation deserve most attention, as in the Burkina Faso case. In areas such as central Tunisia, where slopes are steeper (less gentle) and rainfall is extremely variable, downstream effects, and in particular flooding, may play a role as well.

The assessment of on-site effects appears to be easier for physical soil conservation measures with unchanged land use than for measures involving land use changes, such as conversion from annual to perennial crops. In the latter case it is hard to assess the effects on water and nutrient balances (under the changed land use), crucial for evaluating conservation measures. In semi-arid zones long-term monitoring of the effects of conservation measures on soil losses and water and nutrient balances is important, and should be planned in project preparation. Considering the great variability in annual rainfall patterns in semi-arid zones, some form of probability analysis is required in project preparation studies, of which Section 9.7 gives an example. Even though nutrients are the most limiting factor in the Burkina Faso case study area, the efficiency of stone rows also varies under different annual rainfall patterns.

Although the research areas in the two countries have similar agro-ecological and socio-economic features, different strategies were followed towards sustainable agriculture. Macro-economic differences (e.g. income from oil and tourism) may have accounted for this. Exchanging views about their experiences with these strategies may be important for these countries. The international WOCAT (World Overview of Conservation Approaches and Technologies) initiative (Liniger and Hurni, 1995) and the Soil Conservation Expert System, being developed by Vlaanderen (1995), could be instrumental in this. The role of (multi-purpose) tree crops for cash income and erosion control, and the promotion of feed reserves for the increasing numbers of small ruminants, also deserve attention in Burkina Faso (where cactus rows are unknown), as do conservation techniques and structures to refill groundwater reservoirs. However, the latter activities need to be better monitored and evaluated. On the other hand it is surprising that in Tunisia relatively little emphasis is given to soil fertility problems, and that in the more hilly parts of central-south Tunisia little use has been made of stone rows. This may relate to the fact that the land use conversion led to more extensive forms of land use.

Stone rows appear to be very convenient measures since they can influence production both in the short run (through the water balance) and in the long run (by retaining nutrients and making fertilizer use more efficient). The first is of importance for the participation of farmers, and the latter is needed for more sustainable development.

In semi-arid zones there are usually very few options for agricultural development, and because of a multitude of constraints, complementarity of measures ('package approach') is important. This may lead to consensus about the main strategy and set of objectives to adopt. The role of multi-criteria analysis in project evaluation turns out to be important for the preliminary screening of technological choices, as shown for soil conservation measures in Box 9.1.

APPENDIX 9.1 Central Tunisia agricultural development project in Kasserine province (1969-1981); background information

Ecological and socio-economic setting

The 'Dorsale', a mountain range stretching from the northern part of Kasserine province to the peninsula of Cap Bon in the north east, divides Tunisia in two parts: the 'Tell' in the north with average annual rainfall between 400 - 1200 mm/year, and the 'Steppes' in the central part with rainfall below 400 mm per year (Figure A 9.1). The south forms part of the Sahara.

Kasserine province forms the most western part of central Tunisia, and has a quite rugged topography. Average annual rainfall is only about 330 mm, while potential evapotranspiration is higher than 1,500 mm per year (Table A 9.1). The soils, derived from marls and other sedimentary rocks, are rather poor with a low organic matter content, but rich in calcium. On the basis of soils, rainfall and vegetation three zones can be distinguished: the northern alluvial plains, still suitable for cereals; the central hilly zone, more suitable for tree crops; and the southern zone with low rainfall, sandy soils and large alfa grass (*Stipa spp.*) plains.

Table A 9.1 *Average precipitation and potential evapotranspiration in Kasserine, Tunisia, 1962 - 1982 (mm per month)*

	j	f	m	a	m	j	j	a	s	o	n	d	Total
Precipitation	17	23	34	28	33	26	13	21	44	51	16	26	332
Pot. evapotransp.	59	68	93	117	162	203	235	177	162	106	76	66	1,524

Source: Henia, 1993.

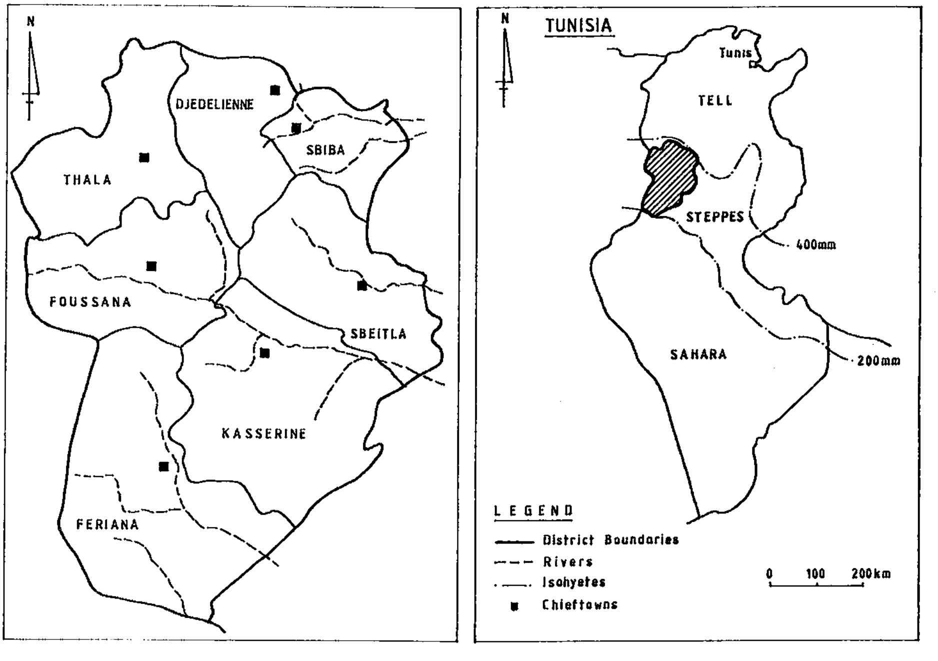


Figure A 9.1 *Map of Kasserine province in Tunisia*

Before Tunisia's independence Kasserine was mainly known as a region of nomadic sheep farmers, travelling from north to south and back. Gradually families settled and the area under cereals increased from about 50,000 ha in 1930 to three times this amount in 1966. However, most families could not live on the meagre agricultural earnings, and except for the paper factory (using alfa grass) non-agricultural employment was scarce. As a result many young people migrated seasonally to the coast or to Libya, while some left permanently for Europe. Nevertheless, the population increased in the period 1966-1981 by over 2% per year to 291,500 in 1981. The increasing population density, the decreasing fallow periods in grain production, the overgrazing and the occasional torrential rains led to an increase in soil erosion. Kasserine is the province with the highest degree of erosion (53% of the land) and no less than 19% of the land suffers from severe forms of erosion.

Soil and water conservation in Tunisia

Soil and water conservation practices were already undertaken in Tunisia before the Roman period. Herodotus tells of the Garamantes who reclaimed their eroded land, by bringing up soil from elsewhere. Within the Zeroud watershed, which more or less covers the whole of Kasserine province, many remains exist of dams, aqueducts, storage basins, stone terraces and bunds, etc., that were constructed in Roman times and after the Arab conquest to control and use the water resources (Hamza, 1991).

Since independence in 1956, the Tunisian Government has paid much attention to soil conservation, which is reflected in texts and decrees, that prescribe contour ploughing and tree planting and prohibit goat grazing in critical zones (FAO, 1959).

From 1962 onwards large scale conservation works were undertaken, mainly consisting of large earth bunds (*banquettes*). In the period up to 1975 these works were undertaken over an area of no less than 700,000 ha, at a total cost of about US$ 55 million (Schröder, 1976). But an inventory undertaken in 1976 showed that of all works undertaken in that period only 23% were still intact (Breuleux, 1976). Technicians raised doubts about the effectiveness of these measures under North African soil and climate conditions (Heusch, 1986), and farmers seldom respected the measures. Most of the works were undertaken by the Forest Department, which undertook the integral treatment of high priority zones or sub-watersheds. Farmers were not involved in planning and often not even in the actual implementation. Only few conservation works were undertaken in the period 1971-1985, probably due to these bad results and in the aftermath of the period of collective farming. In 1977-1980 only about 5% of investment in agriculture went to forestry and conservation, compared to about 24% in the period 1962-1971 (Cleaver, 1982). From 1984 onwards a new attempt was made, whereby more attention was paid to integrate the measures in the farming systems.

Another major change in this new conservation approach was the high emphasis given by the Government to water conservation. Many small multi-purpose lakes (*lacs collinaires*) were created, and large checkdams were established to reduce water losses and to restore the groundwater reserves. In some areas such dams have increased groundwater levels locally by several metres.

Government objectives and policies at the start of the project

In 1965 the Tunisian agricultural sector accounted for 30% of Gross National Product (GNP), 60% of exports and 70% of employment in the country. About half of the people that depended on agriculture were then living in central-southern Tunisia, where hardly any other natural resources and employment opportunities existed. The Government at that time paid much attention to rural infrastructural development in these areas, building roads and schools, establishing irrigation schemes and implementing large scale conservation measures, etc. Land was brought under collective ownership and was to be developed by production cooperatives. These centralistic activities and policies came to a sudden end in 1969 when farmers protested against the collectivisation.

Central Tunisia agricultural development project (FAO/TUN/525-WFP/482)
After detailed land evaluation studies, the FAO Central Tunisia Integrated rural planning project in 1968 recommended the large scale planting of tree and fodder crop species, improved at the Ousseltia and Ouled M'hamed research stations. The aims were to:
- stabilize and increase agricultural production;
- conserve land resources by reducing low input cereal production and overgrazing;
- encourage semi-nomadic farmers to settle more permanently.

The execution of this plan was undertaken jointly by the Tunisian Government, providing large sums of (subsidized) credit, the World Food Programme (WFP 482) providing food rations, and FAO providing technical assistance. The project had offices and staff (370 in total) in all provinces and districts in Central and South Tunisia and a head office in Tunis.

The main components of the project were the establishment and maintenance of tree crop plantations (olives, almonds and pistachios), fodder plantations (*Acacia spp.* and spineless cactus or *Opuntia ficus-indica*) and soil conservation measures (earth bunds). The plan specified for each component and variant the labour inputs and the corresponding amount of food rations and credit. The work was to be undertaken through the production cooperatives, but in 1969, soon after the start of the project, work was to continue with individual farmers. Because of insecurity of land titles, food rations and credit were then distributed through so-called 'service cooperatives', and not much attention was paid to conservation works.

The project lasted from 1969-1978, but most of the plantations were established in the period up to 1976. In Kasserine province this involved more than 100,000 ha. Table A 9.2 shows the total area planted and the total project costs.

Table A 9.2 *Tree crop and fodder plantations by project WFP 482 from 1969-1976 (ha)*

Project activities	Whole project area (Central South Tunisia)	Kasserine Province
New tree crop plantations	98,000 ha	30,000 ha
Maintaining existing tree crop pl.	110,350 ha/yr	27,000 ha/yr
Cactus plantations	90,500 ha	25,000 ha
Total food rations distributed [1]	36.0 million	8.0 million
Total amount of credit (DT)	14.3 million	3.1 million
Total operational costs (DT)	3.8 million	0.7 million

1) One ration per manday, valued at DT 0.340 each:
Source: WFP, 1978; DT (Tunisian Dinar) 1 = US$ 2.30 in 1978.

Major project components
The first land use change concerned the planting of olives (25 per ha) on relatively light soils that had previously been used for wheat and barley in rotation with fallow. Because of the bleak prospects for the olive oil market, intercropping with almonds (75 per ha) was promoted, and generally applied. This required the digging of hundred 1m^3 planting pits per ha, and demanded a total of about 140 mandays per ha. Total costs of planting material, manure etc. were about DT 40/ha. For this work farmers received 146 food rations (at DT 0.34), DT 61 credit and DT 41 subsidies over a seven year period. The credit was to be repaid in the period from years 14 to 20, and the interest on the loan was only 3%.

The second land use change concerned the planting of perennial fodder crops to cover feed shortages in long dry seasons and in extremely dry years. This was considered to be the first step in settling the nomadic population. Apart from some plantings of *Acacia spp.* and *Atriplex* most emphasis was given to the spineless cactus (*Opuntia ficus-indica*). This cactus has its gene centre in the

Americas and was brought to North Africa via Spain (Enserink, 1978). The plant can yield about 7 tonnes of 'disks' per ha per year after about 3-4 years. These parts should be cut and not 'grazed'. The cactus constitutes a good soil and water conservation measure, when planted along the contour, and is beneficial in soil formation. Its third function is the production of fruit. The establishment required 60 mandays (2,000 plants per ha) and about DT 11 per ha for planting material, manure, etc. For its establishment farmers received 55 food rations (at DT 0.34), DT 22 credit and DT 14 subsidies over a three year period. The credit was to be repaid from the 6th to the 11th year, and the interest on the loan was 4% (Dechelotte and Romano, 1975).

Alternative development options

One can ask what other alternative activities could have been undertaken to achieve these production, settlement and conservation objectives. Further industrialisation in the province would have had little prospect, due to its location and the lack of natural resources (apart from the alfa grass). Further strengthening cereal production, by introducing adapted varieties and/or other cereals (e.g. sorghum), would also have been an unlikely option, and if the Government had not interfered at all, there would have been over-exploitation and rapid degradation of the land and a much higher rate of out-migration.

A fourth alternative could have been to pay much more attention to reforestation and conservation for on-site and downstream purposes, while integrating SCWD activities in the farming systems. Such a new soil conservation strategy has in fact been undertaken since 1984, when a separate Department for Soil Conservation was created. The earth bunds have since then been planted with trees and shrubs (*Acacia spp.* and cactus) and the needs of the farmers have been taken into consideration. However, these conservation measures were also accompanied with a conversion from cereals to tree crops and represented a variation rather than a real alternative. Besides these measures were hard to implement in the period just after the political changes of 1969.

On the basis of statistical data from various sources (FAO, 1968; FAO, 1972; de Graaff, 1976; ITC, 1983; Ministère de l'Agriculture, 1991), changes in land use and livestock numbers were calculated for the period 1969 to 1981, and disaggregated over six typical farm patterns in the

Table A 9.3 *Resources and land use in Kasserine province in 1969, by farm pattern*

	Farm patterns						
	A	B	C	D[1)]	E[1)]	F	Total[2)]
No farms (x 1,000)	6	5	5	5	5	2	28
Perc. of total	21	18	18	18	18	7	100
Resources							
farm land (ha)	3	7	10	15	30	60	16
cattle/camels	-	-	1	1	1	5	25,000
sheep/goats	-	5	40	10	25	90	580,000
Land utilization (ha)							
cereals	1.5	3.5	2.0	7.4	8.2	20.0	155,000
horticult. (irr.)	-	-	0.3	-	0.5	-	4,000
tree crops	-	0.3	0.2	1.8	3.0	0.3	27,000
fodder crops	-	-	0.1	0.2	0.5	-	4,000
fallow	1.5	2.5	2.0	2.8	8.0	19.7	125,000
nat. grassland	-	0.7	5.4	2.8	9.8	20.0	133,000
Total farm land	3.0	7.0	10.0	15.0	30.0	60.0	448,000
Forest, alfa, etc.	-	-	-	-	-	-	380,000
Fodder situation							
demand (1,000 UF)	-	1.5	8.1	3.3	5.7	20.1	133.2
supply (1,000 UF)	0.5	1.2	2.2	2.5	5.9	12.1	86.7

Table A 9.4 *Resources and land use in Kasserine province in 1981, by farm pattern*

	Farm patterns						
	A	B	C	D[1)]	E[1)]	F	Total[2)]
No farms (x 1,000)	7	6	5	5	5	2	30
Perc. of total	23	20	17	17	17	6	100
Resources							
farm land (ha)	3	7	10	15	30	60	15
cattle/camels	-	-	0.9	0.7	0.6	4	19,000
sheep/goats	-	4	30	6	15	60	399,000
Land utilization (ha)							
cereals	1.5	3.0	2.2	5.5	6.4	22.0	143,000
horticult. (irr.)	-	-	0.6[3)]	-	0.6	-	6,000
tree crops	-	**1.5**	0.4	**3.8**	**6.3**	0.3	62,000
fodder crops	-	**0.4**	0.1	**1.7**	**2.8**	-	25,000
fallow	1.5	1.8	1.7	1.8	6.0	18.7	106,000
nat. grassland	-	0.3	5.0	2.2	7.9	19.0	115,000
Total farm land	3.0	7.0	10.0	15.0	30.0	60.0	457,000
Forest, alfa, etc.							371,000
Fodder situation[3)]							
demand (1,000 UF)	-	1.3	6.4	2.4	4.4	14.3	102.4
supply (1,000 UF)	0.5	1.2	2.4	3.0	6.6	11.8	93.3

1) Based on surveys undertaken in 1976 in Sbeitla and Fériana.
2) Farm land, under resources, shows here average farm size.
3) Increasingly fodder crops grown in irrigation schemes.

province (Tables A 9.3 and A 9.4). The right hand columns in these tables show that the planting of 30,000 ha of tree crops (excluding 5,000 ha planted on own initiative) and 25,000 ha of fodder crops (not all successful) was at the expense of the area under cereals (12,000 ha), fallow (19,000 ha), and farm operated natural grassland (18,000 ha). The total area farmed increased slightly, at the expense of forest and natural grass land (including alfa grass). The herds of cattle and camels decreased considerably and by 1991 had almost disappeared. The number of sheep dropped from an estimated 520,000 in 1969 to only about 350,000 in the 1980's, but increased again to about 460,000 in 1991. The number of goats probably remained around 60,000.

Although the programme was in principle oriented towards all farmers, except the very large and very small ones, with hindsight it was noticeable that the objectives were less relevant for farm pattern C (settled through irrigation scheme, as in Sbiba district, now well-known for apple production) and farm pattern F (large farms in zones where cereal production is still profitable, as in Thala district). Small farms (farm patterns A and B) would be more reluctant to give up cereals, and could not earn a living from tree crops. It is not surprising, therefore, that the project plantation activities have been most successful among farm patterns D and E in the districts Sbeitla, Foussana (cactus), Kasserine and Fériana. For many of these farms, representing 36% of the total, tree crops became the main enterprise, while the cactus reduced the pressure on the pasture land.

Downstream effects of soil and water conservation

In this chapter little attention has been paid to downstream benefits of soil and water conservation, although they cannot be entirely ignored in the Tunisian situation.

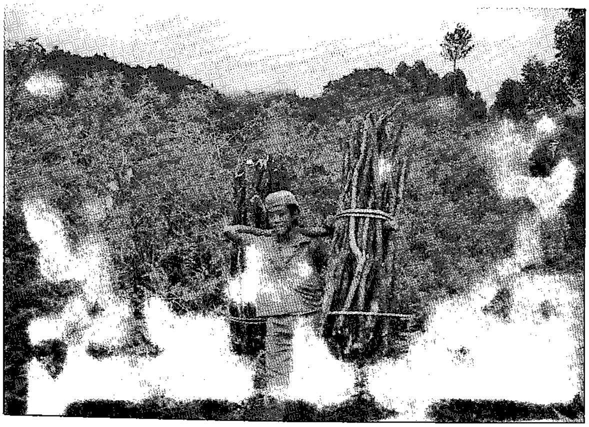
Until around 1980 all excess water flowed through the Zeroud river and its tributaries to the salt lakes east of Kairouan province. In average years the downstream benefits of retaining water on the land and regulating the streamflow therefore consist mostly of a reduction in damage from streambank erosion. In one out of ten years annual rainfall is twice as high as average (Table 9.24) and leads to considerable flood damage downstream, as happened in 1969 around Kairouan. In the early 1980's the Sidi Saad reservoir was completed, which greatly enhanced the importance of upstream soil and water conservation.

The lower run-off under olives (Table 9.24) is of particular importance in wet years, when it can have mitigating effects on the floods. The average annual streamflow of the Zeroud river over the period 1951-1977 was about 77 million m^3 near Sidi Saad. With the construction of the reservoir about 8 million m^3 was earmarked for drinking water and another 36 million m^3 for the irrigation of about 4,500 ha (Thio, 1979). Table A 9.5 shows how tremendously the streamflow can increase after heavy rains. High rainfall in the year 1969/70 alone more than doubled the average annual streamflow over a 27 year period. In Chapter 10 attention is paid to the assessment of downstream benefits.

Table A 9.5 *Monthly streamflow of Zeroud river at Sidi Saad (1951-77), in million m3*

Period	Month												Total
	j	f	m	a	m	j	j	a	s	o	n	d	
Average 27 yrs	1.0	2.6	4.9	2.7	3.5	7.2	2.4	6.1	65.6	74.0	4.6	6.4	181.0
Year 1969/70	0	0	0	0	2.2	0	0	0	1206	1426	0	0	2,634.2
Average 26 yrs	1.0	2.7	5.1	2.8	3.6	7.5	2.5	6.3	21.7	22.0	4.8	6.7	86.7

Source: Derived from: Bouzaien and Lafforgue, 1986.



LAND USE IN KONTO RIVER WATERSHED, INDONESIA

Plate 6 *Degraded natural forest*

Plate 7 *Two reforestation systems*

Plate 8 *Terraced rainfed land*

10 WATERSHED DEVELOPMENT IN SUB-HUMID MOUNTAINOUS ZONES

Setiap pemerintah harus mendekati kemauan rakyat (Every government has to respect the will of the people) Moh. Husni Thamrin, 1894 - 1941.

Introduction

This case study deals with the evaluation of watershed development project activities in sub-humid mountainous zones. Such projects are aimed at the two, often conflicting, objectives of increasing production and reducing the harmful effects of erosion. Emphasis is given here to the quantification and valuation of downstream effects of SCWD activities. The Indonesian case study concerns the third or implementation phase of the Konto River Project (1986-1990). The focus is on land use conversion measures to increase forest and agricultural productivity and to reduce sedimentation and streamflow fluctuations in the river system feeding a reservoir for downstream irrigation and electricity. For the ex post evaluation of the land use conversion use is made of both CBA and MCA. In the last section a comparison is made with watershed development under similar agro-ecological conditions in Jamaica. From the ex post analysis of these two cases recommendations are derived for the preparation and appraisal of such projects.

10.1 The setting of the Konto River watershed in Indonesia

Ecological conditions

The 279 km^2 Kali Konto or Konto River Project area is situated in the Malang district of East Java. The Konto river is a tributary to the Brantas river, which drains a large part of East Java. Four mountain systems of volcanic origin shape the project area into a landscape which can be characterized as an upland plateau surrounded by steeply sloping mountains (Nibbering, 1986). The altitude ranges from 620 to 2,868 m above sea level.

Two thirds of the area is state forest land, while the remainder consists of 'village lands', containing 23 villages and all agricultural land. Administratively the project area comprises the two sub-districts Ngantang, with village lands at an altitude from 620 to 900 m, and Pujon, where village lands are at about 900 - 1250 m altitude. The boundaries of the two sub-districts coincide to a large extent with the Konto River upper watershed area (235 km^2). On the lowest, western side of the area, a multi-purpose storage lake of 260 ha was formed after the construction of the Selorejo dam in 1970. Not far from the present site, dams and hydraulic works have been established, destroyed and restored since 804 A.D. The fact that several dams have been washed away indicates how turbulent the river has been at times after peak rainfall (Setten van der Meer, 1979).

The climatological features of the project area are those of a highland area in the equatorial zone with a distinct dry season. The average annual rainfall is about 2,400 mm (Table 10.1), but rainfall and temperatures are far from uniform throughout the project area, due to large topographical variations. The upper watershed comprises three river systems, draining into the Selorejo reservoir: the upper Konto River, originating in Pujon, and the Pinjal and Kwayangan tributaries in Ngantang sub-district (Figure 10.1). The hydrological conditions in the watershed still compare favourably with conditions elsewhere on Java.

Table 10.1 *Mean monthly rainfall (1950-1982) and potential evapotranspiration in the Upper Konto River Watershed*

District	Altitude	J	F	M	A	M	J	J	A	S	O	N	D	Total
Precipitation (in mm)														
Pujon	1150 m	393	355	311	156	115	49	51	32	42	115	218	308	2,145
Ngantang	630 m	500	413	393	212	158	52	51	34	39	153	195	360	2,560
Potential evapotranspiration (in mm)														
Pujon	1150 m	82	87	88	96	74	78	87	89	116	111	108	112	1,128
Ngantang	630 m	98	104	105	114	88	93	104	107	139	133	129	134	1,348

Source: KRP, 1984a.

The ratio between the water discharge during the rainy season and that in the dry season (Qmax/Qmin) is still small, because of the forest cover and the dominant soil types. The main geomorphological landscape types in the area are the volcanic mountainous complexes (20%), the hilly areas (50%), the intervolcanic plains and plateaux (25%) and the alluvial and lahar valleys (5%). The soils in the project area consist generally of andosols and cambisols: volcanic ashes and their weathered products which have formed thick layers of fertile soils. The combination of steep slopes, fine-textured soils and high rainfall (intensities) makes the area susceptible to erosion, when the closed vegetation is removed and the land cultivated. The high permeability of the young volcanic soils has a neutralizing effect.

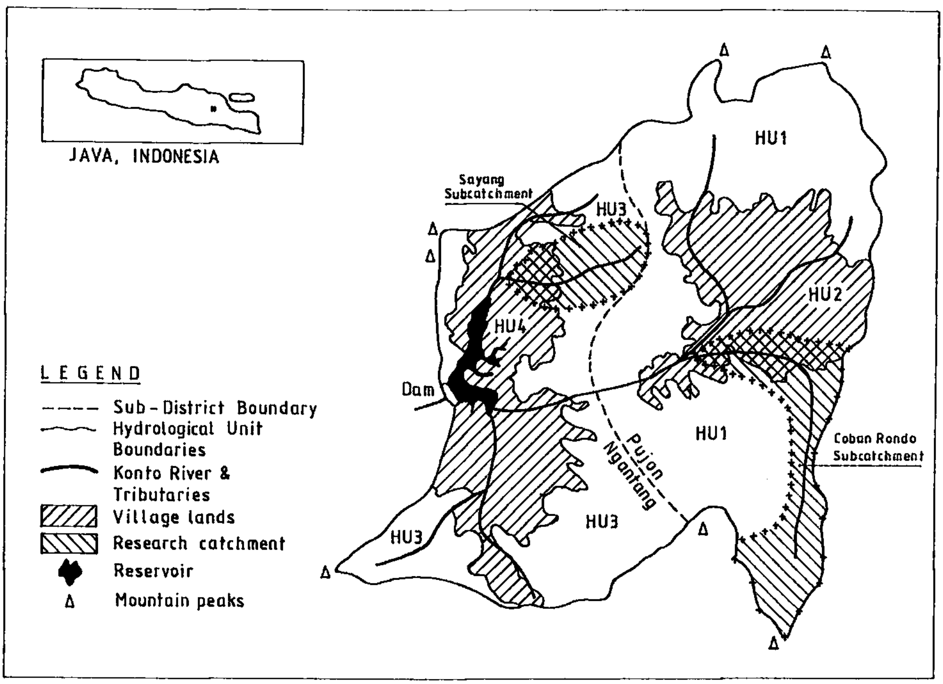


Figure 10.1 *Upper Konto River watershed with sub-districts and hydrological units*

Socio-economic conditions

Indonesia and the island of Java in particular are characterised by a very high population density and a diversified economy, in which agriculture still plays a major role.

In the project area with its total population of about 100,000 in 1990, most people depend for their living on agriculture. The population in Pujon district has grown steadily, because of the increasing employment in vegetable growing and dairying. Population growth in Ngantang has been less consistent. The construction of the Selorejo dam at the end of the 1960's attracted labourers, but since 1970 out-migration has occurred. Population density in the whole area is not that high, but when the state forest land is left out, it is very high: 34 % more than the densely populated province of East Java as a whole (Table 10.2).

The increasing emphasis on vegetables and milk production in Pujon and coffee in Ngantang has boosted trade in the area, particularly in centrally located villages along the main road. Because of the labour-intensive character of these activities, there appeared to be little scope for expanding small-scale industrial activities (van Dijk, 1987).

Table 10.2 *Population statistics for Upper Konto River Watershed*

Area	Total population		Pop. growth (%)		Population density/km²	
	1980	1990	1971/80	1980/90	Total area	Village land
Pujon	44,296	52,625	1.9	1.7	429	1,442
Ngantang	46,952	48,778	0.4	0.4	312	1,016
Total area	91,248	101,403	1.1	1.0	366	1,202
East Java	29 mill.	33 mill.	1.5	1.3	701	922

Source: Kantor Statistik Malang, 1993.

Human influence on ecological systems in the area

Although the large area still under forest cover made it a relatively privileged area compared with other parts of Java, there were signs in 1979 that the situation in the Upper Konto River watershed area was changing rapidly. The Project Inception Report (KRP, 1982) mentioned:

- a rapid decrease of the natural forest area, with shrub taking over;
- a large gap between annual firewood and timber requirements and annual wood regrowth, that hardly amounted to half of these requirements;
- a high and increasing demand for fodder, creating a mounting pressure on forest land.

Table 10.3 shows the differences in vegetation cover between 1895 and 1980. These changes mainly concern the degradation of the montane rain forest and some reforestation in recent

Table 10.3 *Changes in forest cover in Upper Konto watershed between 1895-1980 (ha)*

Forest land	1895	1935	1980
Natural forest	10,700	9,257	3,175
Degraded forest	2,560	4,968	2,940
Grassland (alang-alang)	180	832	-
Shrub (*Chromolaena*)	-	-	6,860
Government coffee gardens	2,000	-	-
Forest plantations	-	383	2,465
Total	15,440 [1)]	15,440	15,440

1) Historical area data converted to present forest area in watershed.
Sources: Nibbering, 1988; Smiet, 1989.

years. The abandoned coffee estates have gradually turned into grass- and shrub- land. Since 1935 the national forest has degraded rapidly, and nowadays more than half of the forest land consists of *Chromolaena* shrub. This forest degradation is clearly related to the increasing demand for firewood and fodder. In Pujon the increasing dairy herd has stimulated the planting of fodder (e.g. Elephant grass) on the village land (where it contributes to erosion control), but a large amount of fodder is still fetched from the forest.

The deforestation, the increasing cultivation on non- or badly terraced rainfed land and the expansion of settlements, are all believed to have contributed to soil erosion and to the accelerated sedimentation in the Selorejo reservoir. During the second phase of the project soil erosion was, on the basis of the USLE formula, estimated at about 1.2 mm per year for the whole catchment. Or about 3 mm per year for the village land and less than 1 mm/year for the forest land (KRP, 1985). The main sources of erosion were assumed to be the rainfed annual crop fields (with 55 % of total erosion) followed by the built-up areas (Table 10.4). As a result the Selorejo reservoir has a high sediment yield, which threatens to reduce its economic life by some ten years as compared with the lifetime assumed in the feasibility study (Nippon Koei, 1962; Fish, 1983).

Table 10.4 *Land use and sediment yield of Upper Konto River watershed (1985)*

Land use	Area (ha)	Share of area (%)	Share (%) in sedimentation
Forest land	15,440	66	9
Rainfed agric. land	4,300	18	55
Irrigated agric. land	2,000	9	6
Residential areas, roads, paths, etc.	1,500	6	30
Selorejo lake	260	1	-
Total	23,500	100	100

Source: Adapted from KRP (1985) and Murdiono and Beerens (1991).

National economic situation and agricultural sector policies and programmes

In Indonesia about 50% of the economically active population is still employed in agriculture. But because of the oil production and increasing industrialisation the importance of the agricultural sector declines in relative terms. In absolute terms agricultural employment and income still increase by about 2 and 3% per year, respectively (World Bank, 1992).

Table 10.5 *Changing composition of exports over the period 1985-1992 (in million US$)*

Selected commodities by sector	Average annual export value (million US $) 1985-86	1990-92	Share of exports (%) 1985-86	1990-92
Agriculture	1,607	1,791	10	7
Coffee	684	271	4	1
Manufacturing	4,036	12,446	25	52
Timber/processed timber	1,295	3,181	8	13
Mining (largely oil)	10,426	9,660	65	41
Total exports	16,069	23,897	100	100

Source: Hobohm, 1987; MacIntyre and Sjahrir, 1993.

During the period 1985 - 1993, considered in this evaluation study, important changes took place in the Indonesian economy. In 1986 the prices of oil and gas on the world market dropped and the share of oil in the value of exports declined from about two thirds to just over one third in the period 1990-1992 (Table 10.5). In the second half of 1986 the Rupiah devaluated from Rp 1,134 to Rp 1,644 to the US$. This helped to boost exports, particularly non-traditional exports. The garment industry showed the highest increase in exports. Timber was increasingly exported in processed form. Most agricultural based exports remained stable. Coffee exports, however, were affected by low world prices and low-quality discounts, and dropped from 11% of non-oil exports in 1985-86 to 2% in 1990-92.

Government objectives in agriculture

In the 1970's and 1980's one of the major national objectives was to attain self-sufficiency in *rice*. The goal was achieved in the early 1980's through mass extension campaigns and financial incentives (e.g. input subsidies and guaranteed paddy prices). Since then some more emphasis has been given to *secondary food crops* (e.g. maize, soybeans and cassava), the bulk of which is grown on rainfed land, vulnerable to erosion. Because of their agro-ecological conditions, some volcanic highland areas (above 1,000 m) have supplied the bulk of horticultural crops since the early 19th century. This concerns in particular the *vegetables* of temperate climates that have now become ingredients in indigenous cooking (Palthe, 1989). Pujon district is one of these areas. Apart from some restrictions on import, there is little government influence in this sub-sector.

These same highland areas are also famous for *dairy* production. In the period 1969-1988 milk output increased ninefold from 33 to 298 million litres (Remenyi, 1986). Since 1979 the Government has taken several measures to expand dairy farming: an import quota scheme, aimed at increasing self-sufficiency in dairy products; minimum farmgate prices above import parity; importation of Friesian cows for smallholders; artificial insemination services and public investment in bulk milk collection, cooling, etc.

Because of climatic suitability and relative cheap labour, Indonesia has always had an important world market share for crops including rubber, oil palm, *coffee* and spice trees. These tree crops are increasingly grown by smallholders. To increase export earnings of coffee, the Government pursued the following lines of action in 1987 (Subiapradja, 1987):

- rejuvenation of low-yielding plantations, or replanting them;
- more emphasis on the reintroduction of Arabica coffee in highland areas;
- quality improvement, through better cultivation, processing and marketing methods;
- attempted increase in its export quota under the International Coffee Agreement (ICA).

Government objectives in forestry, soil conservation and watershed management

The main objectives of the Long-term *Forestry* Plan were (Department of Forestry, 1985):

- to phase out log exports by the end of 1985 and to increase the export of processed products;
- to increase the supply of timber in Java, by rehabilitating the island's forests and importing logs from the outer islands;
- to conserve forests, while at the same time pursuing a long-term forestry strategy to meet growing domestic and export demand; and
- to manage forest lands in a way that yields maximum benefits to the people of Indonesia.

In the Fifth Five Year development plan emphasis was also laid on the development of social forestry and on integrated watershed management, while adopting appropriate soil conservation measures (Department of Forestry, 1989).

Since independence the Indonesian Government has paid much attention to the construction of dams and reservoirs for irrigation development and hydroelectricity, and for the safeguarding of this infrastructure much emphasis is laid on the protection function of the highland forests in Java. As a general rule at least 25% of upland watersheds is supposed to remain under forest cover. The State Forestry Corporation, responsible for forest management in Java, is therefore undertaking an extensive reforestation programme. Their two major approaches concern the reforestation of very steep land (slopes of over 40%) with paid labour (referred to as *cemplongan*) and the reforestation of less steep land by villagers, who in return are entitled to intercrop the forested land for a two year period (*tumpangsari*).

The need for *soil conservation* on rainfed land in Java was already noted at the end of the 19th century and in the 1930's farmers were stimulated to apply conservation measures. Since the city of Solo in Central Java was seriously flooded in 1966, the Indonesian government has focused attention again on the need for soil and water conservation (de Graaff and Wiersum, 1992). Since that time various major donor-assisted watershed management projects have been undertaken (e.g. Solo and Citanduy projects), and special INPRES (national development) funds became available for soil conservation programmes at district level. Through these funds two major activities are financed: establishment of 10 ha demonstration areas (so-called *demplots*) for soil conservation also supposed to affect land of neighbouring farmers, and the construction of checkdams or gully plugs to reduce sedimentation.

While in total seven different ministries are involved in watershed management in Indonesia, the Ministry of Forestry has been vested with overall coordination of these activities. The major objectives of watershed management in Indonesia are: improving hydrological conditions, controlling soil erosion, increasing land productivity and farm income and improving people's attitude towards natural resource management. The four main activities are: management of the vegetation (e.g. forest), management of the land, management of the water resources and community development (Sukartiko, 1987).

10.2 The actual implementation by the Konto River Project (1986-1990)

The pre-implementation situation

In 1979 the Indonesian-Dutch Konto River Project was requested to draw up a masterplan for forestry and agro-forestry for the area, in such a way that a proper balance would be achieved and could be maintained between the functions of the forest and the needs of the population (KRP, 1982).

After an inventory phase (1979-1983) and a planning phase (1984-1985) the implementation of various watershed development activities was undertaken during the third phase of the Project (1986-1990). In the first phase much emphasis was laid on finding appropriate reforestation options, that would generate sufficient commercial wood while satisfying the local (fire)wood and fodder needs. Several trials were undertaken.

At the start of the second phase the objectives were broadened and the project became a pilot project for the planning and management of densely populated watersheds in Java. A land evaluation was carried out for both the forest and the village lands. For the forest land four alternative development options were considered, focusing on 'protection forest', optimal wood production, optimal agro-forestry use and optimal agriculture and forestry use respectively (KRP, 1984b). While the second option appeared to be financially the most attractive to the State Forest Corporation, the fourth option showed the highest economic returns. The Indonesian Government eventually opted for the third alternative, and incorporated several of its features in the Ten-Year Reforestation Plan (1986-1995) for the area. However, for funding and manpower reasons, it scaled down the total target from 7,134 ha in 10 years, as envisaged in the agro-forestry option, to 3,559 ha in the Ten-Year Plan.

During the first phase of the project, it was found that the degradation process could not be adequately understood by focusing only on developments in and around the forest land. It was deemed necessary to study the agricultural and socio-economic development in the village lands as well. The village lands evaluation study (KRP, 1984c) came forward with a comprehensive list of development activities, that were supposed to have a direct or indirect effect on restraining human-induced land degradation (deforestation and soil erosion).

The target groups

During the first two phases a considerable amount of data was also collected about the farming systems and the socio-economic conditions in the project area (Nibbering, 1986). On the basis of this information and the extensive agro-economic data, collected in the third phase through the monitoring programme in the target villages, a total of eight typical farm patterns were constructed (Table 10.6). These farm patterns represent the different categories of farm households found in the watershed area. The main criteria used in distinguishing these farm household patterns were: farm size, type of land, role of livestock and farming constraints (Section 5.3).

Table 10.6 *Farm patterns distinguished in the watershed area (excluding landless)*

Code and short qualification (farm hh type, source of income)	Farm land by type (ha)					Livestock (No)		Annual income (Rp 1000)		
	Irrig land	Rainf annual crops	Peren. crops	Home garden	Total	Dairy cattle	Goats/ sheep	Own farm	Off-farm	Total
P1 Farm/forest labour	-	0.14	-	0.03	0.17	-	2	303	500	803
P2 Small mixed farm	0.10	0.25	-	0.05	0.40	2	-	993	224	1,217
P3 Medium veget. farm	0.23	0.20	-	0.05	0.48	1	-	986	374	1,360
P4 Med./large mixed f.	0.11	0.45	0.12	0.07	0.75	3	1	1,522	263	1,785
Pujon (average per hh)	0.11	0.26	0.03	0.05	0.45	1.5	0.7	951	340	1,291
Total area (ha)	880	2080	240	400	3600					
Number of animals						12000	6000			
N1 Farm/forest labour	-	0.15	-	0.05	0.20	-	3	408	320	728
N2 Small mixed farm	0.08	0.30	-	0.03	0.41	-	1.5	679	229	908
N3 Rice & coffee f.	0.22	-	0.20	0.12	0.54	0.4	-	709	302	1,011
N4 Large coffee farm & trader	0.30	0.06	0.47	0.13	0.96	2	-	1,423	372	1,795
Ngantang (average/hh)	0.14	0.12	0.15	0.08	0.50	0.5	1.1	760	301	1,061
Total area (ha)	1160	990	1205	655	4010					
Number of animals						4000	9000			
Total watershed	2040	3070	1445	1055	7610	16000	15000	856	320	1,176

Notes: - Land does not include built-up areas: 60 ha in Pujon, 130 ha in Ngantang.
- The farm patterns P1-P4, N1 and N2 represent 2000, the pattern N3 2500 and pattern N4 1500 households.

Source: Based on de Graaff and Dwiwarsito, 1990.

The farm patterns are to a certain extent location-specific and were in fact named after the hamlets in which they were observed the most clearly. Each farm household pattern represents between 1,500 - 2,500 households (Table 10.6). Their aggregated land, livestock and off-farm resources correspond with the actual total, as found in the watershed area in 1985/86. The differences in farm size and farm income are more pronounced than those in total household income, because of off-farm income, which for small farms constitutes mostly off-farm labour.

Since part of Ngantang sub-district falls outside the watershed, the total watershed population was estimated in 1986 at 94,000, or 18,800 households with an average of 5 persons per household. Apart from the nearly landless households in patterns P1 and N1, an estimated 2,800 households (1,800 in Pujon and 1,000 in Ngantang) have no land at all. This group can be divided into semi-urbanized households in the centrally located villages, that are not engaged in agriculture or forestry, and landless labourers (P0 and N0), that still continue to carry head loads of produce, firewood, fodder from the hills to the villages (*pikuling*). Average annual household income of this group does not exceed Rp 500,000. Since population projections indicate that rural population growth will drop to about 0% in the coming decades, it is assumed that whatever small population increase will only lead to higher numbers of 'semi-urban' landless, the farming population remaining stable until 2015.

Implementation objectives and approach

This case study concerns the third or implementation phase of the Konto River Project. The ultimate objectives for the implementation of watershed management measures during this phase were formulated as follows:

1. To realize a *decline in the rate of erosion* to acceptable levels and simultaneously to *improve the hydrological balance* in the area as a consequence of better infiltration in both forest and village land, in order to improve the water supply for irrigation and other purposes (downstream);
2. To increase the *productivity of both forest and agricultural land* and to *raise income* levels for the local population;
3. To achieve an *involvement of the local population* in watershed management in general and in soil conservation practices in particular.

In the Phase 3 final report, it was admitted that these objectives were rather vague, and not quantified. However, despite these vague objectives, a great number of watershed development activities were implemented during this phase. Reforestation was undertaken according to Perum Perhutani's Ten Year Reforestation Plan. The main species were Damar (*Agathis* spp.) in Pujon and Mahoni (*Swietenia* spp.) in Ngantang. The inclusion of firewood became a general feature and perennial tree crops (avocado and coffee) were interplanted in the 'tumpangsari' plantations.

On the 'village land' nine out of the 23 villages were selected as target villages. A great variety of watershed development activities were undertaken mostly but not exclusively in these villages. The activities were grouped into four categories (Table 10.7): perennial cropping (incl. village nurseries); physical conservation measures (terracing, gully control and roadside drainage); fodder and livestock programme; and support activities in rural infrastructure and agriculture. The latter included access road improvement, drinking water supply, irrigation improvement, seed supply and extension. These activities could also be considered as 'starter activities' or 'general incentives', to arouse interest among the population in soil and water conservation activities (Chapter 11).

Table 10.7 *Main activities implemented during third phase of project (1986-1990)*

Activities	Extent	Unit	Agencies involved	Incentives provided for farmer participation
Forest nurseries	3	units	KRP, SFC	-
Reforestation				
Cemplongan	600	ha	SFC	Labour wages
Tumpangsari	1,040	ha	SFC	Two year annual cropping, firewood, fruits
Tree crop nurseries	2	units	KRP, PCS	-
Village nurseries	16	units	KRP	Starting capital
Coffee rejuvenation	240	ha	KRP, PCS	Training; material inputs
Tree crop planting	70	ha		Subsidized seedlings
Terracing	7	demplots	SCS	Subsid. inputs; training
Gully plugs	24	units	SCS	-
Goats & sheep schemes	9	schemes	KRP, LS	Two animals (on credit)
Fodder nurseries	2	units	KRP, KOPSAE	-
Grass planting	20	ha		Subsidized cuttings

Abbreviations: KRP = Konto River Project; SFC = State Forest Corporation; PCS = Perennial Crop Service; LS = Livestock Service; KOPSAE = Milk cooperative; SCS = Soil Conservation Service.

Beneficiary monitoring

During the course of the implementation phase (1986 - 1990) a socio-economic monitoring programme was undertaken to investigate both the physical results of project activities and the participation of farmers and their attitude towards the respective activities (de Graaff and Zaeni, 1989). For the latter purpose three 'beneficiary monitoring surveys' were undertaken at the beginning, at mid-term and close to the end of the implementation programme. The survey covered 270 rural households in seven of the nine target villages. Except for a quota of *demplot* participants, the households were selected at random, and included both participants in one or more activities and non-participants. The monitoring surveys gave a good insight into which activities the respective farm household patterns had participated in and which activities they preferred (Table A10.1 in the Appendix). The socio-economic indicators derived from these surveys were very useful for the review in 1994.

Review of implementation activities end 1994

During a short 1994 review mission the results and impact of the third phase implementation activities were analyzed. Field visits were paid to a sample of the implemented activities on both forest and village land. Discussions were held with village elders and staff of government agencies, and interviews were held with 25 farmers in four of the target villages. Some major observations were made during this mission.

- Economic development seemed to have been fast in the period 1989-1994, at least in Pujon. This was confirmed by several socio-economic indicators (e.g. housing, electricity, number of motorcycles, kerosene stoves, etc). While milk and vegetable production must have been the main driving forces, several watershed development activities also contributed to this increased welfare (e.g. *tumpangsari*, access roads, nurseries and drinking water schemes), at least in the target villages.
- The results of the reforestation efforts were no more promising than during the first preliminary evaluation survey undertaken in 1989. The estimated tree survival rate seemed to have dropped from 70 - 80% to about 50 - 60%. The survival rate of the

firewood and fruit trees was particularly low. In the evaluation a distinction is therefore made between successful and less successful reforestation schemes.

- The terracing did not turn out as badly as assumed at project completion: farmers in most *demplot* areas seemed content with it. However, there was little impact on neighbouring areas. Most gullyplugs, access roads and drinking water schemes that were visited were in reasonable condition.
- The coffee rejuvenation programme was more successful in Ngantang than in Pujon. Farmers in Pujon 'allow' coffee next to vegetables, but they let them grow tall so that they provide less shade, and during soil tillage they often damage the roots, causing diseases. Some medium to large farmers were now engaged in apple growing. In Ngantang the low coffee prices over the period 1990 - 1993 appeared to have hampered development, but in 1994 coffee prices had tripled again.
- The dairy herd had increased somewhat further in Pujon. While previously grass was mainly obtained from terrace bunds, roadside and forest areas, many farmers were now growing fodder on their own land. The goat and sheep schemes had been much appreciated, and for some farmers had formed a stepping stone towards dairying.

10.3 Options and evaluation criteria

Project options

Since the activities implemented in the framework of the Konto River Project were directed towards various objectives the eventual result was an 'integrated watershed development project', that included various activities undertaken by several agencies. Many activities were only implemented on a 'pilot scale'. In the evaluation this actual result is compared with three hypothetical alternative options that focus on one of the major project (implementation) objectives: conservation, production and farmer selfhelp. These options were discussed with various actors during the 1994 review, and were generally considered as realistic alternatives. Because of the limited opportunities for small-scale industries and the modest impact of further tourism development, all four are focused on agriculture and forestry, and on land conversion in particular. The four options are referred to as:

A. **The actual watershed development**, based on Konto River Project implementation activities and their present (1994/95) state;
B. A **conservation-oriented** or pure **watershed management** scenario, emphasizing reforestation, terracing, gully control, etc.
C. A **production-oriented** or **agricultural development** scenario, focusing on dairy and coffee development;
D. An **autonomous development** scenario with no government interference, and purely based on farmer preferences and initiatives (the 'without-case' in CBA).

In the actual project situation (Option A) agencies were to some extent competing with each other. At times farmers were too busy with one activity (e.g. *tumpangsari*), to bother about participating in another. Under option B the State Forest Corporation stretches the reforestation programme close to the maximum, given constraints of labour supply, seedling supply and supervision. Participation rates then increase to about 70% among landless and small farmers. The Soil Conservation Service provides more guidance and incentives for terracing.

Under option C farmers in Pujon are given ample opportunities to grow grass on their own land and on forest land, and farmers in Ngantang are provided with incentives to expand the area under coffee, also on both types of land. Participation will be larger among medium-sized and large farmers, with land and livestock resources. The average participation rate is around 50% for grass and 30% for coffee. Some reforestation is still undertaken, with benefits for the landless and small farmers.

Option D represents the situation whereby Government support is brought back to a minimum and farmers themselves look for attractive investment opportunities (e.g. vegetables, apples, dairying). No reforestation is undertaken and no incentives are provided for grass and coffee growing. Without the reforestation programme, farmers cannot benefit from *tumpangsari* schemes and there will be few forest guards. Since the respondents in the evaluation survey have indicated that they would like to expand their farm size to 0.5 ha (for vegetable growing, etc), it is assumed that many landless and about 30% of small farmers will occupy some land in the forest, for vegetables, grass (Pujon) and/or coffee (Ngantang).

While the eventual development under the last option is only based on farmers' resources and preferences and their market response, in the other options the eventual choice of LUST's depends also on activities and incentives offered by the different agencies.

Evaluation criteria

The major criteria and attributes for the evaluation have been derived from both the national objectives for the agricultural and forestry sector (section 10.1), from the project's operational objectives (section 10.2) and from views expressed by the local population and local agencies.

Attributes of the *efficiency* criteria are defined as:
- the goal of maximizing net benefits of food, fodder and firewood production for local use;
- the goal of maximizing net benefits of production for export and import substitution (coffee, timber and milk);
- the goal of minimizing investment costs;

Attributes of the *equity* criterion are defined as:
- the share of income accruing to the inhabitants of the watershed (the uplands) in relation to that accruing to people downstream, now and in the future;
- the share of income accruing to the poor (landless and mini-farmers with less than 0.25 ha);

Attributes of the *sustainability* or *conservation* criterion defined as:
- the goal of reducing on-site erosion and downstream sedimentation in the Selorejo reservoir;
- the goal of retaining a favourable hydrological regime in the watershed, with as low as possible Qmax/Qmin ratio;
- the goal of minimizing the loss of natural forest, because of its functions as gene reserve and ecological research area.

Although it is acknowledged that there are other environmental concerns that need attention in these watershed areas, such as excessive pesticide use and pollution by cattle manure in Pujon, these aspects are not considered in this research.

Constraints
Shortages of firewood and fodder will automatically result in further deforestation by the local population. Average annual demand for firewood in 1986 was estimated at 87,000 ton and is expected to remain more or less constant. When this amount of firewood is not reached in an option, the deficit will be met through further deforestation. With a herd of 16,000 dairy cattle and 15,000 small ruminants the demand for fodder was estimated at around 180,000 ton in 1986. Under each of the options this amount should at least become available annually. Under the scenarios A and B it is assumed that the dairy herd will not increase any more, while under scenario C and D it is assumed that the dairy herd will increase to about 20,000, requiring 210,000 ton of fodder.

Actors involved
The primary decision-makers concerning land use and land management are the households (private land), the State Forest Corporation (public forest land) and the Public Works department (roads, rivers, etc). The various agricultural support agencies also indirectly exercise a profound influence on land use and land management.

For the evaluation the following public and private entities or actors are distinguished:
In the *public or parastatal* sector:
- The Central Government with its objectives for agriculture, forestry and rural development;
- The State Forest Corporation, managing the forest and responsible for reforestation;
- The Ministry of Public Works, responsible for road, river and reservoir management;
- The Soil Conservation Service of the Ministry of Forestry, responsible for the execution and promotion of physical soil conservation measures;
- The Local Government district services for agricultural development activities and extension, and in particular the livestock (dairy) and perennial crop (coffee) services.

In the *private* sector:
- The landless and small farmers participating in reforestation, in farm labour activities and in the transport of produce, fodder and firewood;
- The farmers participating in the other watershed activities;
- Traders and others benefitting from backward or forward linkages effects;
- The downstream communities using irrigation water and electricity from the reservoir.

Criteria weights
During the 1994 review mission the respective actors were asked to attach weights to the criteria. Most of the authorities claimed that their organisations are in the first place interested in increasing the income of the population in the watershed area. Production targets for wood, fodder, etc. were given a surprisingly low priority. Because of their coordinating role in watershed development, the provincial and Brantas watershed offices for soil conservation consider all objectives as almost equally important. But they consider it as the main role of the newly established district soil conservation service (PKT) to focus purely on erosion control and improving hydrological conditions. Since a large part of funds for watershed development activities comes from Central Government (e.g. INPRES), and allocated funds have to be used, it is not surprising that the local agencies were not much concerned with minimizing costs. Table 10.8 shows that the various actors have different priorities. Farm households attach much importance to food, firewood and local income, and central government to erosion, hydrological conditions and foreign exchange. However, there is less controversy between the objectives of local government agencies and farm households

than often assumed. For reforesting steep slopes the population prefers *tumpangsari* schemes, as do the local branches of the State Forest Corporation. These schemes are cheaper for them than the *cemplongan* schemes for which labourers need to be paid. Sometimes farmers agree to work in *cemplongan* schemes without payment, in order to be put on the list for *tumpangsari* schemes. In other zones forest overseers use very strict rules in the reforestation activities and offenders are jailed.

Table 10.8 *Priorities expressed by different actors for the selected attributes of the evaluation criteria*

Actors and weight sets	Local food prod.	Export/ import subst.	Costs	Income local popul.	Income to poor	Ero-sion	Hydro-logical status	Preserv. natural forest
Central government	2	4	6	2	4	6	6	6
Downstream community	2	5	5	2	2	7	7	5
Forest Corporation	2	4	2	5	5	5	5	8
Soil cons. agency	4	2	2	4	4	8	7	5
Livestock Service	5	6	2	6	8	3	2	4
Perennial Crop S.	2	7	2	6	5	5	5	4
Public Works Dept.	2	3	4	4	4	8	7	4
Landless/minifarms	7	5	3	6	8	3	3	1
Other farmers	6	7	3	8	5	3	3	1
Traders, etc.	6	7	4	7	5	3	2	2
Weight set X	2	4	5	2	3	8	7	5
Weight set Y	2	3	1	7	6	7	6	4
Weight set Z	6	7	4	8	5	3	2	1

Note: Score on scale from 1 - 8 (from low to high priority).

The different actors are grouped to derive three weight sets, which more or less represent the 'national, central government, point of view' (weight set X), the point of view of 'local public agencies' (weight set Y) and the farmers and private sector (weight set Z). Table 10.9 shows the evaluation matrix, with all criteria and weight sets. Pulpwood stands for inferior wood for local use. Fodder production is not included, as it is closely related to milk output.

Table 10.9 *Evaluation matrix: attributes of criteria and weight sets*

Criteria and attributes		Unit	Alternatives A	B	C	D	Weight Sets X	Y	Z
C1a	Production food	ton	Combined value/yr (1000 million Rp)				0.06	0.06	0.17
C1b	Production firewood	m^3							
C1c	Production pulpwood	m^3							
C2a	Production timber	m^3	Combined value/yr (million US$)				0.11	0.08	0.19
C2b	Production milk	lt							
C2c	Production coffee	ton							
C3	Costs	mln Rp					0.14	0.03	0.11
C4	(Share of) income to local population	%					0.06	0.14	0.22
C5	(Share of) income to (near) landless	%					0.08	0.17	0.14
C6	On-site erosion	ton/ha/yr					0.22	0.21	0.08
C7	Stream flow Qmin/Qmax	(ratio)					0.19	0.17	0.06
C8	Preserv. nat. forest	ha					0.14	0.14	0.03

10.4 Impact assessment

Impact assessment starts with an analysis of the effects of the different SCWD components on the major actors, represented by the farm patterns. The respective scenarios emphasize different land use conversion activities, but not all farm households will be able or willing to participate in these activities. The participation rates of the respective farm patterns in the different activities determine the eventual land use changes. Attention is subsequently paid to the impact of these land use changes on the various attributes of the three evaluation criteria.

Components and participation
All four scenarios focus on changes in land use and land management in order to reach the watershed development objectives. But under each scenario the funding and hence the institutional support and related incentive structure is different, which determines to what extent farm households engage in the various activities. The beneficiary monitoring surveys have shown in which activities the different farm patterns were keen to participate (de Graaff and Zaeni, 1989). This information is used to estimate participation rates and the average size of plots involved in land use conversion (Table A10.1 in Appendix). On the basis of this assessment the total land use changes were calculated (Table 10.10). Under Scenario A, for example, 12 % of the 2000 farm pattern P3 households participated in reforestation with grass on 0.25 ha plots, which together constituted 60 ha. The land use changes on the village land are modest, since pre-project farming systems on most of this land were already highly productive, and farmers themselves were not very concerned about erosion.

Table 10.10 *Extent of watershed development activities by district and by scenario*

	Pujon				Ngantang			
Scenario:	A	B	C	D	A	B	C	D
SCWD activities	(extent in ha)				(extent in ha)			
Forest land								
Cemplongan refor.	360	700	400	-	190	450	230	-
Tumpangsari refor.	480	720	240	-	500	720	250	-
Reforest. with grass	60	280	410	-	20	60	30	-
Grassland	-	-	480	310	-	-	-	-
Coffee plantations	-	-	-	-	-	-	720	480
Rainfed ann. crops	-	-	-	420	-	-	-	370
Sub-total	900	1700	1530	730	710	1230	1230	850
Village land								
Grassland	-	-	440	160	-	-	-	-
Terraced rainfed	40	500	-	-	40	250	-	-
Treecrop plantings	70	220	-	150	20	90	190	110
Rejuvenated coffee	-	-	-	-	180	-	360	-
Improved homegardens	40	40	40	-	40	30	40	-
Subtotal	150	760	480	310	280	370	590	110
Total	1050	2460	2010	1040	990	1600	1820	960

The land use changes on the *forest land* consist of gradual deforestation (natural forest via degraded forest to shrubland) and of reforestation activities on the shrubland. Reforestation also contributes indirectly to deforestation in other zones. Since farmers can no longer obtain firewood or fodder from former shrub plots that are reforested, they have to obtain it from other shrubland, or from the natural forest. That firewood and fodder are of crucial importance is clear from the state of many reforested plots, where the firewood species and much of the leaves of the main species (Damar) have already disappeared.

In terms of production, the *tumpangsari* reforestation has the major overall impact, not only because of the relatively large area involved, but also because of annual and perennial cropping. For the landless this reforestation scheme is the only way to obtain access to land. The *tumpangsari* reforestation system was already applied in colonial times (Peluso, 1992) for landless and small farmers to plant maize and tobacco. The choice for landless households and for 0.25 ha plots was made in order to promote food (maize) production for the poor, but in the project area farmers plant mainly vegetables.

When reforestation, coffee and grass planting replace shrub, the impact on the water balance (at field and watershed level) is fairly neutral, but erosion increases.

On *village land* grass and coffee are planted to increase farm income, but these activities also reduce run-off and erosion when replacing annual crops. Since the soils are deep and fertile to considerable depth, terracing does not have much effect on on-site productivity, but it reduces erosion and has a retarding effect on run-off. Box 10.1 and Table 10.11 within it illustrate and explain farmers' attitude towards terracing in Ngantang district. Many farmers are rather sceptical about the effects of terrace improvement.

One could therefore probably better focus on waterways to safely evacuate excess water and on checkdams to retain sediments, instead of promoting terraces. In the area described in Box 10.1, the project constructed more than a dozen gullyplugs, that were filled up in less than half a year and do effectively slow down run-off and sedimentation.

Costs and effects on production

For all components data on material and labour costs and on yield projections were compiled from a preliminary cost-benefit analysis and from various project reports. These were verified with the field checks during the review mission. During the first four years the investment costs for the land use conversion components were, for the four scenarios A - D: Rp 834, 1,513, 1,688 and 772 million respectively. For option D investment concerns land clearing and planting by farmers themselves.

Table 10.12 shows the average annual production figures for the different scenarios over a period of 30 years. Despite the considerable extent of land use changes, in particular under scenarios B and C (Table A10.2 in Appendix), the effects on production for the whole watershed are fairly modest, with the exception of the timber production.

Table 10.12 *Total watershed production under the different scenarios. (average annual production per year)*

Product	Unit	Year 1985	Scenarios A	B	C	D
Food (rice & maize)	1000 t	25.4	25.1	24.5	25.2	27.0
Coffee	1000 t	0.7	0.7	0.6	1.0	0.8
Milk	mill lt	14.0	18.0	17.0	23.0	21.0
Timber	1000 m3	-	11.9	19.1	8.4	0.0
Pulp/low value timber	1000 m3	8.6	24.3	25.9	26.7	22.4
Firewood	1000 m3	82.2	90.8	88.6	88.1	89.5
Fodder	1000 t	181.2	183.6	180.6	213.5	216.2
Natural forest stand	1000 m3	27.5	25.0	24.6	22.5	22.8
(Remains after 30 yrs)	1000 ha	3.2	2.5	2.5	1.9	1.6

Box 10.1 *Farmers' attitude towards terracing and the on-site water balance*

A public works official at the Selorejo dam-site claimed that a major reason for increased sedimentation was the growing of shallots on rainfed land and reforestation plots in Ngantang sub-district. The shallots are grown on steep slopes, causing high run-off and excessive rates of sheet and gully erosion. Two 10 ha *demplots* were established in 1986 to show the advantages of reverse slope terraces, and to convince farmers to grow coffee on the steepest slopes. During the 1994 review the terraces in one of the *demplots* had been transformed again into outward sloping terraces, and very little coffee was grown. The soils in the area are deep and fertile and homogenous to considerable depth. Farmers apply much fertilizer and place it in small holes near the plants. It therefore can be assumed that nutrients and nutrient losses do not play an important role in erosion control decisions.

Table 10.11 *Water balances and gross margins for terraced and unterraced shallot-shallot-maize, for coffee and for maize-cassava, for two different rainfall patterns*

	Water balance (mm)				Yred	Gross margin (Rp1000/ha)		
						Not water	Water limited	
	P	R	ETa	D	(%)	limited	per ha	per day
Well distributed rainfall (average 1950-1982)								
Sh-Sh-M; Unterr.	2560	1236	865	459	15	1,658	1,409	1.9
Sh-Sh-M; Terr.1)	2560	494	970	1096	7	1,493	1,388	1.9
Coffee 2)	2560	494	952	1114	2	1,010	990	3.6
Maize-Cassava	2560	989	924	648	5	591	561	2.2
Year with long dry season (1987)								
Unterraced	2243	1316	654	273	37	1,658	1,045	1.4
Terraced 1)	2243	439	723	1081	30	1,493	1,045	1.5
Coffee 2)	2243	439	788	1016	17	1,010	838	3.1
Maize-Cassava	2243	877	693	673	26	591	437	1.7

1) Net cultivable area (and gross margins) reduced by 10%.
2) At 1987 farmgate prices (close to long term average).
Abbreviations: P = rainfall; R = run-off; ETa = actual evapotranspiration; D = flow to groundwater; Yred = yield reduction by water stress.

For understanding farmers' decision-making, the spreadsheet water balance model (Chapter 6) is used to assess how terracing and tree planting affect water availability and yields. Table 10.11 shows that in normal years, yields are not much affected by water shortages and terracing does not reduce water stress sufficiently to increase yields and gross margins. In years with a long dry season, water shortages (in May and October in particular) affect yields considerably, also on terraced land and also for coffee. Farmers are not very keen on terracing, since they fear water logging of the shallots. In one *demplot* internal soil drainage was good enough to avoid this problem, and farmers had therefore maintained the terraces. However, in the other *demplot* farmers preferred the higher direct run-off and the higher gross margins, without the terraces and their risers.

Under coffee run-off would be less, but that constitutes no important advantage to the farmer. With the small plots they have, farmers prefer the high returns per ha of shallots above the high returns per manday of coffee. Elsewhere in the sub-district coffee is replacing the traditional maize-cassava rotation.

Equity considerations
Attention is given to the distribution of income derived from the activities in two different ways: the *spatial* distribution between people within and people outside the (upper) watershed area, and the distribution among social groups within the watershed. For assessing the share of income (or benefits) accruing to the local population one should assess which part of total benefits accrue to Central Government, the State Forest Company, coffee traders, the dairy industry, etc. and are not reinvested locally. In addition, part of the total benefits accrue to downstream users of irrigation water and electricity. The first is difficult to assess, since it requires a thorough analysis of the marketing channels and the margins involved in trade. The latter can be derived from the downstream benefits calculations in Section 10.5.

For the income distribution among *social groups*, the data on income changes for the different farm patterns and landless are used. These are also presented in Section 10.5.

Effects on erosion and streamflow
For the assessment of the downstream effects in particular a spreadsheet watershed model was developed, discussed in Chapter 7 (van Loon et al., 1995). The spreadsheet model was designed to simulate changes in erosion and in streamflow that would take place under different scenarios, with their land use changes.

For the model the watershed area is divided into the two sub-districts areas Pujon and Ngantang, and subsequently each of these areas is subdivided into upper and lower agro-hydrological units (HU1 - HU4), that coincide to a large extent with the main landforms and major soil groups in the area. For reasons of simplicity, the forest boundaries have been taken as boundaries of these hydrological units. The two upper hydrological units contain the mountains, the hill slopes and the colluvial footslopes, with soils ranging from andosols to andic cambisols. The two lower HU's consist mainly of the intervolcanic plains, with cambisols and mediterans as main soil types. A similar distinction was used in the hydrological research programme undertaken in the three sub-watershed areas: Coban Rondo, Manting (both in Pujon) and Sayang (in Ngantang) (Rijsdijk and Bruynzeel, 1990). The results of this research were used to calibrate the spreadsheet watershed model.

The land use within the hydrological units is described by the combination of land unit and land use activity (LUST's), as described in Fresco et al., 1992. Since the landforms and soils more or less coincide with the respective hydrological units, the respective LUST's within an HU only differ with respect to land use and land management activities. On the basis of past land evaluation studies (KRP, 1984a; KRP, 1985) and the actual type of land use changes during the implementation period, a total of 37 different LUST's were distinguished in the two districts (Table A.10.2 in the Appendix). All relevant inputs and outputs are given per LUST. The inputs and outputs per HU are then a summation of the inputs and outputs of all LUST's in the HU, multiplied by the area covered by each LUST.

The evaluation focuses on vegetation changes (one LUST being transformed in another). These changes result in hydrological changes that determine sediment transport and water availability to crops, and thus affect soil erosion and crop productivity. The water in the higher and lower HU's each contain three 'stores': root zone, deep soil and stream flow. For reasons of simplicity irrigation canals are left out. The system has one input (rainfall) and four outputs: evapotranspiration, deep percolation, subsurface run-off and overland run-off.

Sediment follows the same path as the water flows and is either stored (again) on land or in the stream flow (SF). Actual erosion is determined on the basis of rainfall and rainfall intensity, soil parameters, slope and slope length, which are all provided on HU level; and on the basis of the state of the leaf canopy and other crop and management parameters, which are LUST-specific. Since soils are generally quite fertile to a considerable depth, it is assumed that soil losses do not affect the inherent on-site productivity. However, these losses to some extent affect the level of management, and lead to a sub-optimal use of fertilizers on unstable soils.

The land use changes (replacement by other LUST) result in effects on the water balance (water availability in the rootzone), that in turn influence the biomass. For all LUST's input-output data are provided for six periods, also used in cash flow analysis:

```
Period 1 = Year      0    (pre-project situation);
Period 2 = Year      1    (initial investment year);
Period 3 = Years   2-4    (next investment period);
Period 4 = Years  5-10    (period over which impact is reviewed);
Period 5 = Years 11-20
Period 6 = Years 21-30    (final period with tree felling).
```

Table 10.13 provides field level data on erosion rates and water balances for the major land use categories (LUST's), as derived from the Konto watershed spreadsheet model. Erosion is very high along roads and in built-up areas (not shown in this table), on rainfed annual crop land and on badly managed *tumpangsari* plots, until period 4. The LUST level data form a major input in the calculations of erosion and hydrological changes at the watershed level.

Table 10.13 *Field level erosion rates and water balance data for the major LUST's (for period 4 and based on 1987/89 average annual rainfall)*

		Erosion (t/ha)		Water balance (mm)				Rainfall
LUST		**ERw**	**ERm**	**ETa**	**WD**	**ROs**	**ROo**	(mm)
Pujon	**HU1**							
Natural Forest		1	0	1106	1201	133	0	
Shrub		6	1	900	1232	154	154	
Cemplongan reforestation		15	5	1006	1147	0	287	2,440
Tumpangsari refor.(good)		15	5	874	1253	0	313	
Tumpangsari refor. (bad)		50	17	933	904	0	603	
	HU2							
Rainfed annual crops		94	36	510	1026	171	513	
Terraced rainf. ann.		26	10	510	1026	342	342	2,221
Grass planting		5	7	652	314	941	314	
Ngantang	**HU3**							
Natural forest		0	0	1308	561	80	160	
Shrub		5	1	1065	626	104	313	
Cemplongan reforestation		12	3	1191	367	367	184	2,109
Tumpangsari refor.(good)		12	4	1036	429	429	215	
Tumpangsari refor. (bad)		39	13	1104	402	301	301	
	HU4							
Rainfed annual crops		106	40	608	470	313	783	
Terraced rainf. ann.		38	14	608	470	783	313	2,174
Coffee planting		20	6	1193	294	392	294	

Abbreviations: ERw and ERm: Erosion rates according to formulas of Wischmeier and Morgan; ETa Actual evapotranspiration; WD Water draining to deep soil; ROs and ROo: Sub-surface and Overland run-off.
Source: Konto River spreadsheet model.

Table 10.14 shows the overall erosion rates and water balance parameters for the respective scenarios. In order to provide insight into the past development of erosion and the streamflow patterns, some historical land use data have been applied in the model. This shows that erosion was very modest in 1845, when Junghuhn visited the area and most of the area was still under natural forest. The stream flow patterns have also changed, but not drastically.

Table 10.14 *Overall erosion rates and water balance parameters for the Upper Konto watershed, by time period and by scenario (based on 1987/89 rainfall patterns)*

Scenario	Year	Erosion rates (t/ha) ERw	ERm	SS	Water balance elements (mm) ETa	WD	ROs	ROo	Streamflow Qmin	Qmax
Historical development:										
	1845	1.9	0.8	1.0	1254	565	102	192	33	119
	1895	7.6	3.4	5.6	1161	506	199	261	27	139
	1935	17.3	7.6	8.2	1058	502	258	317	27	145
Before implementation:										
	1985	17.6	7.9	14.2	1055	490	223	366	26	160
Alternative scenarios:										
A	2010	17.9	8.3	14.6	1047	475	240	367	25	163
B	2010	17.3	7.8	13.3	1051	463	258	349	25	163
C	2010	16.5	7.8	13.0	1052	470	241	365	25	168
D	2010	21.6	9.8	16.0	1021	480	236	399	25	168
Extreme results scenario A:										
Black	2010	24.1	11.0	18.2	998	479	240	421	24	172
White	2010	15.1	7.1	12.6	1054	474	260	342	25	161

Abbreviations used: ERw and ERm: Erosion rates according to formulas of Wischmeier and Morgan; SS: Sediment in stream; ETa: Actual evapotranspiration; WD: Water draining to deep soil; ROs and ROo: Subsurface and Overland run-off; Qmin and Qmax: Lowest and highest monthly streamflow.

According to the spreadsheet model, there would be no drastic changes in erosion and streamflow, as a result of a three year long implementation of watershed development activities. Even not according to the most pessimistic and optimistic views about final results (black and white). It should, however, be stressed that many of these activities (e.g. *tumpangsari* reforestation) are still continuing and the impact of a ten to twenty year programme will be quite clear. It is obvious that scenario D produces the worst results with regard to erosion and sedimentation in the reservoir. Despite the 10% higher overland run-off with this scenario D, the Qmax/Qmin relation remains fairly stable.

In the spreadsheet model erosion rates were calculated in three ways: applying the formulas of Wischmeier (Ew) and Morgan (Em) and by calculating the sediment in the stream (SS). In their detailed erosion research in the area Rijsdijk and Bruijnzeel (1990) calculated an average erosion rate for the whole watershed area of 13.9 ton per ha per year, of which 85% was estimated to be derived from surface erosion from non-forest land (including roads and built-up areas).

10.5 Cost-benefit analysis

Analysis of components

At project completion a detailed cost-benefit analysis was undertaken of all project components within the five categories reforestation, perennial cropping, physical conservation measures, livestock programme and rural infrastructural activities (de Graaff and Dwiwarsito, 1990). The data on costs were derived from the project's monitoring programme, which also gave indications for the estimation of benefits. But it was acknowledged that it was still too early to assess the eventual long-term benefits of the reforestation, terracing, etc. In 1990 the economic indicators for most components were positive, and in particular for coffee production, access roads and grass on under-utilized land. On the basis of the field surveys during the 1994 review mission, several assumptions about the benefits were revised, and a few new components for the alternative options were defined. A financial cost-benefit analysis was subsequently undertaken for the main land use conversion components (Table 10.15).

Table 10.15 *The efficiency of the main SCWD (land use conversion) components*

LUST's		NPV (at 7%) (Rp 1000)	IRR (%)		NPV (at 7%) (Rp 1000)	IRR (%)
Forest land:		Pujon:			Ngantang:	
Cemplongan reforestation		933	12		642	12
Tump. refor. (well maintained)		1,559	15		1,362	16
Tump. refor. (badly maintained)		37	7		29	7
Reforestation with grass		199	9		426	11
Grass on forest land		81	9		-	-
Coffee on forest land		-	-		1,381	17
Village land:						
Grassland		155	29		-	-
Terracing rainfed land		124	14		124	14
Treecrop plantings	(apples)	3,438	15	(coffee)	758	11
Coffee rejuvenation		-	-		288	11

Note: Results tumpangsari do not include annual crop production.

Effects on actors

The next step was to assess the effects of the different components on the main actors: the households represented by eight farm patterns, the landless and the Government (agencies). For the farm level analysis a simple multiple spreadsheet was prepared, with farm pattern base data, anticipated land use changes, water limited yields, material and labour inputs and prices in four input spreadsheets. In an intermediary sheet financial results were calculated, and transferred to a summary table, which shows resources and resource use for each farm pattern under all four alternative scenarios (Figure 10.2). An example of a summary table is shown in Table A10.3 in the Appendix.

With this spreadsheet model the financial long term results (period 5) were calculated, assuming that the ten farm patterns (including landless) aim both at income maximization and at higher levels of self-sufficiency in food, fodder and firewood. The latter objective is here expressed as minimizing 'expenditure' on food, fodder and firewood. Table 10.16 shows scenario D as the most promising, in particular for smaller farms. This is based on the assumption that farmers will intrude on forest land. Self-sufficiency in food, fodder and firewood is for most farm patterns highest under scenario B, with its emphasis on forest and grass plantations. Since the analysis concerns period 5 (years 11-20), it does not include any more income from annual crops in *tumpangsari* schemes. During period 3 (Years 2-4) the highest farm income is obtained under Scenario B (emphasizing reforestation, with plots of food crops), followed by A and C.

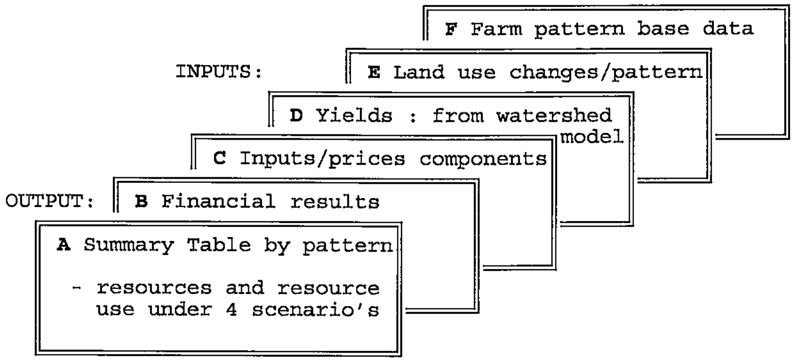


Figure 10.2 *Multiple spreadsheet farm pattern analysis model*

Table 10.16 *Financial long term results for farm patterns (period 5)*

	Farm pattern						Farm pattern						Total
	P0	P1	P2	P3	P4	Aver.	N0	N1	N2	N3	N4	Aver.	aver.
Annual income (Rp1000)													
Before	454	803	1217	1360	1785	1198	454	728	908	1011	1795	1026	1114
Scen. A.	470	979	1304	1380	1780	1262	473	767	967	984	1765	1037	1153
Scen. B.	495	858	1270	1428	1860	1258	508	799	962	979	1750	1041	1153
Scen. C.	476	988	1342	1411	1834	1292	511	778	908	1151	1953	1110	1204
Scen. D.	607	1054	1351	1374	1847	1317	637	1032	1007	1089	1862	1166	1244
Food, fodder & firewood self-sufficiency (expressed in expenditures: Rp 1000)													
Before	144	173	173	50	231	156	144	77	34	18	116	60	109
Scen. A.	143	223	197	41	230	169	142	88	32	22	142	69	119
Scen. B.	140	160	165	31	219	144	138	73	28	23	114	59	103
Scen. C.	143	238	187	42	193	163	137	68	28	44	146	69	117
Scen. D.	100	186	197	42	248	160	52	22	30	42	154	55	109

Source: Derived from farm pattern spreadsheet model.

Efficiency of options, based on on-site effects

The combination of land use conversion components within the four options determines their overall efficiency in this analysis. The other SCWD activities, such as the goat schemes, road improvement and other supporting activities, also functioning as incentives in Scenario A, are not included here. However the options do consider the loss of income through the further deforestation and the larger area taken up by paths and gullies, particularly under scenario D. Overhead costs are included to the extent they can be attributed directly to the components, such as costs of tree nurseries, extension, supervision, etc. Apart from the (pilot) implementation of activities in cooperation with the various services, the Konto River Project had several interlinked objectives, such as training of staff, agro-forestry research and watershed planning activities in other watersheds. It was therefore difficult to determine the real extent of overhead costs.

Table 10.17 shows the overall results of the cost-benefit analysis. The IRR and the first NPV columns only include the on-site effects of the different components. If intrusion on forest land takes place, Scenario D has the highest IRR (22%) and NPV (at discount rates of 5% and higher). Scenarios A and C come next with an IRR of about 11%. However, at lower discount rates Scenario B, with its emphasis on reforestation, has the highest NPV. Whereas the actual project (Scenario A) had still the character of a pilot project, Scenarios B and C comprise larger-scale interventions. To account for this difference in size of project, affecting the NPV (and assuming budget constraints), the Net Benefit-Investment ratio (at 7% and 4% discount rates) is also given. This provides a ranking for the analysis of the on-site effects, which at a discount rate below 10% is: D > A > B > C. At higher discount rates, Scenario C comes second.

Inclusion of downstream effects

In CBA external effects should be incorporated, where possible. Therefore monetary values could be attached to the effects of changes in erosion and sedimentation rates and in the hydrological regime, affecting the capacity of the Selorejo reservoir. On the basis of the results of earlier calculations (Section 7.3) and the small changes in the Qmax/Qmin ratio for the four options, only the sedimentation effects will be included.

Table 10.17 *Overall results of cost benefit analysis of land use conversions: efficiency criteria for the 4 scenarios, at different discount rates (Rp milliard)*

	IRR	Net Present Value (Rp 1000 mill)						Net Benefit-Investment ratio					
		On-site effects			Overall results			On-site effects			Overall results		
Scenario	%	10%	7%	4%	10%	7%	4%	10%	7%	4%	10%	7%	4%
A	11	0.2	1.3	3.4	1.2	3.0	6.5	1.2	2.5	5.1	2.5	4.6	**8.8**
B	10	0.0	2.0	**6.0**	1.2	**4.0**	**9.5**	1.0	2.3	5.0	1.8	3.6	7.3
C	11	0.3	1.8	4.6	1.6	**4.0**	8.5	1.2	2.1	3.7	2.0	3.4	6.0
D	**22**	**1.9**	**3.2**	5.4	**1.9**	3.2	5.4	**3.5**	**5.3**	**8.0**	**3.5**	**5.5**	8.0
D*	7	-0.5	-0.1	0.7	-0.5	-0.1	0.7	(NBI ratio not applicable)					

D* is equal to Scenario D, but without farmers' intrusion on forest land.

The annual sediment volume in the reservoir was 0.23 million m^3/yr, according to sounding surveys in 1977 and 1982. For 1988 annual sedimentation is set at 0.25 million m^3.

The annual net benefits of the reservoir consist of the supply of water for 5,700 ha of irrigated land (valued at Rp 1,200 million), the generation of 49 million Kwh electricity (valued at Rp 1,000 million), flood control (damage foregone of Rp 500 million) and recreation, valued at Rp 300 million per year. These values are in accordance with earlier calculations made during the design stage of the dam (Nippon Koei, 1962). The total value of these annual benefits amounted thus to Rp 3,000 million.

On the basis of the erosion rates from the watershed spreadsheet model, it has been calculated that total sedimentation will reach the level of dead storage (12.2 million m^3) in the years 2021, 2022, 2023 and 2017 for scenarios A,B,C and D, respectively.

However, sediment is not generally evenly deposited over the reservoir (Chapter 7) and sedimentation could reach as high as 17 million m^3 before benefits are reduced to zero. That level of sedimentation will be reached in years 2029, 2030, 2031 and 2023 for the four scenarios A to D. The irrigation, electricity and flood control benefits from the reservoir can be assumed to decrease gradually from the allowable sedimentation of 4.5 million m^3 (already reached in 1988) to this total of 17 million m^3, and the real benefits of the soil conservation activities (Scenarios A, B and C) and without any measures (Scenario D). Comparing Scenario A as 'with-case', with Scenario D as 'without-case', these benefits are equal to an annual gradient series with an annual increment of Rp 12.5 million over a period of 35 years (1988-2023), and some final benefits over the period 2023-29, negligible after discounting. The gradient series is equivalent to an annuity of Rp 133 million at a 7% discount rate, which gives a Net Present Value (in 1988) of Rp 1,727 million, as 'soil conservation' benefits due to the implemented measures. Similar calculations were made for the Scenarios B and C, and using discount rates of 4% and 10%.

When these benefits are added to on-site benefits, Scenarios B and C have at a discount rate of 7% the highest NPV, followed by options D and A. This is shown in Table 10.17 under NPV: overall results. The Net Benefit-Investment (NBI) ratio, reflecting the different investment levels (shown at the right hand side of the table), gives at 7% discount rate a different ranking: D > A > B > C. At discount rates of 5% and less Scenario A scores best on the basis of this NBI criterion.

10.6 Multi-criteria or integrated evaluation

The cost-benefit analysis reflects the efficiency of the four investment options, and by including downstream benefits as major external effects, does pays attention to some attributes on the sustainability criterion. However, the above analysis does not take into account attributes of the equity criterion and the bio-diversity aspect of natural forests. These evaluation aspects can more easily be considered through the application of MCA.

Table 10.18 summarizes the impact the four options have on the attributes of the three main criteria, and Table 10.19 gives the standardized impact matrix with the weights attached to the attributes by the three main groups of actors (Section 10.3). The costs concern the total of all material and labour inputs used during the investment period (Years 1-4), while the production values concern the overall agricultural production in the upper watershed.

For the analysis the weighted summation technique is applied. Under weight set X, representing central government priorities, Scenario A scores highest, followed at some distance by B and D (Table 10.20). The local government agencies, with their weight set Y, also prefer Scenario A, followed by B and D. However, according to the local farmers' preference, expressed by weight set Z, D scores highest, closely followed by A. Scenario C scores lowest under all three weight sets, since this option does not contribute much to income to landless and has the highest investment costs, and the high foreign exchange earnings do not compensate for this.

Table 10.18 *Impact Matrix*

Attributes of criteria		Unit	Alternatives A	B	C	D
C1	Ann. value food, fire- & pulpwood	Rp 1000 mln.	4.4	4.3	4.4	4.6
C2	Ann. value coffee, milk & timber	US$ mln.	4.1	4.0	5.1	3.8
C3	Investment costs (mat. & labour)	Rp mln.(-)	834	1,523	1,688	772
C4	Share of income to local popul.	%	23	27	20	30
C5	Share of income to landless	%	68	48	33	60
C6	On-site erosion	t/ha/yr(-)	17.9	17.3	16.5	21.6
C7	Stream flow: Qmin/Qmax	%	15.3	15.3	14.9	14.9
C8	Remaining natural forest	ha	2,500	2,500	1,875	1,650

Table 10.19 *Standardized impact matrix, with weights*

Attributes of criteria		Alternatives A	B	C	D	Weights X	Y	Z
C1	Local production	0.50	0.49	0.50	0.52	0.06	0.06	0.17
C2	Traded production	0.48	0.47	0.60	0.44	0.11	0.08	0.19
C3	Investment costs	- 0.33	- 0.60	- 0.66	- 0.30	0.14	0.03	0.11
C4	Income to local pop.	0.46	0.53	0.40	0.59	0.06	0.14	0.22
C5	Income to landless	0.63	0.45	0.31	0.56	0.08	0.17	0.14
C6	On-site erosion	- 0.49	- 0.47	- 0.45	- 0.59	0.22	0.21	0.08
C7	Stream flow: Qmin/Qmax	0.51	0.51	0.49	0.49	0.19	0.17	0.06
C8	Remains natural forest	0.58	0.58	0.43	0.38	0.14	0.14	0.03

Note: Use is made of vector standardization (Min. van Financiën, 1992).

Table 10.20 *Results of multi-criteria analysis, by weight set*

Weight sets	Scenarios A	B	C	D
X	**0.185**	0.140	0.107	0.131
Y	**0.295**	0.269	0.216	0.241
Z	0.338	0.297	0.264	**0.341**

One could also use the results of the cost-benefit analysis as the only attribute of the efficiency criterion, by replacing these for the first three attributes (production and costs). Van Pelt (1993) refers in this case to an integrated evaluation. However, in this case study actors were asked to attach weights to the above included eight attributes, and not to economic efficiency as a criterion as such. Besides, the NPV would lend itself best for inclusion in the MCA method selected here, whereas the Net Benefit-Investment ratio provides a correct ranking under the budget constraint.

Discussion

The analysis shows first of all clearly the dilemma between 'opening' the forest area for more productive activities, which are very efficient in the short run, or trying to preserve as much as possible the other functions of the forest (hydrology, erosion control, bio-diversity), important in the long run and for downstream interests. Through the *tumpangsari* schemes part of the forest area is already used for intensive agriculture for the benefit of landless and small farmers. It is not in the interest of the latter that all land is properly reforested, and in many schemes the trees do not survive. If no reforestation were attempted forestry field staff would only function as 'forest police'. In Scenario D it is assumed that this would be ineffective and that farmers will intrude into the forest, as though the gates to this 'open access resource' were wide open. It is not surprising, therefore, that option D scores highest in financial and partial CBA, when only on-site effects are considered, and in MCA when the farmer's point of view is emphasized.

The analysis further shows that the effects of a three-year implementation programme on streamflow and on downstream sedimentation are not (yet) very large, but that the present modest effects already have considerable impact on the functions of the reservoir.

The hydrological and erosion parameters in the spreadsheet model were calibrated with the results of research in two sub-watersheds, and the reservoir sedimentation was in line with the results of soundings in 1977 and 1982. More recent studies of the Selorejo reservoir suggest much higher sedimentation rates (Puslitbang Pengairan, 1994). In some other, much larger reservoirs in East Java (e.g. Sengguruh) sedimentation is reported to be dramatic. In the preparation and appraisal of watershed projects, the quantification and valuation of downstream effects therefore require major attention.

In densely populated watershed areas changes in land use and production in one spot (e.g. field) also have repercussions for land use and production elsewhere in this watershed (e.g. reforestation of shrubland leads to deforestation elsewhere). Therefore, and for assessing the downstream effects, one needs to consider the overall land use and total production in the watershed in the analysis, and not only the costs and direct benefits of the project activities.

It is often suggested that cost-effectiveness analysis (CEA) be applied in situations where it is hard to estimate the benefits. That presupposes, however, that the options to be compared would have more or less similar benefits, whereas this case study suggests that such benefits differ both in magnitude and in composition (on-site and downstream).

The application of both evaluation methods in this case study clearly shows the strengths and weaknesses of either method. CBA shows which option has the highest overall efficiency in relation to the investment. The short-term effects of the 'intensive farming on previously protected forest land' weigh very heavily in the judgment at discount rates above 5%. MCA allows the inclusion of some other important criteria and focuses on the conflict of interests, which leads to different choices by different groups. It illustrates the need to reconcile the opposing views by offering incentives to farmers. Under option A, representing the activities that were actually undertaken, these incentives played a major role. In Chapter 11 the role of these incentives is further discussed.

10.7 Watershed development in southern Blue Mountain zone in Jamaica (1980-1993); an ex post evaluation

Similarities

Upland watershed areas similar to those in East Java are found in many other mountainous tropical zones, e.g. in the Philippines, in parts of India and Nepal, in Ethiopia and parts of East Africa, in the Andes, in Central America and also on some of the Caribbean islands. In this section the Indonesian case will be compared with watershed development activities in Jamaica, in the steep watersheds south of the Blue Mountains and around the capital Kingston (here referred to as Kingston watersheds). Like the island of Java, Jamaica faces considerable deforestation and soil erosion problems, which among others affect the lifetime of reservoirs. About a quarter of the area of both islands is forested, but these areas are very scattered and are easily encroached upon.

The upper part of the Kingston watersheds has some agro-ecological features which are similar to the Konto River watershed area: the average annual rainfall is also around 2,200 mm, the terrain is steep and one finds similar species in the vegetation. Typical for these agro-ecological conditions are the production of coffee and highland vegetables (e.g. shallots, cabbage) in both zones. The Jamaican farmers also do not mind much about the on-site effects of soil erosion; not because of deep fertile soils (they are not), but because of the relatively fast soil formation. Therefore soil conservation is also in the first place needed for down-stream interests.

Differences
Despite several agro-ecological similarities, there are also clear differences between the two zones. With two-thirds consisting of forest land, population density in the upper Konto River watershed is 400 persons per km^2, while in the Kingston watershed areas (with 20% under forest) it is 140 persons per km^2. The mountain peaks and steepest slopes in the Konto watershed are all government owned, which is only partly the case in Jamaica. While in the Indonesian situation agriculture is (still) the most important sector, it only contributes 6% to GDP in Jamaica, and many of the Kingston watershed inhabitants derive income from industry, trade and services.

The location of the watersheds near Kingston makes several demands on the area: for residential space, for intensive agriculture (e.g. vegetables, small livestock) and for the city's drinking water supply. Safeguarding this latter function is crucial, whereas in the Konto case emphasis is on prolonging downstream irrigation and electricity benefits.

Because of the very steep terrain, much emphasis is given in Jamaica to land capability in the planning and implementation of watershed development activities (Sheng, 1972). In Indonesia more emphasis is given to differences in soil types, and land suitability. In other words, in selecting land use and measures, one focuses in Jamaica more on the slope or S-factor in the USLE formula, and in Indonesia more on the soils or K-factor. The landslides and damage to vegetation caused by the hurricanes are major problems in Jamaica.

In both watershed areas four similar development options could be distinguished: conservation-oriented watershed management, production-oriented agricultural development, sustainable production-oriented watershed development, and no outside interference at all. While in the Konto River watershed the third option was chosen with a large number of components and many so-called 'starter activities', in Jamaica a choice was eventually made for tree crop development. In order to undertake at least some direct erosion control a separate soil conservation demonstration project was undertaken in one watershed.

The Kingston watershed project proposal and actual developments from 1983 - 1993

In 1982 an FAO project finalized detailed plans for six watersheds surrounding Kingston (Figure A 10.1), and prepared a US$ 13 million (1982 prices) follow-up implementation project with various watershed development activities, focusing on a target group of about 1,200 full-time and interested farm households (original proposal: FAO, 1982b).

An IFAD mission visited Jamaica in 1983 and made several changes in the project design. The project was to focus mainly on coffee and cocoa plantations, and on small scale rural enterprises. This 'Hillside Farmers Support Project' was appraised in 1987 and started in 1988 for a period of six years, focusing first on the Kingston watershed areas and thereafter on a much wider area. Not much attention was paid to soil conservation in critical areas, but a specific watershed management project was undertaken in the Hope River Watershed. This UNEP project implemented various physical erosion control measures on both public and private lands and undertook a public awareness campaign.

(IFAD) Hillside Farmers Support Project (1988-1994)
This project was aimed at providing credit for coffee and cocoa planting and rehabilitation and starting up small-scale enterprises, in order to enhance income and employment and to reduce soil erosion. Project coordination was in the hands of the Agricultural Credit Bank (ACB), which channelled funds through six People Cooperative Banks (PCB's) in the rural

areas. Technical extension support was provided by the Coffee Industry Development Corporation (CIDCO) and the Cocoa Industry Board (CcIB), which entities would also collect repayments and guarantee the loans. Interest on loans was initially set at 12% for the customers and 4% to be repaid to IFAD. The 8% spread was to be divided between the PCB's (4%), the commodity boards and the ACB. The small-scale rural enterprise credit programme was promoted through the National Development Foundation of Jamaica (NDFJ). The target group for coffee and cocoa development were bona fide hillside farmers, who live in the project area and own or operate 1 to 5 ha. IFAD estimated that 35% of farm families would participate in the programme (Table 10.21). Until 1993 tree crop development was slower than planned, except for Blue Mountain coffee (Table 10.21). Only about 400 ha were planted and 60 ha rehabilitated in the original project area.

There were both external and project related reasons for this. Firstly, prices of coffee and cocoa were very low over the period concerned. Secondly as result of high inflation, all credit interest rates were adjusted to commercial levels after 1990, increasing up to 24%. Thirdly rumours spread about tree crop diseases (e.g. coffee leaf rust), and fourthly farmers complained about the inadequacy of the delivery of inputs. For this reason the ACB took control of the field operations in 1994. In order to fulfil the erosion control objective some 160 ha of hillside ditches were established. The small-scale industry development component assisted about 45 small enterprises, mostly dealing with grocery retail and other services.

Table 10.21 *Number of participants planned and realized under the IFAD Hillside Farmers Support Project, in original project area only.*

	Total rural families	Farm families	Participants in: Rehabilit. of Coffee	Rehabilit. of Cocoa	Planting of Coffee	Planting of Cocoa	Perc. of farm families
Originally planned in 1988							
Original area:	10,800	6,200	1,020	300	630	190	35 %
Realized until 1993							
Original area:	10,800	6,200	81	92	570	129	14 %

Source: IFAD, 1988; ACB, 1994.

Hope River Project (1988-1991)

Short term objectives of this UNDP/UNEP funded project were to increase ground cover and reduce erosion and sedimentation. In the long run the objectives were to increase total stream flow, while reducing fluctuations, to reduce disaster effects, to increase water holding capacity and to increase agricultural production. On public land different forms of checkdams, retaining walls and landslide rehabilitation techniques were demonstrated. On private land various conservation activities were demonstrated, whereby farmers contributed 50% of the costs. The implementation was entrusted to the National Resources Conservation Authority (NRCA), which used staff from various other organisations (e.g. Forestry Department). All work was based on contracts. For major tasks, such as the public awareness campaigns, private organizations were called upon, through tender operations. The project started in early 1988, but because of the damage caused by hurricane Gilbert, it only became effective in 1989. The project made extensive use of local (waste) materials, such as so-called 'Gilbert logs and poles' and discarded rubber tyres. Table 10.22 shows that the project achieved a major part of its targets during its short lifetime.

Table 10.22 *Hope River Watershed Project achievements (1989 - 1991)*

		Planned	Realised
Land use activities			
Firewood plantations	(ha)	8.1	6.8
Orchard terraces and agro-forestry	(ha)	41.2	34.1
Revegetated landslides	(ha)	1.5	1.0
Firebreaks	(ha)	27.1	3.4 *
Total area	(ha)	77.9	45.3
Erosion control measures			
Hillside ditches and contour barriers	(m)	1,207	1,066
Individual basins	(No)	2,000	2,678
Area affected	(ha)	6.2	7.1
Ballasted waterways	(m3)	229	212
Retaining walls	(m3)	585	362
Checkdams	(m3)	1,267	899

* Forests considered for firebreaks were affected by hurricane Gilbert.
Source: Colterell, C., pers. comm.

Other development activities undertaken from 1983-1993

More or less independent of the above two projects, the following major changes have occurred in the watershed areas in the period 1982 - 1993:

- The highest part of the Yallahs watershed became part of the National Park;
- A Japanese supported project planted some 1,150 ha Blue Mountain coffee, of which part (about 400 ha) is located in the Hope River and Upper Yallahs watersheds;
- Another 400 ha 'ruinate' land was reforested;
- The USAID supported Hillside Agricultural Project (HAP), mainly operating in adjacent areas, chose and campaigned for agronomic soil conservation measures;
- The increased number of urban dwellings has somewhat reduced the agricultural area, and has contributed to erosion and sedimentation;
- Since water has been taken from the Yallahs river for Kingston, insufficient water is available for 280 ha irrigable land in the Lower Yallahs, curtailing food production.

Alternative options and evaluation criteria

The two implemented projects, described above, are here referred to as option A. Other options could have been:

B - to undertake the original project proposal for soil conservation and agro-forestry;
C - to concentrate only on watershed management to safeguard water supplies; and
D - to refrain from any development activity.

The most important Government objectives for the development of these watersheds are to enhance employment and income, to increase foreign exchange earnings and to increase, or at least not decrease, the water yield from these areas. Increasing income for the small hillside farmers also contributes to equity considerations. Many agencies were directly or indirectly involved in the implementation of the two projects: for the IFAD project this concerned in particular the ACB and rural PC banks and the commodity boards, and for the UNEP project the NRCA and Forest Department. However, the Planning Institute of Jamaica and the donor organisations played also an important role. The National Water Commission (NWC), the Underground Water Authority (UWA) and the urban consumers are all interested in the impact of the watershed activities on the water supply. Table 10.23 shows the 'imputed' rankings by these organisations of the four main criteria.

Table 10.23 *Criteria rankings by different participants*

Criteria	Organisations Gov't PIOJ	Donors	ACB/ PCB's	Commod. boards	NCRA/ For.Dpt	Farm pop.	NWC/ UWA	Urban pop.
Costs	2	4	3	3	2	2	2	2
Income	3	1	2	2	3	1	3	3
Foreign exchange	1	2	1	1	4	3	4	4
Water yield	4	3	4	4	1	4	1	1

Effects and impacts of activities

Project costs

Total costs of the IFAD project amounted to US$ 14.2 million (1987 prices), 41% of which for investment in coffee and cocoa and 10% for small scale enterprise development. Since the project expanded after a few years to a wider area, only 60% of the costs concern the original project area. Total costs of the Hope River Project were about US$ 4 million. The original proposal (option B) had an estimated cost of US$ 13 million (at 1982 prices), with 30% for farm development, 25% for public land development and 14% for upgrading the rural infrastructure. Option C would focus exclusively on erosion control in the 'water supply' watersheds and cost around $US 10 million (1987 prices).

Changes in farm income

The FAO project undertook a baseline socio-economic survey of the watersheds in 1981. The data were used in the preparation of the IFAD project (IFAD, 1988). The latter project collected data from participants and commissioned a socio-economic study, but these data are not yet available for assessing the impact of the project on farm income. In their farm survey Riksen and Versteeg (1994) found that average farm resources had hardly changed between 1981 and 1993: average farm size was 1.7 ha of which 70% owned; half of the farms had some livestock, etc. Average annual family earnings and expenditures increased from J$ 4,000 to about J$ 40,000, or roughly following inflation (Annex 1). Participants of the IFAD project seemed to be slightly better off than other farmers. With average coffee plantings of 0.6 ha IFAD farmers probably increase net income by about J$ 20.000. It is assumed that options A and B have a similar impact on farm income, higher than options C and D.

Effects on foreign exchange earnings

Foreign exchange costs were estimated at US$ 3 million (1982 prices) for the original project proposal and at US$ 5.5 million for the IFAD project in 1987. Since the IFAD project focuses on export crops, option A is likely to contribute more to foreign exchange earnings than the other options. World market prices for coffee and cocoa were depressed from 1986-1994, but rose again in 1994. The main product, Blue Mountain coffee, is sold to Japan and receives a 50% premium price. Tree crops and Pinus plantations suffered from hurricane Gilbert, which reduced export earnings.

Changes in land use

To assess the impact on the water supply, one should first assess the changes in land use, soil erosion, stream flow and sedimentation. For all six watersheds aerial photo interpretation and land use mapping were undertaken in 1982, but for two of them only a rough assessment could be made of the changes that occurred since. For the Hope River watershed new aerial photos were analyzed in 1990, and for part of Upper Yallahs aerial photos were available in 1993. Photo interpretation was difficult because of the lack of difference between degraded natural forest, fallow land and food forest, the heavily shaded cocoa and the tiny isolated plots of annual crops. Table 10.24 shows the increase of coffee and a deforestation of about 2% per year. The two projects only partly contributed to the changes.

Table 10.24 *Estimated land use changes in two watersheds (1982-1993; in ha)*

	Hope River			Upper Yallahs		
Land use categories	**1982**	**1993**	**Change**	**1982**	**1993**	**Change**
Natural forest	2,217	1,820	- 397	2,880	2,400	- 480
Plantation forest	295	392	+ 97	716	836	+ 120
Ruinate, fallow, bamboo	890	809	- 81	1,426	1,235	- 191
Food forest, bananas	477	545	+ 68	580	610	+ 30
Annual crops	135	205	+ 70	495	550	+ 55
Pure stand coffee	23	238	+ 215	125	571	+ 446
Urban, water, bare rock	57	85	+ 28	95	115	+ 20
	4,094	4,094	0	6,317	6,317	0

Sources: FAO, 1982c; FAO, 1982d; Hope River Project, pers. comm.).

Changes in soil erosion

Some erosion and sedimentation research was undertaken in the watersheds but no systematic monitoring. With estimated annual rates of erosion of 5 t/ha for steep natural forest land, 30 t/ha for plantation forest, food forest and ruinate, 40 t/ha for coffee plantations and 200 t/ha for unprotected annual crop land, the land use changes of Table 10.24 indicate that erosion must have increased in Hope River watershed from 23 to 27 t/ha/yr and in Upper Yallahs from 33 to 38 t/ha/yr. Without the Hope River Project erosion would have increased further to 29 t/ha/yr. Coffee plantations had few positive effects on erosion, since they on balance replaced ruinate land. In their soil conservation study for the IFAD project, Lindsay and Douglas (1993) found that 42% of farmers did not apply any measure and that others often applied simple contour barriers. It is therefore unlikely that soil conservation measures have had much impact on soil erosion in the watersheds (except Hope River watershed).

Changes in river discharge

The gradual deforestation and increased plantings of annual and perennial crops shown above would normally lead to an increased total discharge and possibly to a lower well distributed stream flow throughout the year. However, Table 10.25 shows that the annual mean daily discharge of the rivers has clearly decreased in two of the three watersheds. This may well relate to the long term gradual decrease of annual rainfall as discussed by Eyre (1987), but it is remarkable that it affected Hope River watershed much less. There the discharge distribution over the year deteriorated. The Qmin/Qmax (month with lowest and highest mean daily discharge) ratio became less favourable in Hope River and Rio Pedro watersheds. However, because of the large fluctuations in the annual and monthly discharge it is not possible to compare the situation in the short period of 1989-1993 (after implementation of the two projects) with the situation in the past. The small network of stream gauging stations established by the FAO project were not maintained. In all three watersheds water holding capacity and base flow are low, since the soils (conglomerates and shales) do not allow much groundwater storage within the catchments.

Table 10.25 *Annual and seasonal mean daily discharge (m^3/s) of main rivers.*

River: Station:	Yallahs Llandewey			Rio Pedro Harkers Hall			Hope River Cooperage		
Mean daily discharge:	Annual	Wet months	Dry months	Annual	Wet months	Dry months	Annual	Wet months	Dry months
1954 - 1979	3.40			1.84			0.85		
1970 - 1979	3.89	4.79	3.00	1.98	2.92	1.04	0.69	0.87	0.49
1980 - 1990[1)]	2.71	3.12	2.31	1.16	1.72	0.60	0.67	0.94	0.38
1986 - 1991	2.03	2.50	1.56						
Qmin/Qmax:									
1970 - 1979		0.206			0.154			0.241	
1980 - 1990[1)]		0.213			0.122			0.231	
1986 - 1991		0.071							

1) For Yallahs period 1980-85; since 1985 water was detracted by pipeline.
Sources: FAO, 1982e; Underground Water Authority; pers. comm.

Effects on reservoirs

Of the two reservoirs, the Hermitage reservoir is the most affected by sedimentation. This watershed of 1,300 ha is 80% owned by the National Water Commission, but has been encroached upon by squatters. Due to sedimentation the reservoir capacity declined in the period 1927-1963 from 2.2 to 1.1 million m^3. Since then dredging was undertaken until 1980, when the capacity was 1.8 million m^3. Miller (1992) calculated that dredging would cost about US$ 2.5 million (J$ 55 million in 1992) while the benefits would amount to J$ 2 million per year (0.4 million m^3 water sold annually at about J$ 5 per m^3). Dredging is thus quite costly and only addresses the symptoms. The original project proposal included the reafforestation of the Hermitage watershed (with species not using much water), reducing erosion from 50 to 25 t/ha/yr (after 5 years), or extending the remaining life of the reservoir from 30 to 60 years. This would save a gradually increasing amount of water from year 0 (zero m^3) to year 30 (2 million m^3) and thereafter a same amount of 2 million m^3 decreasing to 0 in year 60. This is equivalent to discounted savings of 4.8 and 6.5 million m^3 per year (at discount rates of 12% and 10%), or at net present values (at J$ 5 per m^3 water) of J$ 24 and J$ 32 million. This is clearly in excess of the reafforestation cost of around J$ 10 million calculated by Miller, 1992. This reafforestation forms part of options B and C.

Changes in water supply

Table 10.26 shows that the average yearly supply of water to Kingston has increased by about 54% between 1975-79 and 1990-93. This is largely due to the pipeline from Upper Yallahs (about 22 million m^3 per year).

Table 10.26 *Water supply to corporate area of Kingston and St-Andrews in million m^3/ year (1975-1993)*

Year:	1975/76	1977/78	1978/79	**Average 1975-79**	1990/91	1991/92	1992/93	**Average 1990-93**
Production	61.4	57.4	65.6	**61.5**	94.8	91.7	98.3	**94.9**
Consumption	45.6	45.0	48.1	**46.2**	69.1	73.4	78.6	**73.7**
Share of prod. consumed (%)	74	78	73	75	73	80	80	**78.0**

Source: Statistical Institute of Jamaica. Pocketbook of Statistics, 1980,1993.

Consumption has increased by no less than 60%, much more than the 20% population increase.

Requests were made to obtain data on intake of water at the two processing plants (at Constant Springs and Mona Reservoir), in order to assess how changes in river discharge affect the drinking water intake. These data are collected daily, but are not accessible.

Evaluation

Except for two studies on soil conservation practices (Lindsay and Douglas, 1993) and on socio-economic conditions, no detailed physical and socio-economic monitoring activities were undertaken in the watersheds to assess to what extent the tree crop activities have contributed to changes in erosion, water flows, income and employment. Moreover, the UNEP project did not last long enough to engage in a meaningful hydrological and erosion research and monitoring programme. In contrast to the Indonesian case, it is therefore hard to apply CBA or a quantitative MCA method in an evaluation that includes downstream benefits. Because of the slightly different aims of the options and the lack of data, cost-effectiveness analysis cannot be applied either. A qualitative MCA analysis is then the only possibility. Table 10.27 shows the evaluation matrix, with rankings for the four options and with three weight sets, representing the priorities and preferences of the Government (X), the farmers (Y) and the water suppliers and consumers (Z).

Applying Regime analysis, it turns out that for the Government (with weight set X) and for the farmers (weight set Y) option A, or the actual implementation, scores highest, followed by the originally proposed project (option B). Farmers would prefer option B if the effects on income would be higher. But for the last group of actors (Z) the third, watershed management option (C) is preferred, with option B coming second and option A only third. Contrary to the situation in the Indonesian case study, the *laissez-faire* option D scores low. Without development activities, farmers are unlikely to increase production, at least not for export, and the impact on erosion and water supply will not be favourable.

Table 10.27 *Evaluation matrix: ranking of scores on criteria*

	Development options				Weights		
Criteria	A	B	C	D	X	Y	Z
Costs	3	4	2	1	0.2	0.2	0.2
Income	1	1	3	4	0.3	0.6	0.1
Foreign exchange	1	2	4	3	0.4	0.1	0.2
Water yield	3	2	1	4	0.1	0.1	0.5

Note: ranking from 1 (best) to 4 (worst)

Discussion

By implementing two different projects, consciously or not, a certain compromise was already arrived at: the IFAD project focused more on production (and export earnings) and the Hope River Project on erosion control. However, this second project did not last very long and only concerned one 'water supply' watershed. No measures were taken in the Hermitage watershed and not much erosion control activity took place in Upper Yallahs.

The land use changes brought about by the two projects were not very large when compared to changes resulting from other initiatives. The hurricane damage also had considerable effect on land use. Because of these factors and because of a lack of data on erosion rates and on relations between the hydrological changes and the resulting water supply, no quantitative impact assessment could be undertaken and only a simple, qualitative MCA evaluation method could be applied.

The eventual choice for two projects scores quite well in the evaluation, but this option has not contributed much to the important issue of Kingston's drinking water supply. Following the National Soils Policy activities, a new FAO project is now operational under the title 'Formulation of a soil erosion control programme'. Admitting that the previous watershed projects have been disappointing, it will embark on a new approach, whereby the activities will be better embedded in a national policy framework (FAO, 1994).

10.8 Comparison and lessons for project preparation and appraisal

The two case studies show the importance of incorporating downstream effects in the evaluation of SCWD projects. With this inclusion the need arises to review land use and land degradation in the whole (upper) watershed. Changes in overall erosion rates and Qmin/Qmax ratios in such watersheds may be rather small, but these changes can incur considerable costs or benefits, particularly when sedimentation in downstream reservoirs has already reached the dead storage level.

In the Indonesian case the key issue is the use of the publicly owned forest land. The choice is between giving in to pressure from local people to use more of it for agricultural purposes, or respecting the other functions of the land, which aim at longer lasting irrigation and electricity benefits for the downstream population. The *tumpangsari* scheme is a typical example of a compromise: it combines early cropping benefits for local people with long term reforestation to restore the functions of the forest. It is matter of reaching a mutual agreement about sharing costs and benefits. This is elaborated in Chapter 11.

In the Jamaican case the key issue is how Government and farmers can agree about less erosive land use in the watersheds, which provides sufficient income to the 'mini'-farmers and satisfies the Government's need for foreign exchange earnings. Planting tree crops like coffee would fulfil this best. A small watershed management demonstration project was thought of to help solving the future water supply problem. Frequent hurricane damage frustrates long-term soil and water conservation planning.

The two cases illustrate how much economic evaluation depends on the availability of data. In the Indonesian case detailed research data were available. An intensive hydrological and erosion research programme yielded data on erosion and streamflow for representative sub-catchments. A detailed socio-economic monitoring programme provided much information about participation in and costs and benefits of the different project components. In the Jamaican situation the original project proposal eventually resulted in two separate small projects, one focusing on traded production in the whole area, and the other on erosion control in one watershed. Neither of them could take responsibility for watershed-wide physical and/or socio-economic monitoring activities. Only few data on land use changes and erosion rates were available, and it was not possible to link the effects of these changes to the downstream water supply situation.

Watershed development projects or programmes should be preceded by a preparatory phase, to:

a. set up a hydrological and erosion monitoring system;
b. undertake pilot implementation of major components to assess their effectiveness,

efficiency and organisational requirements; and

c. carry out socio-economic baseline studies to assess farmers' attitudes, preferences and likely participation, to enable subsequent socio-economic monitoring and to determine the needs for incentives.

The two evaluation methods, CBA and MCA, appear to have strongly complementary features. It is hard to include equity and sustainability considerations in CBA, but this method shows clearly whether an activity is worthwhile undertaking from a financial and economic point of view (the efficiency criterion). MCA, on the other hand, can focus attention on the divergent views and interests of the main actors involved. This feature is of great importance in SCWD projects where opposing views are more the rule than the exception. Additional components could be brought in (as in the Konto case) to reconcile parties without affecting efficiency too much. These components are sometimes referred to as 'start-up' or 'complementary' activities, but constitute in fact a form of incentive, an issue taken up in the next chapter.

APPENDIX 10.1 The Konto River Watershed Project: background tables for the ex-post evaluation

Table A 10.1 *Participation of farm patterns in main SCWD activities under respective scenarios* (participation rates in % and average plot size in ha)

	Farm patterns										Total
	P0	P1	P2	P3	P4	N0	N1	N2	N3	N4	partic.
On forest land:											(No.)
Tumpangsari (0.25 ha plots)											
Scen A:	36 %	46 %	32 %			40 %	48 %	42 %			3,920
Scen B:	72 %	60 %	48 %			64 %	64 %	48 %			5,760
Scen C:	18 %	24 %	16 %			20 %	24 %	20 %			1,960
Grass tump. (0.25 ha plots)											
Scen A:				12 %						5 %	320
Scen B:			16 %	15 %	25 %					16 %	1,360
Scen C:		8 %	24 %	20 %	30 %					8 %	1,760
Grass only (0.25 ha plots)											
Scen C:	12 %	12 %	26 %	12 %	40 %						1,920
Scen D:	10 %	10 %	20 %	7 %	20 %						1,240
Coffee planting (0.20 ha plots)											
Scen C:						48 %	36 %	20 %	50 %	67 %	3,600
Scen D:						48 %	36 %	10 %	30 %	33 %	2,400
Annual cropping (illegal; 0.25 ha plots)											
Scen D:	50 %	36 %	20 %	4 %		48 %	42 %	20 %			3,160
On village land:											
Grass only (0.10 ha plots, also homegarden improvement, Pujon)											
Scen A:					20 %						400
Scen B:			4 %	6 %	10 %						400
Scen C:		20 %	60 %	60 %	80 %						4,400
Scen D:			20 %	15 %	45 %						1,600
Terracing (0.20 ha plots)											
Scen A:				10 %				10 %			400
Scen B:		12 %	20 %	50 %	40 %		20 %	31 %		15 %	3,750
Coffee planting (0.20 ha plots; also homegarden improvement, Ngantang)											
Scen A:			5 %		12 %				5 %	12 %	650
Scen B:			20 %		35 %			22 %	4 %	4 %	1,700
Scen C:								40 %	8 %	10 %	1,150
Scen D:					37 %			25 %		4 %	1,300
Coffee rejuvenation (0.30 ha plots)											
Scen A: (Under coffee plantings)									6 %	30 %	600
Scen C:									16 %	53 %	1,200

Note: Uniform plot size is obtained by adapting some participation rates.

Table A 10.2 *Land use development according to respective scenarios*

Land use/crops	Historical (1895)	Before (1985)	Land use development by scenario (in ha) (period 4: 1990/95) A	B	C	D
Forest land Pujon:						
Natural forest	6,100	1,975	1,875	1,700	1,300	1,400
Degraded forest	2,700	1,700	1,700	1,700	1,700	1,700
Shrub	-	3,960	3,160	2,535	3,105	3,805
Grassland	90	-	-	-	480	310
Plantations	-	1,365	1,365	1,365	1,365	1,365
Cemplongan refor.	-	-	360	700	400	-
Tumpangsari refor./good	-	-	288	360	96	-
Idem; less successful	-	-	192	360	144	-
Reforest. with grass	-	-	60	280	410	-
Rainfed annual crops	-	-	-	-	-	420
Coffee plantations	1,200	-	-	-	-	-
Village land Pujon:						
Grassland	181	-	-	-	440	160
Irrigated land	500	880	880	880	820	880
Rainfed annual crops	700	2,080	1,960	1,355	1,690	1,750
Terraced/improv. rainfed	-	-	40	500	-	-
Mixed garden	1,150	240	240	240	240	240
Orchards	-	-	70	220	-	150
Homegardens	124	400	360	360	360	400
Improved homegardens	-	-	40	40	40	-
Roads, paths, buildings	15	60	70	65	70	80
Forest land Ngantang:						
Natural forest	4,600	1,200	1,100	950	800	900
Degraded forest	1,937	1,240	1,240	1,240	1,240	1,240
Shrub	-	2,900	2,290	1,920	2,120	2,400
Grass	490	-	-	-	-	-
Coffee plantations	800	50	50	50	720	480
Plantations	-	1,050	1,050	1,050	1,050	1,050
Cemplongan refor.	-	-	190	450	230	-
Tumpangsari refor./good	-	-	300	360	100	-
Idem; less successful	-	-	200	360	150	-
Reforest. with grass	-	-	20	60	30	-
Rainfed annual crops	-	-	-	-	-	370
Village land Ngantang:						
Irrigated land	950	1,160	1,160	1,160	1,160	1,160
Rainfed ann.	600	990	915	645	780	850
Terraced rainfed	-	-	40	250	-	-
Mixed coffee gardens	1,050	1,205	1,025	1,205	845	1,205
New coffee plantings	-	-	20	90	190	110
Rejuvenated coffee	-	-	180	-	360	-
Homegardens	398	655	615	625	615	655
Improved homegardens	-	-	40	30	40	-
Roads, paths, buildings	15	130	145	135	150	160
Selorejo lake	-	260	260	260	260	260
Average erosion (ton/ha)	8	18	18	17	16	22
Qmin/Qmax relation	27/139	26/160	25/163	25/163	25/168	25/168

Total land in upper watershed 23,500 ha (incl. reservoir)

Table A 10.3 *Example of summary table from farm pattern spreadsheet model*

```
SUMMARY TABLE  FARM PATTERN   P2          KONTO RIVER PROJECT  - PUJON
--------------------------------------------------------------------------
Family size:    5       Objectives: Sufficient food, fodder, firewood
Farm size:    0.4 ha                Maximizing income       Period    1
--------------------------------------------------------------------------
LAND (ha)  LABOUR (w/eq) LIVESTOCK    INCOME    EMPLOY.  DEMAND (yearly)
Irrig  0.10 Adult     2 Draft   0.0   (Rp 1000) (w/eq) Food Fodder Firew
Rainf  0.25  Adol     1 Dairy   2.0 Off-w     8    0.0  (ton) (ton) (m3)
            Child     1 Goats   0.0 Oflab   216    0.9   1.0  22.1   4.0
Peren  0.00 Elder     1 Sheep   0.0 Crops   550    1.0   SUPPLY (yearly)
Homeg  0.05 Hired   0.5             Live    736    1.5   1.3   7.6   0.5
                                    Expens  292          Purchase/Sale
Total   0.4 Total   3.5  A.U.   2.0 Total  1217    3.4  -0.3  14.5   3.5
--------------------------------------------------------------------------
SCENARIO A: Actual changes after project implementation     Period    5
--------------------------------------------------------------------------
LAND (ha)  LABOUR (w/eq) LIVESTOCK    INCOME    EMPLOY.  DEMAND (yearly)
Irrig  0.10  Changes      Changes     (Rp 1000) (w/eq) Food Fodder Firew
Grass  0.00             Dairy   0.3 Off-w     8    0.0  (ton) (ton) (m3)
Rainf  0.23             Goats   0.0 Oflab   207    0.9   1.0  24.7   4.0
Terr.  0.00             Sheep   0.0 Crops   578    0.9   SUPPLY (yearly)
Orchar 0.03 Hired   0.5             Live    828    1.7   1.2   7.6   0.7
Refor  0.08                         Expens  318          Purchase/Sale
Total  0.48 Total   3.5  A.U.   2.3 Total  1304    3.5  -0.2  17.1   3.3
--------------------------------------------------------------------------
SCENARIO B: More emphasis on conservation                   Period    5
--------------------------------------------------------------------------
LAND (ha)  LABOUR (w/eq) LIVESTOCK    INCOME    EMPLOY.  DEMAND (yearly)
Irrig  0.10  Changes      Changes     (Rp 1000) (w/eq) Food Fodder Firew
Grass  0.02             Dairy   0.0 Off-w     8    0.0  (ton) (ton) (m3)
Rainf  0.16             Goats   0.0 Oflab   216    0.9   1.0  22.0   4.0
Terr.  0.04             Sheep   0.0 Crops   594    0.9   SUPPLY (yearly)
Orchar 0.04 Hired   0.5             Live    736    1.5   1.2   8.1   0.8
Refor  0.12                         Expens  284          Purchase/Sale
Total  0.52 Total   3.5  A.U.   2.0 Total  1270    3.3  -0.2  13.9   3.2
--------------------------------------------------------------------------
SCENARIO C: More emphasis on dairying (and coffee)          Period    5
--------------------------------------------------------------------------
LAND (ha)  LABOUR (w/eq) LIVESTOCK    INCOME    EMPLOY.  DEMAND (yearly)
Irrig  0.10  Changes      Changes     (Rp 1000) (w/eq) Food Fodder Firew
Grass  0.12             Dairy   0.6 Off-w     8    0.0  (ton) (ton) (m3)
Rainf  0.19             Goats   0.0 Oflab   161    0.7   1.0  28.6   4.0
Terr.  0.00             Sheep   0.0 Crops   525    0.9   SUPPLY (yearly)
Orchar 0.00 Hired   0.5             Live    957    2.0   1.2  12.3   1.0
Refor  0.04                         Expens  308          Purchase/Sale
Total   0.5 Total   3.5  A.U.   2.6 Total  1342    3.5  -0.2  16.3   3.0
--------------------------------------------------------------------------
SCENARIO D: No interventions, autonomous development        Period    5
--------------------------------------------------------------------------
LAND (ha)  LABOUR (w/eq) LIVESTOCK    INCOME    EMPLOY.  DEMAND (yearly)
Irrig  0.10  Changes      Changes     (Rp 1000) (w/eq) Food Fodder Firew
Grass  0.07             Dairy   0.5 Off-w     8    0.0  (ton) (ton) (m3)
Rainf  0.28             Goats   0.0 Oflab   135    0.6   1.0  27.5   4.0
Terr.  0.00             Sheep   0.0 Crops   606    1.1   SUPPLY (yearly)
Orchar 0.00 Hired   0.5             Live    920    1.9   1.3  10.5   0.6
Refor  0.00                         Expens  318          Purchase/Sale
Total  0.50 Total   3.5  A.U.   2.5 Total  1351    3.5  -0.3  17.0   3.4
--------------------------------------------------------------------------
Note: w/eq stands for worker equivalent in man years.
```

APPENDIX 10.2 Watershed development in southern Blue Mountain zone in Jamaica (1980-1993); background information

Ecological setting of Kingston watersheds
Jamaica was called 'Land of Wood and Water' by its early Arawak inhabitants. One wonders whether the island still merits this title (Advocate News, 10-3-1983).

With its 11,425 square kilometres Jamaica probably contains a greater variety of landscapes than any other country of comparable size. The terrain varies from towering mountains to coastal plains. Some 65% of the land is composed of hilly limestone areas used for bauxite mining and extensive cattle raising. Another 15% comprises alluvial plains, devoted to sugar and banana plantations for export. The final 20% comprises three areas, developed on cretaceous deposits, which are used for intensive, small-scale hillside farming and produce mainly food crops for local consumption (Ramsay, 1981). These areas are located in the Western region, in the central part of the island and around the Blue Mountains in the eastern part of the island. Much of these lands are either too steep or have soil too thin to support intensive agriculture. This research concerns the watershed areas south of the Blue Mountain range, for which areas plans were prepared by an FAO project in 1982. These watershed areas form an arc around Kingston (Figure A 10.1).

The predominant soil types in this area are derived from granite porphyry, from conglomerates and shales and, in the lower parts of the watersheds, from limestone. All of these soils are shallow, with rapid internal drainage, rapid run-off and high erodibility. Most have a low fertility (Vernon and Jones, 1959). The watershed areas are situated on the leeside of the Blue Mountains and have an average annual, bimodal, rainfall of about 2,000 mm (Table A 10.4). The island is regularly ravaged by hurricanes. The hurricanes Charlie (1951), Flora (1963), Allen (1980) and Gilbert (1988), were accompanied by severe flooding.

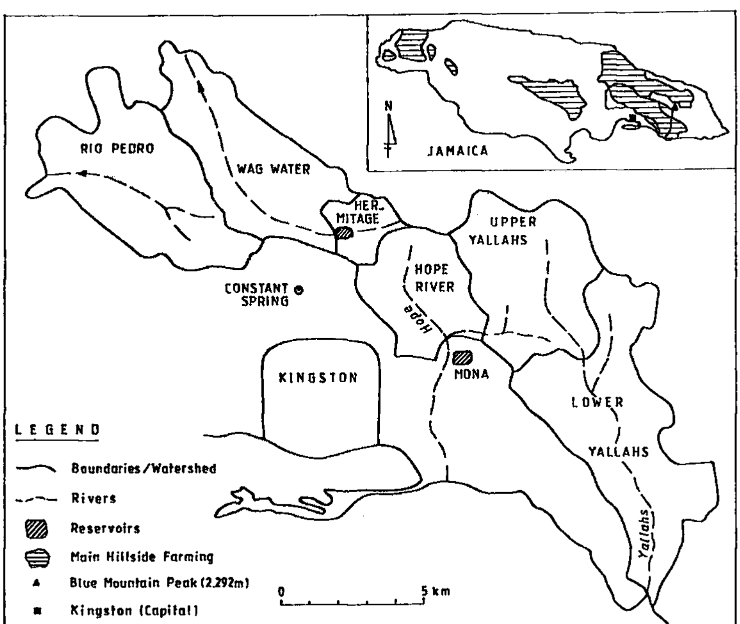


Figure A 10.1 *Map of Kingston watersheds in Jamaica*

Table A 10.4 *Mean monthly rainfall and potential evapotranspiration (1931-1977)*

Watershed	Altitude	j	f	m	a	m	j	j	a	s	o	n	d	Total
Precipitation (in mm)														
Hope River	305 m	39	52	42	97	176	125	87	177	233	373	183	87	1,671
Wagwater	414 m	62	64	54	123	222	147	133	242	280	380	203	100	2,010
Upper Yallahs	1248 m	126	115	103	172	236	140	76	183	225	342	397	235	2,350
Potential evapotranspiration (in mm)														
Wagwater	414 m	97	100	126	129	137	135	144	135	117	114	96	96	1,426

Source: RPPD, 1990; Stations: Stony Hill, Gordon Town and Chinchona.

Socio-economic situation

About one third of Jamaica's relatively large population of 2.4 million lives in and around the capital Kingston. The town has attracted many people from the rural areas seeking work. The agrarian structure is highly uneven: 80% of all farms have less than 2 ha and control only 16% of the land, while the very large farms constitute less than 1% of the total and control 57% of the land (Rao, 1990). The former, called mini-farmers by Wright (1979), are the main suppliers of staple food and vegetables in the country, but because of the steep terrain the production is not sufficient to meet the needs of the people. Soil erosion will also eventually destroy the basis of this important form of agriculture and livelihood system.

The Kingston watershed areas, as defined by the FAO project in 1980, cover the district of St-Andrew, and part of the districts of St-Catherine and St-Thomas. According to the 1970 census about 50,000 people were living in these watershed areas, and this total had not increased much in 1980. The 1980 socio-economic survey showed that no less than 45% of the rural dwellings in the areas had only tiny plots of land and were not really engaged in farming (Non-farm landless in Table A 10.5). Only about a quarter of the small and medium farm households were considered to be full-time farmers with an 'advanced' level of management, keen on further developing their farm. Most other farmers were either much involved in off-farm activities or too old or not much interested in farm development. These latter farmers often keep part of their land uncultivated or under 'food forest', a multi-storey mixture of trees and crops, which provides good protection against erosion.

Table A 10.5 *Rural households.in the Kingston watershed areas (1980)*

		Watersheds		
		Wagwater/Rio P.	Yallahs/Hope R.[1)]	Total
Watershed areas	(ha)	14,770	20,940	35,710
Rural population	(p.)	30,300	19,500	49,800
Population density	(p./km2)	205	93	140
Total rural dwellings/households		6,500	4,300	10,800
Non-farm landless households		2,950	1,750	4,700
Small farms	(< 1 ha)	1,420	680	2,100
Medium farms	(1- 5 ha)	2,020	1,680	3,700
Large farms	(> 5 ha)	110	190	300

1) Not including Hermitage watershed (1,400 ha), that is totally Government owned and uninhabited.
Source: de Graaff, 1981.

Jamaican economy and agriculture sector policies and programmes

The Jamaican economy's performance since 1975 has been adversely affected by a series of external shocks. Oil prices increased, while the prices of bauxite, alumina and agricultural export commodities declined. Investments slowed down, domestic income declined and unemployment rose from 21% in 1974 to 28% in 1980. A considerable proportion of the adverse influences on the Jamaican economy showed up as a severe foreign exchange bottleneck, which explains the great emphasis on export earnings and import substitution in the development objectives of the 1980's.

Obstacles facing the Jamaican agricultural sector in 1980 included the following:
- Land ownership was highly skewed with the small farms concentrated on steep land;
- Insufficient legal documentation of ownership of land in the hillside areas;
- Despite unemployment, there was a continued disenchantment with agricultural work, and consequently a chronic shortage of agricultural labour;
- A lack of adequate agricultural support services to farmers (e.g. extension, credit);
- Inadequate measures and organisation to conserve and protect the limited soil resources.

The Government objectives for the agricultural sector in the early 1980's were:
- To raise income and standard of living (of hillside people);
- To increase employment in rural areas in order to reduce urban migration;
- To improve income distribution;
- To increase foreign exchange earnings by stimulating exports and reduce imports;
- To control erosion to safeguard future agricultural production and water supplies.

Soil conservation programmes

The Government of Jamaica has gained considerable experience with rural development, soil conservation and afforestation activities over the last four decades (Edwards, 1995). In 1945 the Land Authority approach was recommended for rehabilitating watershed areas with the Yallahs Valley as pilot project. Simpler soil conservation measures were favoured, but most of them gradually disappeared.

In 1967 the Government initiated an FAO forestry and watershed management project, which prepared a national soil conservation programme and established the Smithfield training and demonstration centre. Its recommendations were followed up by two large integrated rural development projects in the western and central parts of the island. The project in the central region focused on multiple cropping systems on terraced land. However, because of absentee land owners and disinterest, the measures could not be executed on a microwatershed basis and were often insufficiently maintained (Blustain, 1982). Besides, the generous subsidies (up to 75% of all terracing costs) allowed farmers to make profits by hiring local labourers.

Attention to the eastern part of the island was given by FAO Project JAM 78/006 (here referred to as the FAO project), that was involved in institutional strengthening and watershed planning from 1980-1982. The project provided in-service training courses to 20 counterparts, made plans for six major watersheds and prepared a follow-up project, which in adapted form was implemented as the IFAD-Hillside Farmers Support Project (IFAD, 1988).

Human influence on ecological systems

Most of the watershed areas remained under natural forest until after the British occupation of the island, in 1655. The introduction of coffee after 1717, applying fire clearance and clean weeding, caused much man-made erosion and this was aggravated when ex-slaves acquired small plots of land after 1838, and population pressure increased (McGregor and Barker, 1991). As a result of high rainfall intensities, steep slopes and erodible soils, natural rates of soil erosion are quite high in the watershed areas (Vernon and Jones, 1959; Barker and McGregor, 1988). On the basis of land use mapping and the USLE formula, the FAO project estimated in 1982 the overall soil erosion for the Kingston watershed areas at over 100 t/ha/year (FAO, 1982). More than half of this erosion was assumed to be derived from the 10% of the area under annual crops, part of which was rented land. Other land use consisted of perennial crops, 'food forest', mixed plantings, grassland, fallow or 'ruinate' and governmental forest land. Recent small scale erosion research in the upper watershed areas suggests that the erosion rates were over-estimated. This research found (sheet) erosion rates for farm land and natural forest of 16 and 1 t/ha/yr respectively (McDonald et al., 1993). On the basis of suspended sediment data in the Hope River over 1988-1990 a mean annual sediment yield of 13.7 t/ha was calculated. A sediment delivery ratio of 0.5 would then give an erosion rate of about 30 t/ha in this small and steep watershed. However, since soils are derived from shales and other materials with high soil formation rates, farmers do not mind much about erosion (Lindsay and Douglas, 1992).

The water supply situation

Since 1930 the Jamaican Government has had difficulties coping with the water demand of Kingston, in particular after years of severe droughts. Soil erosion, sedimentation in the Hermitage reservoir, and surface and ground water contamination have reduced water supplies over the years. In 1980 domestic water for Kingston was supplied by surface water and by 18 deep wells, supplying 104,000 and 68,000 m^3 per day respectively. Surface water was obtained from the Hermitage- and Mona-reservoirs (with storage capacities of 1.8 and 2.7 million m^3) and from three rivers outside the area. Watershed management is needed to induce a more continuous flow of surface water, without reducing the supply to the wells.

Intensive water supply studies have been made since 1966 (Champion, 1966), and the need for a long term programme has long been recognised, but financial considerations have often proved to be a barrier (McBain, 1985). Some investments have already been made, such as the 30 km pipeline (including a tunnel) between the Yallahs river and the Mona reservoir (Porter, 1990). It cost in 1985 about US$ 26 million and adds some 60,000 m^3 per day to the Mona reservoir. In 1989 the Water Resources Development Masterplan analyzed the water supply and demand situation up to the year 2015. It drew up water balances for ten areas regrouping the island's 26 watersheds. Table A 10.6 shows the water balances for Kingston and St-Andrew and for the two adjoining areas now supplying Kingston's drinking water. It also shows the situation in the northern part of the Blue Mountains, that contributes 45% of total surface water run-off on the island, and which may be the ultimate source of additional water. However, this requires the laying of a costly pipeline through the Blue Mountains.

Table A 10.6 *National water balance of Jamaica, by watershed (1989)*

	Watershed areas					
	Blue Mt. South	Kingston St-Andrew	Rio Cobre	Blue Mt. North	Other watersheds	Total island
Water supply (million m3/yr)						
Rainfall	1,694	312	2,009	5,068	......	21,212
Evapotranspiration	912	208	1,450	2,346	......	11,945
Surface water run-off	662	81	187	2,452	......	5,576
Groundwater discharge	120	23	372	270	......	3,691
Exploitable surface water	96	10	15	334	......	666
Exploitable groundwater	53	36	404	270	......	3,419
Water use (million m3/yr)						
Non-agric.: present	4	72	45	12	......	232
2015	8	113	59	17	......	346
Agricultural: present	12	2	260	12	......	682
2015	62	2	391	31	......	1,338

Note: Exploitable stands for minimal reliable supply.
Source: GOJ, 1989.

Table A 10.6 illustrates that in 2015 the exploitable water resources from the three southern areas will not suffice for Kingston's water needs. Further measures are required to increase production. Since part of the groundwater under Kingston is subject to pollution, it is planned to replace this with water from the Rio Cobre area, used for irrigation.

Watershed development planning

The target farm households

Experiences of projects in other areas and the 1980 socio-economic survey data (de Graaff et al., 1981) showed that the mini- or hillside farmers are facing many constraints, and that it is important to differentiate between farm households. From the ten farm patterns distinguished in the Kingston watershed areas, only two farm patterns constituted full-time, progressive farmers, interested enough to participate in terracing their land for annual cropping and/or engage in tree crop plantations. The 1981 financial analysis indicated that for such farmers these activities were viable on moderately sloping land (see below). Three other farm patterns represented farmers with an intermediate level of management with low off-farm earnings and some land of their own. The financial analysis indicated that for such farmers terracing would not be a viable option, but that tree crops would be an attractive investment.

Of the other five farm patterns, with low levels of farm management, two had quite high off-farm earnings, while two others had only rented land on steep slopes. The FAO project suggested providing the latter with support in off-farm employment (technical and financial aid, and vocational training). This was taken up by the IFAD follow-up project.

The FAO project prepared plans for the watershed areas: Rio Pedro, Wagwater, Hermitage, Hope River and Upper and Lower Yallahs. Since 80% of the area constitutes private land, the emphasis was on farm development. To test the technical feasibility, economic viability and social acceptability of the various soil conservation measures (developed at Smithfield), the FAO project established two pilot zones of about 40 ha in 1980, where two different approaches for implementation were followed. The attempt to implement a conservation plan for a whole sub-watershed in Rosemount (Wagwater) failed for various reasons, while the concentrated individual approach in Mount Charles (Upper Yallahs) was more promising. Tree crops (coffee, cocoa and citrus) were most successful.

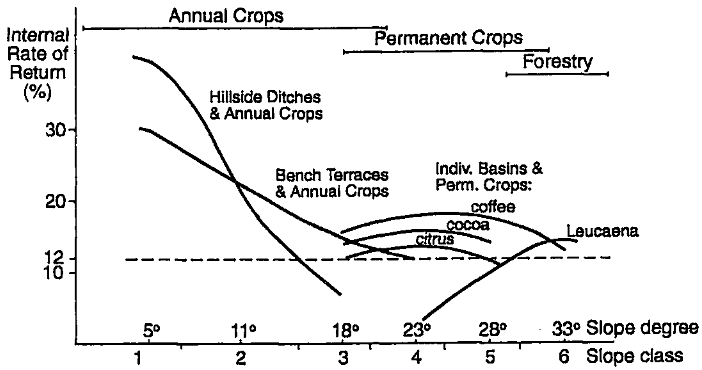
Screening of watershed development components

In the framework of the watershed planning activities of the FAO Project, a detailed cost-benefit analysis was undertaken for the major conservation and production activities, tested in the pilot-implementation areas (de Graaff, 1981). This included: hillside ditches and bench terraces with annual crops, tree crops (coffee, cocoa and citrus) with 'individual basins', and forestry. The forest species were *Leucaena leucocephala, Pinus caribbae* and Blue Mahoe (*Hibiscus elatus*).

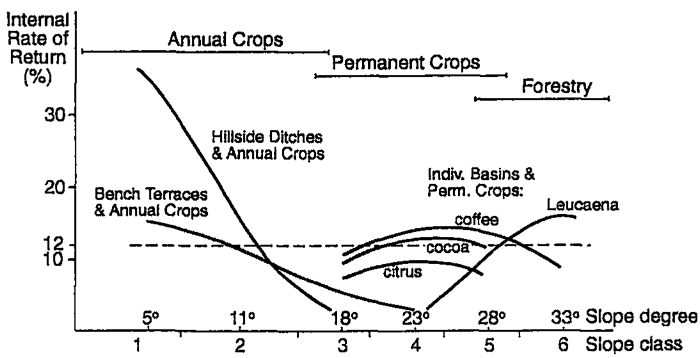
In the analysis special attention was paid to differences in costs and benefits of the activities, when applied on land with different slopes and soil depths (de Graaff and Sheng, 1994). A distinction was also made between public and private land and between three levels of management of private land users (advanced, intermediate and traditional). Differences in level of management were reflected mainly in use of material and labour inputs. For all interventions an economic lifetime of 20 years was considered and the downstream benefits of the conservation measures were not included.

Figure A 10.2 shows the results of the financial analysis on private land for two levels of management. On the horizontal axes the slope classes (1-6) and the middle value within each slope class (in degrees) are presented. On the vertical axes the internal rates of return on investment in the activities are presented. The 'without-case' was defined as a continuation of annual cropping on the slopes, with a declining production due to on-site erosion. Erosion increases with slope. Therefore each activity shows a peak at a particular slope, in which situation the efficiency (cost/benefit relationship) is highest. Some conservation measures are more efficient than others for one slope range and less efficient for another slope range. In Figure A 10.2 a distinction is made between the efficiency of interventions for (a) farmers with a relatively advanced level and (b) those with an intermediate level of management. For farmers with a relative advanced level of management the optimal land use is to cultivate annual crops and establish hillside ditches on land with a slope below 11°, to grow annual crops on bench terraces on land from 11 - 18°, to grow coffee (or cocoa) on land from 18 -30°, and to plant Leucaena on land from 30 - 33°. Steeper land should not be planted at all. Such recommendations correspond with the recommendations made in the land capability classification (Sheng, 1972). For farmers with an intermediate level of management the benefits of bench terracing only exceed the costs at slopes less than 11°, when hillside ditches provide sufficient erosion control and are more cost-effective. These farmers should apply hillside ditches with annual cropping on slopes less than 15°, plant tree crops on slopes between 15 - 28°, and plant Leucaena on slopes from 28 - 33°.

For public land the analysis is different (Figure A 10.3). Government land is acquired for protection purposes and is always steep. Annual cropping is not considered on such land and squatters are prevented from doing so. The 'without-case' is defined as a situation of gradual deforestation and unproductive natural vegetation, of importance for erosion control. Therefore the curves are only downward sloping: the efficiency is highest on the least cumbersome slope. The Government was interested in investing in tree crops (coffee and citrus) and forest plantations. For the latter a credit line was available from the Commonwealth Development Corporation (CDC) at an interest rate of 6.5%. Figure A 10.3 shows that it would be attractive for the Government to plant tree crops on slopes from 18 -28°. In higher zones with steep slopes Blue Mountain coffee can be planted. This fetches premium prices on the world market. For reforestation Pinus could be considered on very steep slopes. The firewood species Leucaena could be an option on lesser slopes. Figure A 10.3 makes clear why fierce discussions were held about the choice between coffee or pine forest on public land. Intercropping of coffee in pine forest was tried, but not successful.



A. Private farms with relative advanced level of management



B. Private farms with intermediate level of management

Figure A 10.2 *The efficiency of SCWD activities on private land, by slope and level of management (FCBA)*; social discount rate of 12%.

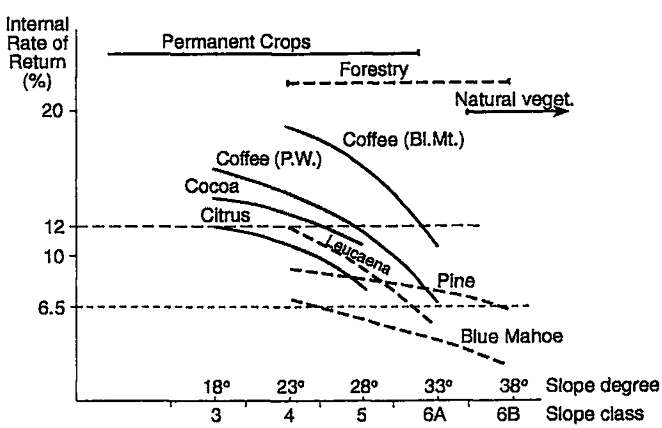


Figure A 10.3 *The efficiency of SCWD activities on Government land, by slope (FCBA)*

11 INCENTIVES FOR SOIL CONSERVATION AND WATERSHED DEVELOPMENT

Si quelqu'un te lave le dos, il faut que toi-même tu te laves le ventre. If someone washes your back, you have to wash your belly yourself (Mossi proverb, cited by Minnaard, 1994).

Introduction

The case studies have clearly shown the importance of incentives to stimulate farmers to invest in soil and water conservation measures. Both in semi-arid zones and sub-humid mountainous zones farmers seldom undertake such activities without outside support, since the benefits only partly accrue to themselves.

In semi-arid zones, subject to gradual soil depletion, future farmers are the main beneficiaries and in sub-humid mountainous zones it is often the downstream communities that benefit most from upland conservation activities. Figure 11.1 shows typical profiles of costs and benefits of soil and water conservation activities in semi-arid (A1-A3) and sub-humid mountainous zones (B1-B3), respectively. In semi-arid zones costs comprise erosion control and fertilization measures (or land use conversion as in Tunisia). After early benefits because of water retention, further soil fertility-related benefits only develop slowly. The farmers' contribution to the costs is limited to the extent of their benefits (Figure A2), and it is up to the government to provide subsidies and possibly long-term credit repayable by future land users (Figure A3). In the sub-humid mountainous zones investments costs (e.g. of terracing or tree crops) are generally higher, but so are the potential benefits. Where there are downstream benefits, cost sharing would be appropriate, which would allow farmers to recuperate their share of the costs (Figure B2) and the government to recuperate its contribution through taxation of downstream beneficiaries.

In taking care of the interests of future and downstream farmers affected by land degradation, governments should clearly define the objectives and instruments of incentive policies, and establish rules for their implementation (Colman and Young, 1989). However, as is implied by the Mossi proverb above, governments can only be expected to offer a hand on behalf of future and downstream farmers. The present farming community has to be convinced of the short- and long-term effectiveness of conservation activities, and should commit itself to a reasonable contribution to cost recovery.

In Chapter 5 various types of economic incentives were presented in connection with two other options: regulatory measures and moral persuasion. The rationale and purposes of incentives are reviewed below, after which the incentive systems that were applied in the case study areas are discussed. From this discussion lessons will be drawn for future project preparation and appraisal.

11.1 Rationale for and purposes of incentives

Incentives constitute general or targeted government interventions, which can be based either on the efficiency rationale or on other major objectives, such as equity and sustainability (Sadoulet and de Janvry, 1995). In soil conservation and watershed development projects both arguments are valid. Major forms of market failure that legitimize government interventions in this field are the public goods nature of (much of the) land and water

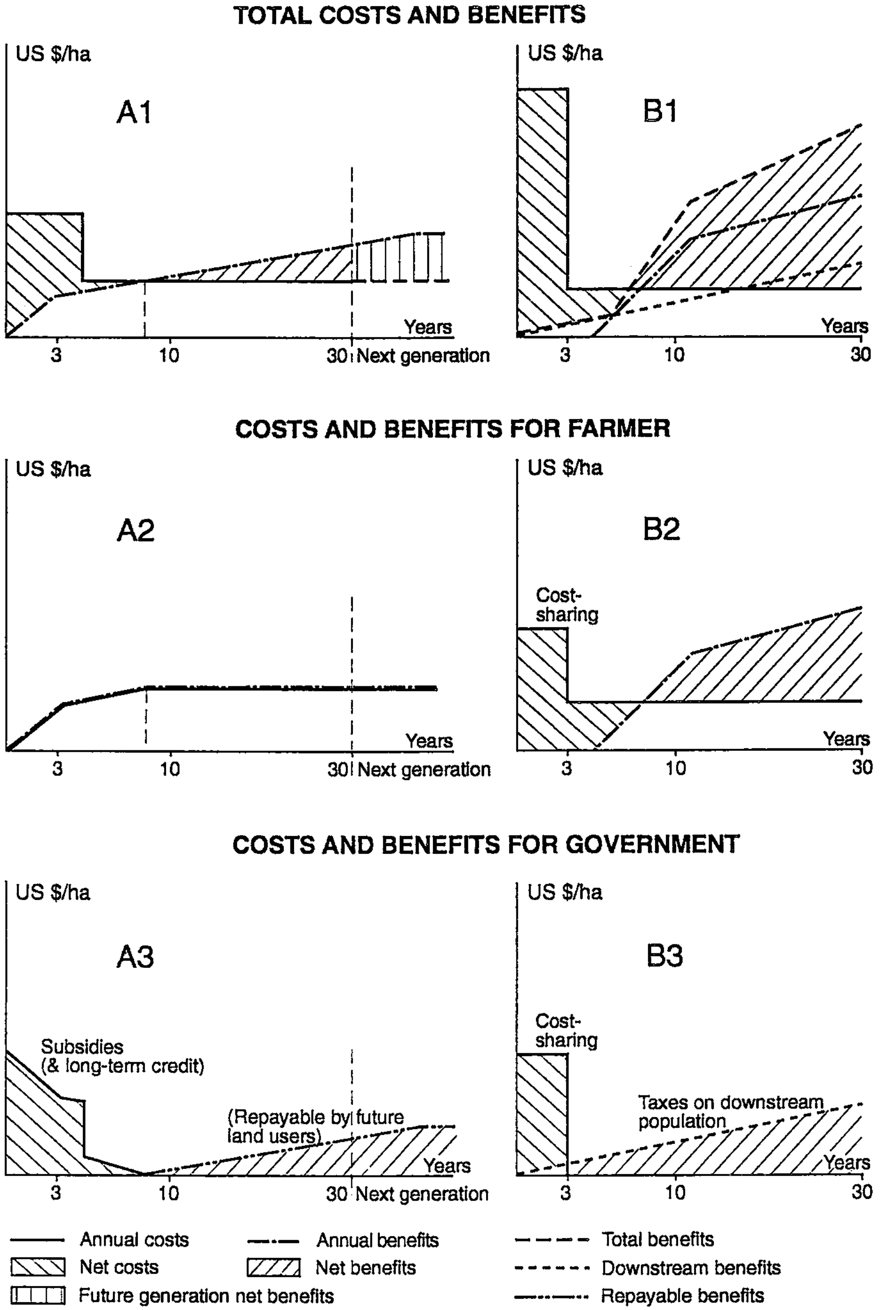


Figure 11.1 *Typical profiles of annual costs and benefits of soil and water conservation measures, showing the need for incentives (A1-A3: semi-arid zones; B1-B3 sub-humid mountainous zones).*

resources and externalities such as downstream effects (Chapter 3). Other arguments like economies of scale and market power are less important here. Sadoulet and de Janvry (1995) have added transaction costs and imperfect information as recognized forms of market failure. These may play a role in semi-arid zones and sub-humid watershed areas, where the institutional infrastructure is generally weak: markets for inputs, outputs and finance can be distorted or lacking and limited opportunities may exist for information exchange.

Non-efficiency oriented interventions are motivated by intra- or inter-generational equity, sustainability or security considerations. These often play an important role in SCWD projects. Table 11.1 shows the most likely arguments for targeted government intervention in the case study areas. In Burkina Faso the productivity of (officially publicly-owned) land needs to be restored to ensure food security for present and future generations. Because of the risk of crop failure and the weak institutional infrastructure, the present population cannot achieve this on its own. In Tunisia regional income (re)distribution objectives also played an important role. In Indonesia and Jamaica the long-term efficient use of 'national' water resources demands soil and water conservation in upland watersheds. The relatively poor upland farmers have to be compensated for that part of the costs of conservation measures from which they do not derive benefits themselves. In Indonesia the intrusion on public forest land may justify intervention.

Table 11.1 *Rationale for Government intervention in case study areas*

Case study in:	Public goods		Externa-lities	Transact. costs	Income distrib.	Future generat.	Food security
	land	water					
Burkina Faso	x			x		x	x
Tunisia	(x)				x	(x)	x
Indonesia	x	x	x		x		
Jamaica		x	x	x	x		

Incentives can be *defined* as: any stimulus positively influencing the willingness and/or potential of an individual or organization to undertake a 'desired' action, or to abandon an 'undesired' action (van Campen, 1993). Incentives for SCWD activities are meant to change the behaviour of the land user. In a broad sense incentives could cover all activities which increase the chance that a land user will adopt the recommended soil and water conservation activities. This follows the general patterns of *adoption* of agricultural innovations (Rogers, 1962; Feder et al., 1985). Following the steps distinguished in Figure 3.1, incentives could constitute extension efforts to make farmers aware of erosion and of control measures, consist of material and financial instruments (e.g. subsidies, credit) and institutional interventions to reduce the material constraints to adoption, and could also help to eliminate other reasons for reluctance (e.g. risk, traditions).

In this study the focus is on targeted material and financial instruments, or economic incentives. Most analyses of policy interventions concern price and subsidy measures, where most attention is paid to the more or less immediate market response. The effects of incentives for SCWD should preferably be divided into short-term response effects and gradual long-term effects (e.g. actual and future production, consumption, trade, etc.).

Actors concerned

Within the framework of project preparation and appraisal, incentives are required when a project scores sufficiently high on most evaluation criteria, but is not (financially or otherwise) attractive enough for one or more major actors. These actors could be compensated if the project creates sufficiently large positive externalities that benefit non-target groups or society at large. If no compensation is given, a conflict of interest arises which may well lead to project failure. Major actors concerned about the on-site effects in semi-arid zones are present local farmers, future farmers and the government of the country. In areas with important downstream effects, downstream communities form an additional major group of actors. In countries receiving much development assistance, the international (donor) community is also an important party. Incentives will not be needed when the activities benefit or satisfy all categories of actors. De Janvry et al. (1994) refer in this case to a win-win-win situation. When one of the group of actors is faced with a loss of income, while others gain income, a transfer could achieve compensation.

When for equity reasons the project focuses on the poor, these would form an additional group of actors to be considered for the determination of the incentive structure. Intermediary actors, such as project organisations, credit agencies, cooperatives, etc. are also important interest groups, that need to be given adequate incentives in the form of trade margins or allowances to operate adequately. For these groups a financial analysis is usually undertaken in CBA.

Incentive system

The effectiveness of economic incentives depends on several *institutional factors*. The transfer of control over usufruct or ownership rights of land and water resources from central government to local communities, households and individuals may constitute an important prerequisite (van Campen, 1993). Farmers can only respond to incentives if they are *well-informed* about appropriate technical solutions and their short and long-term effects, and when they have received extension training in these techniques. *Extension* services therefore play a crucial role. Other important prerequisites for an adequate response to incentives are *infrastructural* elements such as roads, access to markets for inputs, output and credit, which Mosher (1969) considered to be essential for a progressive rural structure.

While the emphasis here will be on direct or targeted incentives, *indirect or general incentives* or general policy instruments can also play an important role in changing farmer's behaviour towards conservation. Examples are pricing measures, elimination of market distortions, general fertilizer subsidies, educational programmes, changes in interest rates and the foreign exchange rate, etc (Section 5.4). In the framework of structural adjustment programmes, intended to raise agricultural prices and output, many developing countries have reduced public support to the agricultural sector. Because of these lower budgets and the fair trade conditions imposed by GATT (now WTO), there is now less room for general farm incentives. The argument that farmers should be able to withstand worldwide competition lacks conviction, however, since the support to farmers in developed countries often exceeds that in developing countries. The producer subsidy equivalent (PSE, which stands for the amount of support as a percentage of the total value of production) in the OECD countries in 1992-93 was no less than 44%, and in Japan it was even 71% (Pretty, 1995).

Direct financial incentives to farmers as a policy instrument for conservation are quite common in developed countries. In many states in the U.S.A. cost-sharing arrangements are applied, and in the United Kingdom standard payments and capital grants are provided. The first are offered as an inducement to accept constraints on farm operations or to engage in additional activities that are beneficial for conservation, and can be seen as a compensation for costs incurred. The latter are subsidies on environmentally beneficial capital investment (Crabtree and Chalmers, 1994). Conservation grants for walls, hedges, shelterbelts, etc usually constitute 40 - 50% of the investment. With standard payments one should carefully select the target population, whose change in behaviour has the highest impact on public benefits (e.g. farmers on steep slopes or erodible soils). If not, uptake may be low or costs become excessive, depending on the payment in relation to cost.

Where a well administrated land tax system exists, governments can also use these to change farmers' cultivation patterns. Panayotou (1991) advocated a progressive land tax, varying according to slope, for rubber on steep slopes in Thailand. However, most developing countries do not have the means to supply targeted grants to their large number of hillside farmers, and they seldom have adequate land taxation systems. Therefore large scale conservation programmes in these countries have made much use of food aid and input subsidies, provided through foreign aid.

Purposes and types of incentives

Based on the indicated rationales for intervention, the major *purposes* of incentives in SCWD programmes in developing countries can now be listed as follows:

Rationale:	**Purpose (and possible type of incentive)**
Public goods (land)	- To prevent farmers from growing certain annual (food) crops on erosion prone (land) steep slopes; land use conversion or land retirement (temporary food aid or alternative employment could be appropriate incentives in this case);
Externalities; Public goods (water)	- To reconcile private and public interests in land and water resources, whereby the government represents the interest of downstream population (adequate overall economic rate of return, but for upland farmers only financially attractive with incentives);
Transaction costs	- To incite farmers to participate in SCWD components, that may generate sufficient net benefits to farmers, but only after a certain timelag (adequate financial and economic rates of return); improved access to credit may suffice in this case; - To create a more positive attitude towards conservation activities, among others by reducing risk (financial and economic rates of return both sufficiently high);
Intragenerational equity	- To prevent farmers in backward rural areas from abandoning the land and moving to town, where unemployment is high; - To stimulate semi-nomadic people to settle and apply more sustainable farming systems (move away from shifting cultivation);
Intergenerational equity	- To reconcile private and public interests in land and water resources, whereby the government represents the future population (economic rate of return sufficiently high, but for present farmers only financially attractive with incentives);
Food security	- To restore land productivity to achieve food security for present and future generations (incentives to improve soil fertility).

Table 11.2 *Various types of incentives used for selected SCWD components*

	Incentives						
	Credit	Subsidies		Food	Facilities	Cultiv.	Extension
SCWD components		cash	kind	aid	for free	rights	training
Soil & water cons. measures:							
Stone/earth bunds				(x)	x		x
Vegetation strips			x				x
Terracing		(x)	x	x			x
Fertiliz. materials			x		x		x
Land use conversions:							
Tree crops	x		(x)	(x)			x
Grass/fodder crops			x			x	
Reforestation	(x)		x	(x)	x	x	x
Leaving land to rest		x		x			

Table 11.2 shows what type of incentives are often provided for different components. While the focus may be on one incentive, in most cases there are more objectives at stake and use is made simultaneously of several incentives. Although a general service to farmers, extension is added to the list of incentives, since most projects provide additional, specialised extension training to participants in their programmes (also for moral persuasion).

In the Burkina Faso case study the main incentive in the establishment of stone rows is the provision of transport. A major issue there is the search for possible incentives to increase the use of organic and inorganic fertilizers. In the Tunisian case study a combination of soft credit, subsidies and food aid was used to promote the planting of tree and fodder crops. The Hillside Farmers Support Project in Jamaica focused largely on the provision of credit for coffee, cocoa and small scale enterprise development. In other areas in Jamaica generous subsidies had been provided for terracing. In Indonesia so-called INPRES funds are made available for the two major soil conservation components. In the case of checkdams the contractors are reimbursed and in case of terracing the coordinating agencies provide subsidies (in cash and in kind) to all farmers in the 10 ha *demplot* areas. The effectiveness and impact of this type of incentive can only be evaluated after several years.

A quite different situation, with other type of incentives, is that whereby the government offers incentives to farmers in order to change their *attitude towards open access resources* such as public forest land. Governments realise that their reforestation activities are bound to fail if they do not involve the local population. This is the case in the Konto River watershed, where the poor local population has always considered it their right to collect firewood and fodder from public forest and shrubland. On reforested land this would no longer be possible, unless firewood and fodder trees were included. The landless and small farmers are therefore involved in the reforestation schemes and are granted certain incentives for their participation.

In the next two sections the different incentives for soil conservation and sustainable agricultural activities are reviewed in the four case study countries. An investigation is made as to why certain incentives were chosen for the major SCWD activities, whether these incentives were appropriate and to what extent they have been effective. The situation in Jamaica is discussed before that in Indonesia, because of the special attention to reforestation in the latter case.

11.2 Incentives to prevent land degradation in semi-arid zones

In semi-arid zones the emphasis is on erosion control and soil fertility measures to increase (on-site) production and income of both the present and the future population. Incentives to compensate farmers for part of the costs are needed for two reasons (Figure 11.1): since these costs are only gradually recuperated by benefits and since a part of these benefits accrues to future generations. For the first reason, the provision of long-term credit would suffice, but for the second reason a transfer payment (subsidies) to farmers is needed from the government that then acts on behalf of the future population.

Incentives used in sustainable agriculture in Burkina Faso

Free facilities

For the establishment of stone rows, farmers in several areas in Burkina Faso benefit from transport facilities from projects and/or government agencies. The analysis in Chapter 9 illustrates that the use of donkey carts for stone transportation is cheaper from a national economic point of view, but since the transport by lorry is free of charge, farmers seldom use donkey carts for this purpose, and wait their turn for the lorry.

The Regional Agricultural Office (CRPA) in Kaya did in fact offer farmers credit for a donkey cart when they had constructed a compost pit. Farmers participated in this programme mainly in order to obtain a donkey cart for multiple use, but did not yet appreciate the compost pits. It is therefore also doubtful whether farmers would use the donkey carts for stone transport, when they could acquire them on credit or subsidized. The use of lorries could theoretically also be justified on the grounds that it may accelerate the establishment of stone rows and that the responsible agencies can steer the programme towards the conservation priorities. On the other hand it creates an attitude of *dependency* among farmers, who are not involved in the planning of conservation measures, and will also wait for the next steps on government assistance. Once the project or programme terminates, farmers will not be ready to continue stone row construction. Besides, this dependency will reduce efforts to shift towards other measures that they could implement themselves, such as grass strips and hedges, even though these appear to be less effective (Section 9.3).

Subsidies on inputs

The term subsidies in fact covers a large number of incentives, which range from free or subsidized inputs, such as seedlings and fertilizers, payments for conservation works on the own farm, subsidized credit, use of facilities at subsidized rates, etc.

The provision of good quality free of charge *seedlings* for trees and tree crops can be an important contribution when commercial nurseries do not exist in an area. However, for the promotion of tree crops on a large scale, it may be better to assist in the establishment of cooperative (farm group) or commercial nurseries. The Ministry of the Environment and Tourism in Burkina Faso assists village farmer groups in the establishment of temporary nurseries for village forests and private tree plantings.

For the earlier mentioned programme of *compost pits* in Burkina Faso, farmers could obtain a few bags of cement to reinforce the pits. The first bags were given in the first year free of charge, but thereafter the subsidy rates were gradually reduced. Without the free cement farmers do not reinforce their compost pits. The increased lifetime and 'quality' of reinforced compost pits are benefits that are hard to assess by farmers.

A major issue in Sahelian countries is to find appropriate incentives to stimulate farmers to apply more *fertilizing materials*. The target group of farmers in densely populated villages are generally aware of the importance of using mulch, compost and manure, but do not have enough of these materials to apply it on more than one or two plots. It has to be supplemented with external, inorganic fertilizers, to have major effects and to allow them to farm less land in a more sustainable way. Many farmers operate more or less outside the monetary economy, and most others have so little cash from non-agricultural activities or migration, that it does not exceed the family and community demands that are more pressing than the investment in soil fertility. Data from various Sahelian countries show that the application of *inorganic fertilizers* to food crops only becomes widespread and reaches significant levels (over 25 kg/ha) after the area of cultivable land available per capita falls below approximately 0.2 ha (FAO, 1995a). In such case yields should reach 1 t/ha to maintain self-sufficiency (about 200 kg grain per capita per year). The case study shows that in the more densely populated villages on the Central Plateau in Burkina Faso cultivable land per person is already close to 0.2 ha, and that in these villages farmers are more inclined to intensify land use with fertilizers (Table 9.6 shows that soil fertility is lower too). This seems to confirm the theory of Boserup (1981). Since farmers may only adopt fertilizer application when yield increases are about two or three times as high as additional costs, a system could be devised whereby farmers can obtain subsidized fertilizers (e.g. urea and Rock Phosphate) after making investments in stone rows, compost pits, mulching, etc. The subsidy rate should gradually diminish over time, and take into account drought periods.

It is generally argued that a *temporary fertilizer subsidy* may be justified in some cases to assist the adoption of the use of fertilizer in a particular region. The only theoretical case for a permanent subsidy would be the existence of a non-optimal tax on output for public revenue purposes. The temporary subsidy is justified primarily for highly fertilizer-responsive crops such as irrigated rice and maize. The same rationale can be applied when the goal of the government is to increase self-sufficiency (food security), despite the fact that the objective is usually not economically efficient. In both cases, using subsidies for highly responsive crops will be more effective for the treasury than using output price support (Ward and Deren, 1991). However, this type of subsidy is not recommended in the countries of the Sahel because of poor fertilizer response of the crops grown there (Binswanger and Shalit, 1984).

Table 9.19 in Section 9.6 shows that higher urea prices reduce the efficiency of fertilizing considerably. If urea prices are CFAF 255 per kg, only the high level applications with stone rows, that bring the nitrogen balance in equilibrium, are efficient. With a 33% subsidy, fertilizer use clearly becomes more attractive to farmers, even at sub-optimal rates (e.g. of only 100 kg/ha) and without stone rows. Although the subsidy will increase fertilizer use, it is not evident that it will lead to the most appropriate use of fertilizers. Besides, food production in the case study area is mostly for home consumption and most farmers have insufficient cash income to pay for fertilizers. It is a financial (or income) problem, which, because of a lack of repayment capacity, cannot be solved with credit.

In the more densely populated villages on the Central Plateau, emphasis has to be laid for the time being on balanced-external-and-internal-input agricultural systems (*BEIA*), as opposed to the LEIA and HEIA (low and high external input) systems.

Incentives used in sustainable agriculture in Tunisia in the 1970's

Long-term subsidized credit
In the Tunisian case study project a conversion from annual crops to tree and fodder crops was envisaged. Credit could eventually be recuperated through the sale of olives, almonds and pistachios. However, because of the long gestation period of the tree crops (olives and pistachios only bear fruit after 10 years) a long grace period and very low interest rates (0% in early years and 3% later) were applied. In addition, only part of the loan had to be repaid, and this soft credit was also accompanied by food aid. Because of the long period involved, effects of droughts, and mixing of credit with subsidies, the final repayment rate was not very high. The project objectives were not only directed towards farm income and conservation, but also to interregional equity considerations of the central government. At project identification, the government was concerned about the relative backwardness of the central-southern part of the country, and it feared that the inland population in this area would move to already crowded northern and coastal zones. The areas had to be developed to stimulate the semi-nomadic population to settle more permanently. Part of the objective was to transfer income towards relatively backward areas, which this country (as minor oil producer) could apparently afford. The long-term subsidies to farmers and the final results of project activities have certainly contributed to this last objective, but it is hard to analyze whether it has been cost-effective, and credit was not provided in an appropriate manner.

Agricultural credit is often not a viable option in semi-arid zones, because of the high degree of poverty, the insecure land titles of farmers and lack of other security, the large climatic fluctuations combined with the risk of other calamities (hailstorms, locusts, etc.). Farmers concentrate heavily on food crops for their own consumption and their repayment capacity is low. Credit for investment in soil conservation measures, with their long term impact, is therefore an unlikely option. Even for water harvesting measures, with their faster and less risky returns, repayment capacities may limit the opportunities for credit.

Because of the fact that for smallholders in developing countries the strict distinction between credit for productive and consumptive purposes does not always make sense, the focus is now more on strengthening *rural financial systems* (e.g. through savings and credit schemes) than on the provision of agricultural credit (Moll, 1989).

Food (aid) for work
For the Tunisian Government the WFP food aid formed, together with credit and extension, part of the incentive structure to achieve the above mentioned regional development objectives. For the farmers (and former herdsmen), on the other hand, it constituted a directly targeted incentive to undertake planting activities, and to give up at least part of the cultivation of food crops. If food production were indeed to be reduced, there would be less fear of the displacement effect of food aid.

Although the food aid did not always arrive in time, did not always contain the prescribed commodities (e.g. yelllow maize instead of wheat flour, soya instead of olive oil) and was not always consumed by the farmers themselves (e.g. cheese), the food aid as such was generally appreciated. It was indeed seen by farmers as a compensation for the *hard work* involved in digging hundreds of 1 m^3 planting holes, planting fodder and trees and making eyebrow terraces, etc. Many participants did also reduce their cereal acreage, but in the province as a whole the area under cereal cultivation did not decline much.

Apart from issues related to the effectiveness of food aid, discussed in Chapter 5, there is also the economic issue of the *valuation of food aid* in economic evaluations. Keddeman

(1992) found that food as payment for soil conservation works could either be considered as a cost or as an incentive payment. If it would have been imported anyway and current consumption is the main objective of the country, food aid constitutes a cost. In the second case food is a means of financing only and has no economic value as such. The opportunity costs of labour for undertaking the soil conservation works, for which food rations are provided, is then the real cost.

Planting activities in Tunisia were not very efficient, but probably contributed to the political aim of interregional equity. The costs in terms of food aid, subsidies, credit and operational costs were quite high, and the internal rate of return for investment in tree and fodder crops was only about 3%. However when the food aid donation is not considered to be a cost, and the lower opportunity cost of labour is considered, the IRR increases to 7%. This would probably have satisfied the government, which took charge of the other incentives (subsidies, partly not recovered credit and operational expenses).

Lacking in most evaluation studies is an assessment of the nutritional benefits of food aid, which could be substantial in situations of severe malnutrition. But in practice different types of food aid are reserved for different groups, and food aid for soil conservation should not be confounded with food aid for poor, malnourished people and with emergency food aid. The SCWD activities should be economically efficient and become financially attractive once the food aid is terminated.

11.3 Incentives to protect upland watershed areas in sub-humid zones

In sub-humid mountainous zones the emphasis in SCWD projects is often on controlling the massive erosion in order to prevent downstream sedimentation and deteriorating hydrological conditions. This is most urgent once sedimentation in reservoirs has passed the dead storage stage. Reforestation, gully control works, tree crops and terracing are the major activities. The first two usually constitute a government responsibility, whereby gully control could be considered as part of reservoir maintenance activities. The other two are usually individual farm activities, which have high short-term costs and slowly emerging long-term benefits. As in the semi-arid zones incentives to farmers are also needed here for two reasons: to bridge the period when costs are not yet compensated for by benefits, and to compensate local farmers for that part of the benefits that accrues to the downstream community. For the first reason, the provision of long term credit would suffice, but for the second reason a transfer payment (subsidies) to farmers is needed from the government acting on behalf of the downstream population. By collecting water fees and taxes on electricity from the downstream population, the government could recover these funds immediately.

Incentives used in SCWD activities in Jamaica

Subsidies for terracing

Blustain (1985) reviewed the IRDP project (1977-1983) that was designed by the Government of Jamaica and USAID to encourage small hillside farmers to conserve their soil resources. He argued that the project had not reached its objectives after five years of intense activity, largely because of the unproductive manner in which farmers were induced to participate. The project's target was to reduce the average erosion rate from 54 to 7 t/ha/year, two years after the project ended. Blustain analyzed in particular the terracing component, and looked mainly at four aspects: appropriate technology, unit of action, incentives and sustainability. He doubted whether terracing was the right technology, since it was hard for farmers to replicate on their own, and he argued that more group action should have been promoted. The system of generous grants and subsidies set the tone for farmers' expectations and attitudes. Apart from various subsidized inputs, the project paid 75% of the establishment costs of terraces, at the official wage rate. However, farmers hired labour at lower rates and were able to make a small profit on terracing. An important operational indicator of project activity was the number of farm (conservation) plans drawn up, approved and implemented. Farmers and field staff together achieved a high success rate in terms of area treated, but very little emphasis was given to maintenance. Many treated areas deteriorated after a few years and some land was not cultivated after treatment. Blustain attributed the generous use of subsidies to the highly centralized and 'clientistic' Jamaican political culture, heavily influenced by the competition between the two political parties. Average increases in public spending in the period 1959 and 1977 were, for example, twice as high in election years as for the entire period. The rural sector played an important role in this 'clientistic' system.

Subsidies for tree cropping

Because of the problems with terracing in this IRDP project, and the conclusion by the FAO project that terracing would only be an attractive investment for farmers with an 'advanced' level of management, the emphasis shifted to vegetative measures, and in particular to the planting of tree crops. One important proponent is the USAID Hillside Agriculture Project, the broad objective of which is to fund self-managing projects that promote production and productivity of perennial crops. A 1992 impact evaluation report of this project (USAID/Jamaica, 1992) states that 'the impact on both productivity and production is clearly positive', but this assertion is largely based on guestimates. Impact on income, living standards and degradation remains unclear, due to a lack of monitoring. The report paid little attention to the incentive systems. Lewis (1994) analyzed the incentive system for a cocoa sub-project. She argued that the incentive system consisted of both general policy measures and targeted incentives to groups and individual farmers. The first comprised the deregulation of cocoa marketing; institutional strengthening through grants to cooperatives; and education about cocoa and simple conservation techniques. The targeted incentive consisted mainly of crop-lien, interest free, credit for inputs, of which 50% would be granted upon adoption of the improved management practices. Special grants were given to farmers who reached high production levels: 'more than six boxes of wet cocoa'.

Farmers said that access to inputs was the main reason for their participation. Despite the subsidies, most farmers did not adopt all improved practices and fell into the 'modifiers' category in between the categories of 'adopters' and 'non-adopters' (Lewis, 1994). Considering the budgetary restrictions under the Structural Adjustment programme, it is questionable whether these subsidized activities can be continued after withdrawal of USAID.

Credit for tree cropping

The IFAD Hillside Farmers Support Project has also focused on tree crops (coffee and cocoa), but has developed as a 'credit project'. In comparison to those in semi-arid zones, farm households in sub-humid mountainous zones generally have more choice in farm enterprises and more often have cash revenues. Climatic conditions are also less uncertain. The provision of credit for tree crops (to replace annual crops) is therefore feasible as long as there are good market opportunities for the tree crops, and the crop is marketed through official channels.

The two original objectives of IFAD were: raising income at farm level and improving soil conservation practices, whereby the lack of access to credit was seen as major constraint. However, the implementing agency of the project, the Agricultural Credit Bank (ACB), followed the main objective as stated in the loan agreement: making available financing to small farms to improve their income, create employment and help reduce out-migration (IFAD, 1994). The result was that most emphasis was on extending credit, less on improving income and very little on soil conservation. This was to some extent also reflected in the monitoring mechanisms: the approval and disbursement of loans was very tightly administered, while a single (and much delayed) socio-economic survey and a one-time soil conservation study were all there was to shed light on the income and conservation situation.

The focus on credit of the IFAD project showed much more clearly which components farmers found attractive to invest in, than the mixed incentive system of the USAID project. Despite very positive financial rates of return for both crops in the appraisal (IFAD, 1988), IFAD credit was mainly used for Blue Mountain coffee, and very little for cocoa.

Credit for small-scale enterprises as alternative employment

The detailed watershed planning activities in the FAO project showed that the bulk of soil erosion was derived from a few areas, where tenants or squatters were farming very steep slopes. The socio-economic survey confirmed that small groups of more or less landless households were responsible for these malpractices. In the project identification and preparation reports a component was included to provide such households with assistance and vocational training to start or further develop small rural enterprises. The IFAD project attached strategic importance to this component, and provided credit for small-scale enterprise development. However, the mid-term evaluation report states that the performance of the programme after four years was disappointing (IFAD, 1994). The ACB could only deal with agricultural credit, and institutional arrangements were rather complicated. There were misunderstandings between parties involved, the target group had been too narrowly defined, and the loan ceiling had not followed inflation. A new institutional set-up is now being put in place, and a revolving fund and a loan guarantee fund will be established.

Incentives used in SCWD activities in Indonesia

Subsidies for terracing

Dutch colonial agricultural advisors in Indonesia, recognizing the threat of soil erosion on upland farms, recommended already in 1873 the construction of bench terraces on sloping land. The use of terraces on upland fields was evaluated in 1889 by the forester Berkhout. Apart from the conservation benefits he mentioned two other advantages (cited in Pelzer, 1945): 1. Terraces would lead to a more sedentary population from which tax collection would be easier; 2. Terracing would reduce land requirements of the native population, leaving land for private and governmental plantations. On the other hand Berkhout listed four arguments against terracing: 1. People were not used to terracing dry land; 2. Terracing demands more labour; 3. It reduces productivity in the first year(s) after establishment; 4. It ties the native more to the soil; so that he can less easily escape the Treasury and the officials (disadvantage for individual, advantage for government). In the first half of the twentieth century farmers undertook terracing only because it was a precondition to being granted permission to plant coffee. This coercive approach did not help to convince farmers about the usefulness of terraces, and this historical note also shows that not much thought was given to economic incentives at that time.

The present Indonesian government's approach to combatting upper watershed degradation on privately owned land is known as 'regreening' (*Penhijauan*). It evolved from the FAO-funded Solo Watershed project on Java (1972-1976), and recognized the limitations of reforestation as a means to rehabilitate upper watersheds cultivated by poor farmers (Belski, 1994). The focus was again on terracing, which would allow farmers to continue annual cropping, albeit more sustainable. This form of more intensive annual cropping was seen as important for both the small farmers, and the government which was concerned about food security and downstream hydrological conditions. Farmers that terrace their land within 10 ha *demplots* are eligible for subsidies [1]. These are given partly in kind (planting materials, etc.) and partly in cash (for labour), and are accompanied by extension training.

In a survey in a relatively densely populated upper watershed in Sumatra, Belski (1994) found that terracing was still not very popular among farmers. In one village poor farmers were reluctant because of the initial disturbance of the soil and the loss of cultivable area due to the risers, both factors which reduce production. In the other village upland farms preferred an agro-forestry system, whereby young cinnamon trees are interplanted with annual crops in the first four years and the trees provide for soil conservation. In this area terraces were often not maintained after these three years, and few farmers built terraces without subsidies.

The situation in the Konto River watershed on Java was quite similar, although in some areas farmers had maintained the terraces reasonably well. Apart from the terracing subsidies these farmers had also benefited from other 'accompanying or starter' activities. As in Jamaica, a move away from physical measures towards vegetative measures can also be seen in Indonesia. Therefore much effort is made to promote tree and fodder crops.

Promotion of tree crops

Perennial crops like coffee, clove, rubber and cocoa have always been important estate crops, but most are now grown by smallholders. In the nineteenth century the Javanese, under the *Cultuurstelsel*, had to cultivate export crops on one fifth of the village's arable land or to work 66 days a year in Government estates or enterprises. This familiarized farmers with crops like coffee, sugarcane and tobacco. On other islands smallholders gradually grew more rubber, pepper and cocoa. In 1979 the Directorate of Estate crops established packages for the promotion and intensification of export crops among smallholders. This included rubber, coconut, cocoa, tea, pepper and coffee. Farmers obtained credit and would become eligible for a certificate of landownership (de Graaff, 1986). This may have accelerated the adoption of the crops, although Jamal and Pomp (1992) state that neither access to credit nor formal titles to land seems to have been an important barrier to cocoa adoption in Sulawesi.

Village nurseries for perennial crop production

In the Konto River Project area coffee has always been an important crop. Many farmers also participated in the 1979 coffee intensification project, but not all of them were satisfied with this programme. Therefore, in 1986, the provision of credit for tree crops did not seem to be the right approach for stimulating farmers to replace low yielding, low value annual crops

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[1] Subsidy consist of Rp 100,000 per ha (US$ 60 in 1987) in the first year, and Rp 50,000 in the next two years. Average plot size per farmer is about 0.5 ha.

(e.g. maize, cassava) on steep slopes with trees. Instead of credit to individual farmers the Konto River Project focused on better input supply and on marketing. Since good quality seedlings constitute, next to labour, the highest cost component in the establishment of perennial crops and are often hard to obtain, two central production nurseries and a total of sixteen 'village nurseries' were established in the watershed area (van der Hoek, 1993). The village nurseries were managed by school teachers, members of the community development organisations or enterprising farmers. Of the total of 34,000 coffee and fruit tree seedlings produced 22,000 were sold, whereas only 30% of the 30,000 firewood/fodder trees were sold. Firewood seedlings could not be sold at the Rp 20 cost price. They were often given for free in combination with coffee seedlings to serve as shade trees. Taking this into account the cost price of coffee seedlings became about Rp 160, and the seedlings were sold at Rp 175 and Rp 200 for Robusta and Arabica respectively (de Graaff and Dwiwarsito, 1990). Before the start of the village nurseries, seedlings of inferior quality were obtained from private nurseries at prices between Rp 200 and Rp 400. Most farmers bought no more than 100 seedlings, and planted them in homegardens or on rainfed fields. The larger farms, more specialized in coffee, used larger numbers for coffee rejuvenation and replanting. Farmers reported tree crop survival rates of around 75%. Whereas some village nurseries continued their activities until after the expiration of the project, most were not able to continue their 'revolving fund' type operations, due to a lack of supervision. Nevertheless village nurseries can constitute an important instrument for promoting sustainable agricultural systems with tree crops.

Improved processing and marketing for coffee production

Barbier and Bishop (1995) argue that improved marketing and value-added processing can increase the potential of new cropping systems (e.g. agro-forestry). Often excessive marketing margins arise out of monopolistic practices. In Java the poor relative share of producers in the overall returns from perennial crops has slowed their incorporation in upland cropping systems, although poor post-harvest processing and marketing infrastructure appear to be just as much at fault as monopolistic pricing (Barbier, 1989).

Since Indonesian coffee is known for its rather low quality and low prices for farmers (de Graaff, 1986), in 1987 the Government envisaged paying much more attention to quality improvement, through disease control, better harvesting and processing methods and more efficient marketing (Subiapradja, 1987).

At the start of the Konto River Project implementation phase, studies were undertaken of the coffee production, processing and marketing systems (de Graaff and Dwiwarsito, 1990). These showed low average yields and inadequate post-harvest practices: drying on bamboo mats, and incomplete pulping, referred to as *kneuzing*, with simple tools. Hulling was also badly done, either at home with a pestle and mortar or at the local rice mill. All coffee was sold to intermediary, village or district level, traders.

To respond to this situation, the project assisted with the establishment of drying floors and the introduction of two mini mobile pulping and hulling units. When regularly used, the cost price of this processing unit was slightly higher than the fee charged by the millers, but the quality was much better, with less broken beans and a higher 'outturn'. The Surabaya based export firm Kapalapi started to buy this high quality coffee in 1989. One unit was operated by the Perennial Crop Service, and the other by a village committee. Proper maintenance and management remained a problem. Organisational problems may reduce the effectiveness of this type of incentive.

Starter activities in watershed development

In watershed areas where on-site benefits of erosion control are minimal, because of deep fertile soils, and where most benefits accrue to people downstream, the local or upland population often realises that the conservation activities are basically meant to reduce downstream sedimentation, and that it may actually restrain their own development. Watershed development programmes therefore often include 'starter activities'. They form a special form of incentives from which a whole village or part of it can benefit. They should provide short term benefits, but also fit into long term scenarios (de Graaff and Schipper, 1991). During the start of the implementation phase of the Konto River project, several meetings were held with the people in the target villages in order to explain to them the objectives and the activities planned in cooperation with the different services. During these meetings the villagers were also asked to express their most urgent needs. Responding to these needs the project repaired an irrigation dam near one village, improved about ten access roads and bridges and built drinking water schemes in nine villages. A detailed cost-benefit analysis showed that these interventions were in fact economically efficient. The repair of the irrigation dam was very effective. Construction of two access roads created daily time savings for different forms of transport, and showed internal rates of return of 14% and 22%. Similarly, on the basis of time savings, it was calculated that the most expensive drinking water supply scheme would have to last about ten years to be economically efficient. During the 1994 review mission it appeared that at least several of the schemes, built in 1987 and 1988, were still in operation. The monitoring surveys showed that the schemes had improved water quality and that the time savings had mainly accrued to women (de Graaff and Dwiwarsito, 1990).

Reforestation and social forestry in upper watersheds

The Konto River Project in Indonesia offers a clear case of conflicts of interest in densely populated zones in sub-humid mountainous zones, where upper watersheds or mountain peaks are still covered by forest land. Apart from wood production the natural forest area has important regulating (hydrological and environmental) functions, that the Government wants to safeguard (e.g. flood control, reservoir management, bio-diversity). The initial major objective of the project, therefore, was to draw up a masterplan for forestry and agro-forestry for the upper watershed, in such a way that a proper balance would be achieved and could be maintained between these functions of the forest and the needs of the population. The reforestation programme had to respect on the one hand the forest functions and on the other hand the wishes of the population, to obtain more food, fodder and firewood from the area.

Two examples are given below of how the two main actors (Forest Corporation and villagers) have tried to share the costs and the benefits, and how financial cost-benefit analysis could be helpful in analyzing the (potential) conflict situation.

Mutually beneficial social forestry contracts.

As indicated in Chapter 10, one of the two major reforestation methods is the *tumpangsari* system. *Tumpangsari* means co-occupation for a limited period, and in Indonesia is the name of a temporary agro-forestry system used for the establishment of forest plantations. It was successfully practised for the first time in 1883 by Buurman in Central Java (Kartasubrata, 1979; Peluso, 1992).

In the Konto River watershed development programme the *tumpangsari* reforestation system can have a high overall impact, because of the large area involved (two third is forest land, of which much is degraded to shrub) and because of the production of annual and perennial crops under the trees. Landless and small farmers undertake all tree planting activities on a 0.25 ha plot and receive in return the right to cultivate annual crops for two years and firewood and perennial crops for a longer period. It is clear from the state of many reforested plots that firewood and fodder are of crucial importance to farm households in the area, where the firewood species and many leaves of the hardwood species have already disappeared, affecting the final reforestation results.

Table 11.3 *Financial results of tumpangsari reforestation for State Forest Corporation and participating farmers (investment components in last three columns)*

1. In case of successful reforestation:

	Results for farmers								
	Total net benefits		Annual crops (2 years)		Planting costs & benefits of perenn. crops		**Results for State Forest Corporation**		**Overall results**
IRR (%)	n.a.		n.a.		14		15		15
	(				Rp 1,000				)
NPV (at 10%)	1,028		903		125		529		654
NPV (at 7%)	1,227	-	958	=	269	+	1,290	=	1,559
NPV (at 4%)	1,493		1,019		474		2,869		3,343
NPV (at 0%)	1,981		1,112		869		8,088		8,957

2. In case of less successful reforestation (final cut 50%):

	Results for farmers								
	Total net benefits		Annual crops (4 years)		Planting costs & benefits of perenn. crops		**Results for State Forest Corporation**		**Overall results**
IRR (%)	n.a.		n.a.		neg.		11		7
	(				Rp 1,000				)
NPV (at 10%)	1,266		1,600		- 334		94		- 240
NPV (at 7%)	1,323	-	1,738	=	- 415	+	453	=	37
NPV (at 4%)	1,330		1,899		- 569		1,205		635
NPV (at 0%)	1,119		2,162		-1,043		3,708		2,665

n.a. = not applicable

The beneficiary monitoring programme has clearly shown that the *tumpangsari* reforestation programme is very much appreciated, not only by the landless and small farmers, but also by large farmers, who sometimes buy off the 'participation rights' from landless and small farmers (in 1987 for about Rp 100,000 per 0.25 ha).

An analysis of the costs and benefits accruing to each of the two main parties involved (the State Forest Corporation and the farmers) illustrates very well why both parties are content with the *tumpangsari* arrangement, even when the resulting reforestation is less successful.

The results of the financial analysis in Table 11.3 show that the State Forest Corporation obtains sufficiently high returns on their investment (IRR at least 11%), even when only half of the planned number of main trees are remaining at the time of the final cut (after 25-30 years). The farmer/participant, who undertakes all the work without payment, could already be compensated for his work by the proceeds from the perennial crop, the firewood and fodder planted (IRR for this investment can reach 14%), but he is more interested in the direct benefits of the annual crops (the incentive to participate). The final evaluation survey showed that perennial crops (avocado) and firewood had already disappeared on many plots, but this does not affect the farmers' results very much, since they had often managed to extend their annual cropping to 3 or 4 years. At private discount rates of 7% or higher the latter strategy is in fact more attractive to farmers (first column in Table 11.3).

Distribution of the benefits of firewood production

In the Konto River watershed area a dispute arose about the use of firewood between the State Forest Corporation and farmers participating in social forestry schemes. Farmers are normally only allowed to collect thin and dead branches from the forest, but the participants in the schemes wanted as compensation for their reforestation work not only a food production plot but also a larger share of the firewood production. A financial cost-benefit analysis was undertaken for three different social forestry schemes, considering seven different arrangements for sharing the firewood production, ranging from all firewood for the Forest Corporation (FC) to all for the villagers (V).

Table 11.4 *Financial results for State Forest Corporation (FC) and villagers (V) participating in strip rotation (Eucalyptus) reforestation schemes*

	Arrangements						
	A	B	C	D	E	F	G
Costs and benefits							
Tree planting by	FC	V	V	V	V	V	V
Inputs & supervision	FC	FC	FC	FC	FC	FC	V
Foodplots	-	V	V	V	V	V	V
Firewood:							
All to:	FC	FC			V		V
Share (40%) to:				V			
All at small fee to:						V	
Thin wood to:			V				
Financial results for							
Forest Corporation (FC)							
(IRR; timber & firewood)	22	34	33	31	13	34	-
(NPV; idem, at 10%; Rp 1,000)	178	252	242	188	19	223	-
Villagers (V), in Rp 1,000							
(NPV, 10%; firewood only)	-	-146	- 94	- 52	90	- 38	24
(NPV, 10%; food & firewood)	-	394	448	489	631	503	567

Source: de Graaff, 1987

Table 11.4 shows the results for one scheme. The most reasonable options for the two parties were a forty-sixty percent sharing of firewood (option D) from thinnings or the selling of all firewood at a nominal fee of about Rp 5 per kg (option F). The latter option could discriminate against the poor landless households which have little cash. However, the analysis also showed that the granting of a share of the firewood to the participants would not affect the financial efficiency (net present value) of the reforestation schemes very much for the Forest Corporation.

These two examples show how financial CBA can provide 'ingredients' for conflict resolution.

11.4 The effectiveness of incentives

Dixon et al. (1989) indicate a few characteristics of effective incentives, that could also be seen as criteria for their effectiveness. The first criterion is the *dependability* or reliability of the effects of the incentives. Targeted government action is in this regard more effective than general pricing measures. A second factor is the *adaptability* to new (economic) circumstances. Inflation may soon erode the effectiveness of 'cash' incentives. The third criterion is *equity*. An incentive will be more effective if all or most parties concerned agree in principle who will qualify for it. Incentives should not imply enforcement, but should leave the land *user* some *flexibility* to react individually. Finally incentives should also be *cost effective*. It should be the 'cheapest' way to reach a compromise between the national economic and the private financial feasibility.

Yapp and Upstill (1984) remark that in evaluating incentives one should not only focus on the beneficiaries but also on the losers, or those that are disadvantaged by the incentive. They also refer to some practical considerations, such as the *administrative simplicity* and the *public-sector impact* of incentives.

With regard to tree planting by small farmers in upland watersheds (in Central America), Tschinkel (1987) states that plants should be readily available, either free or for sale, and that other incentives should be kept at a minimum to sway already interested farmers. Incentives should also be *temporary* with the flexibility to permit amounts and procedures to evolve with experience.

Here the following criteria will be applied for incentives to be effective in the respective soil conservation and watershed development projects:

- The 'economic incentive' should only be provided when the target group would otherwise incur *financial loss*, and when moral persuasion does not suffice;
- The 'incentive' should reach the *target group* and be used for the *purpose* for which it is meant (in terms of reconciling efficiency, equity and sustainability aims), and exclude as much as possible non-target groups and other purposes;
- The 'incentive' should have minimal *side-effects* that work counter-productively, or may bring about financial loss to other actors (including misuse of incentives);
- The value of the 'incentive' should *not exceed* the net *social gains* (to other actors and society at large), resulting from the right use of these incentives (cost-effectiveness);
- Other actors should consider these incentives as a fair compensation for the financial loss otherwise incurred (*equity*);
- The 'incentive' should be flexible enough *to cope with changes* in broader economic parameters (e.g. inflation, marketing prospects) and with changes in agro-climatic conditions (e.g. droughts, flooding);
- The 'incentive' should leave the *land user* enough *flexibility* to reach the intended purpose in his own way, considering the socio-cultural conditions;
- The 'incentive' needs to be *administered* relatively *easily* and should be the most simple or cheapest way to reconcile the conflict of interest;
- The 'incentive' has a *temporary character* and can be withdrawn at least after a period of 5 to 10 years, without creating a dependency situation or counterproductive effects.

The impact on the public sector (budget, etc) should be added as a tenth criterion. However, not enough information is available on this for the case studies.

Table 11.5 *Assessment of effectiveness of incentives in case-study areas*

Country & type of incentive	1 Clear need	2 Target group	3 Side effects	4 Cost effect.	5 Others agree	6 Cope w. change	7 User flexib.	8 Easy admin.	9 Tempo-rary
Burkina Faso									
Transport services for stone rows	+	++	+	o	+	+	o	+	-
Fertilizer subsidies	+	o	o	+	+	-	+	o	-
Tunisia									
Soft credit for tree and fodder crops	+	+	o	o	o	-	o	-	-
Food aid for tree and fodder crops	o	+	o	+	o	o	-	o	-
Jamaica									
Terracing cash subsidies	+	o	-	-	-	o	+	-	+
Commercial credit for treecrops	+	+	+	+	+	-	o	-	o
Credit for rural enterprises	+	o	o	o	o	--	o	-	o
Indonesia									
Terracing subsidies in kind	+	+	o	o	-	o	+	-	+
Planting materials for coffee	+	++	+	+	o	o	o	o	o
Cultivation rights in reforestation	+	-	-	++	o	+	+	o	--
Starter activities	o	+	o	+	o	o	+	o	o

Note: Score on criteria: very positive (++), positive (+), neutral (o), negative (-) and very negative (--)

Table 11.5 shows that in none of the cases do the incentives score well on all criteria. When the nine criteria are given an equal weight and the qualitative scale is changed into a quantitative scale (from +2 to -2), the transport services for stone rows in Burkina Faso and the provision of planting material in the Konto River Project appear to be relatively 'good' incentives. Subsidies for terracing and credit for rural enterprises in Jamaica, and soft credit for tree and fodder crops in Tunisia score lowest, and have indeed not been successful.

Most incentives score well on some criteria: there was almost invariably a clear need for the incentives; they were usually used for the right purpose and target group; and more than half of them seemed cost-effective on the basis of a rough assessment of costs and total benefits. However, most incentives are rather complicated to 'organise and/or administer', and it is often not clear whether the incentive is of temporary nature and can be abolished after some time. The cultivation rights for landless in Indonesia and the transport service for stone rows in Burkina Faso have clearly created a dependency situation.

Most incentives have side effects: the use of lorries for stone transport may result in the accelerated removal of stones and rock from collection sites, which may affect these sites (e.g. erosion). On the other hand, with lorries one can more easily reach suitable collection sites. Fertilizer subsidies may result in overemphasis of inorganic fertilizers. In Indonesia subsidies on fertilizers and pesticides have led to overuse, in particular on vegetables.

Inflation can harm the effectiveness of credit. It is difficult for farmers to accept that interest rates can suddenly soar to over 30%, because of inflation, as was the case in the IFAD coffee and cocoa credit project in Jamaica. Incentives 'in kind' can cope better with changing economic conditions. Except for the food aid rations, which were provided in the Tunisian project after the completion of specific tasks (and were not supposed to be sold), most incentives leave some flexibility to land users to use them in their own way.

The assessment in Table 11.5 shows that it is in fact hard to determine the effectiveness of incentives, unless the use and effects thereof are also carefully monitored. In order to assess the real burden or simplicity of the handling of incentives, one needs to know, which part of project costs and which part of the value of incentives is used for the handling and administration of the incentives. In order to assess the cost-effectiveness one needs to know both more about the total costs of incentives and about the overall social gains.

In evaluating the effectiveness of incentives, attention should not only be paid to explicit but also to implicit objectives. In the Tunisian project the explicit objective was to improve land productivity (*mise en valeur*) through the planting of tree and fodder crops. However the implicit objective of the government was to further settle the partly nomadic population. In Indonesia many different objectives play a role in social forestry schemes: to reforest shrubland for hardwood and firewood, to undertake planting at low cost (without paying wages), to assist the landless, etc. Before selecting incentives it is necessary to analyze all the objectives of major actors and to find out where the real conflicts of interest lie, and which types of incentive would reconcile the different parties.

Financing incentives

The provision of incentives for large long-term soil conservation programmes may be very costly, and governments often need funds for more immediate needs. One way of funding the upland conservation works would be to charge downstream beneficiaries: those who benefit from irrigation water and electricity could be charged higher water or irrigation fees and electricity rates, and land users who will be less affected by occasional floods might be required to pay additional land tax. In relatively small watershed areas farmer organizations may include both up- and downstream farmers; compensation mechanisms can then be worked out within these organizations. Unfortunately these opportunities often do not exist in semi-arid zones, where low and uncertain yields also limit the use of credit.

Conclusions

In this chapter the various incentives used in the case studies are reviewed. Although many factors play a role in the selection of incentives, a general impression has been obtained about which incentives best fit the different rationales for SCWD activities. Credit can only play an important role in fast maturing tree crops, in sub-humid mountainous zones. In these zones downstream beneficiaries should be taxed. Food aid and subsidies should be dealt with carefully (targeted and temporary). In semi-arid zones subsidized inputs in-kind and public facilities may be the only options. Depending on circumstances the following incentives seem to be the most appropriate for the implementation of SCWD activities:

* When on-site effects dominate:	
- Erosion control measures:	- grant; food aid; public facilities
- Fertilizer measures:	- input subsidies; public facilities
- Land use conversion/tree planting	- long term credit; input subsidies
* When downstream effects dominate:	(- taxation of downstream community)
- Erosion control measures:	- cost-sharing; facilities; long term credit;
- Land use conversion/tree planting	- input subsidies; long term credit

The above analysis shows that it is hard to determine the effectiveness of incentives, unless their rationale is well-defined and their use and effects are carefully monitored.

12 CONCLUSIONS AND CHALLENGES

Life is served by the sciences, it is governed by wisdom (Seneca). In: Epistulae 85, 32.

12.1 Farmers and soil and water conservation approaches

It is generally acknowledged that the traditional soil and water conservation and/or watershed management projects, with their top-down orientation and emphasis on mechanical measures, have often failed. Farmers were not convinced about the usefulness of conservation measures and did not feel responsible for their maintenance. Conservationists now prefer to speak about 'land husbandry' (Shaxson et al., 1987; Hudson, 1991). In French terminology the abbreviation CES (*Conservation des eaux et du sol*) has been replaced by GCES (*Gestion conservatoire des eaux de surface, de la biomasse et de la fertilité du sol*) (Roose, 1994). Many development organisations now focus on participatory methods, and the World Bank emphasizes the importance of beneficiary commitment (World Bank, 1992a).

Although *farmer participation* is of crucial importance, new soil conservation approaches should not focus too narrowly on the interests of present farmers, but also pay attention to other stakeholders, e.g. *future farmers and downstream communities*. As illustrated in some of the case studies, the emphasis in soil conservation and watershed development projects often shifts towards short-term production goals, not seldom at the expense of conservation objectives. After a political change in Tunisia in 1969, which changed the collective into an individual approach, the Central Tunisia agricultural development project drastically reduced the implementation of physical conservation works and focused entirely on tree and food crop planting. The Konto River Project in Indonesia too, gradually put more emphasis on the promotion of coffee, fruit trees and grass plantings, as attention to terracing declined. It did however continue to work on controlling gully and roadside erosion. In Jamaica an original proposal for a soil conservation project was eventually transformed into a coffee and cocoa credit project, which involved little erosion control.

In these three projects *tree crop development* could be considered retrospectively as a *compromise* between government and farmers' production and conservation objectives. Trees constituted a form of land use with less erosion hazard than annual cropping, which was financially attractive enough to farmers. In these trade-off situations governments in developing countries often put emphasis on production and foreign exchange earnings. Tree crops like coffee (which mature within a few years) fit well in such strategies, but if tree cropping is not combined with soil and water conservation measures (such as 'eyebrow' terraces), the effect on erosion control may not be very large. Tree crops which take a long time to mature, such as the olive trees in Tunisia, form a less efficient compromise for which generous incentives to farmers are required.

In the Jamaican case another compromise situation emerged, when in addition to the above-mentioned coffee and cocoa credit project, a separate soil conservation demonstration project was initiated in one of the watersheds. However, such a 'sister projects' approach can only be successful when there is sufficient interaction between these projects. Since actor involvement in these projects takes place at different scales (at village, regional and national level), which may have similar but also conflicting interests, attention should be paid to the *subsidiarity* principle: some initiatives can come from the local, village level, while others can be undertaken by the regional or national government. Knowledge should be pooled and responsibilities should be shared according to abilities. As well as partnership, leadership is also required. These important prerequisites for the planning of SCWD activities came to light clearly in the series of multi-disciplinary and multi-actor 'Local land development planning' exercises in the framework of the Konto River Project (van der Hoek, 1993).

Soil and water conservation programmes were and are still largely focused on a *single measure*, such as on stone rows in Burkina Faso and on the *demplot* terracing programme in Indonesia. Some are based on tradition and some on new technology. The effectiveness and efficiency of such measures however differ very much by zone (e.g. locational factors) and by farm type. The analysis of farm patterns in the case studies shows that farm households can differ considerably in resource availability (e.g. land, livestock, cash earnings) and resource use (e.g. enterprise choice, power source) and may have a different attitude towards erosion and its control. Some farmers already employ more or less sustainable farming systems (e.g. food forest in Jamaica, rice and coffee farmers in Indonesia), others have made part of their system sustainable (e.g. the crop land of livestock farmers in Burkina Faso). However, many other farmers have insufficient land and capital resources, and can not pay much attention to conservation practices in their livelihood strategies. Severe forms of soil erosion are often highly concentrated in a few areas, where tenant farmers or squatters have no options. The creation of alternative employment for this relatively small group, through land reform, transmigration or off-farm employment, may well be the most cost-effective solution. This research therefore stresses the importance of thorough analysis of farm types, with their production systems, in the preparation phase of these projects. Here the expression *farm patterns* is used, since it is realized that a differentiation in the project preparation phase will be mainly based on the availability and use of farm resources and less on personality factors for which more in-depth studies are required. Clearly defined farm patterns facilitate the targeting of SCWD activities and the corresponding incentives.

The six villages in the Burkina Faso case study were divided into two groups on the basis of the man-land ratio. In the more densely populated village areas, intensification strategies are more efficient than the continuation of extensive land use systems. Once the cultivable area per person has dropped below about 0.2 ha (needed for self-sufficiency) in these semi-arid zones, farmers fully realise this and are ready to engage in conservation and fertilizing activities. However, farmers generally lack on-farm fertilizer materials (e.g. manure, compost, mulch) and cash for inorganic fertilizers, and can only use part of their land in a sustainable way. They may also improve soil fertility of their own fields at the expense of common fields. For the time being emphasis should be laid in these circumstances on balanced-external-and-internal-input agricultural systems (*BEIA*), as opposed to LEIA and HEIA (low and high external input) systems. The question remains, however, of who should take care of the interests of future generations and how.

Sub-humid mountainous zones often offer good agro-ecological conditions for agriculture and as a consequence have a very high population density. In areas like the Konto River Watershed many households have less than 0.25 ha farm land (0.05 ha per person), and obtain part of their income from activities on other farms, from trade, etc. This group of mini-farmers form a threat to deforestation and is very keen to participate in social-forestry. These latter activities require much supervision and monitoring, without which reforestation efforts can easily lead to further deforestation.

12.2 On-site and downstream impact assessment

Soil conservation and watershed development activities often have several on-site and downstream effects, which are not easily detected and hard to quantify and value. Therefore, in the appraisal of soil and water conservation measures, attempts were seldom made to estimate these effects. It was simply assumed that without measures production would gradually decline and that with measures production would remain constant or even increase. These assumptions can be quite fallacious. The Burkina Faso case study makes clear that with stone rows alone production will still decline, and the Indonesia case study shows that farmers are not impressed by the on-site productivity increases after terracing. Considering that in the past many soil conservation projects have failed because of a lack of knowledge about the effects of measures, it is argued here that more attention should be paid to *impact assessment* in preparing such projects. Such a more detailed analysis can now be undertaken, thanks to research efforts in the past few decades.

Much attention has been paid to research on watershed hydrology and on erosion, which has greatly improved the *knowledge about erosion* processes and erosion factors. This has made it possible to use locally modified versions of the Universal Soil Loss Equation (USLE) and to calibrate them. It has also led to the development of a model by Morgan et al. (1984), which emphasizes the role of transport capacity of run-off in erosion processes. In this research use is made of these two simple models, even though many computer packages (e.g. WEPP, ANSWERS) have been developed that use more sophisticated models. The stringent data requirements of the latter models make them less suitable for individual project preparation studies.

In the last twenty years much attention has also been paid to research on the complex *relationships between soil, water, nutrient and plants*. Systems research and simulation models have played an important role in this. Again, because of data requirements, a choice is made here for the development of simple spreadsheet modules to assess the on-site effects of erosion and soil and water conservation measures. These facilitate the estimation of changes in crop yields as a result of changes in soil, water and nutrient losses. With monthly or ten-day data on precipitation, potential evapotranspiration, crop coefficients and yield response factors, a yearly or seasonal *spreadsheet water balance module* is presented. With this module one can obtain an impression about the yield effect of conservation measures, if the order of magnitude of the effect on run-off is known. Similarly a module has been developed with which the *yield effects of reduced losses of nutrients* and organic matter can be estimated. With these simple spreadsheet modules yield effects can be calculated quickly for different crops, seasons and rainfall years, with and without soil conservation measures. Since the effects of physical soil conservation measures (line interventions) on the water balance often have a direct effect on yields, this analysis may also play a role in the assessment of farmer participation rates in certain activities.

The same modules form the basis for the assessment of the downstream effects of conservation measures, but these field level or on-site effects subsequently require 'upscaling' to assess watershed level impact. For the Indonesian case study a *watershed level spreadsheet model* has been developed, with which the downstream effects (on sedimentation and streamflow in the river system and reservoir) of land use changes can be estimated. It allowed a comprehensive comparison in an ex post evaluation of four alternative watershed development options.

A distinction has been made here between soil and water conservation activities and strategies in *semi-arid* and in *sub-humid mountainous zones*. In these two zones emphasis is on on-site and downstream effects, respectively. This does not imply that on-site effects are not important in sub-humid mountainous zones and that downstream effects could be ignored in semi-arid zones. There are always on-site effects, but on deep fertile soils in sub-humid mountainous regions these may be less serious than the downstream consequences, as shown in the case studies. Considering the large number of dams and reservoirs built in the last few decades, that practically all have sedimentation problems, more emphasis needs to be given to the downstream effects in these regions. However, when sedimentation and fluctuations in streamflow, including flooding, have few downstream consequences (direct drainage in the sea), on-site effects become more important (e.g. in coastal limestone areas of Java and Jamaica). Conversely, downstream effects should not be completely ignored in semi-arid zones. In the Tunisian case study area they are in fact important. However, in these zones on-site soil, water and nutrient losses through soil erosion cannot be easily compensated for both physical (e.g. low and erratic rainfall) and economic (no cash for and much risk with fertilizers) reasons. In these zones the on-site land degradation effects usually far outweigh the downstream effects.

It is interesting to discover that within the two zones distinguished, the emphasis within soil and water conservation strategies may differ as well. In Sahelian countries, like Burkina Faso, much attention in research and implementation is currently paid to the problem of soil mining, or the *nutrients* issue, while in Tunisia many efforts have been made in the field of *water conservation*. In Indonesia soil and water conservation strategies focus heavily on differences in *soil type*: a major distinction is that between volcanic and sedimentary derived soils. Erosion hazard and effects on these soils differ considerably and the average production value and household income in the Brantas watershed area (one third of East Java) was three times higher in upper volcanic zones (as in the case study) than in lower sedimentary zones (de Graaff, 1989). In Jamaica, on the other hand, the most important criterion for soil and water conservation measures was the *slope of the land*. Most of the hillside agricultural land in Jamaica has very steep slopes (over 40%), and according to the local land capability classification (Sheng, 1972) land use recommendations are made on the basis of slope (and soil depth). In these mountainous areas soils do not differ much.

These differences in emphasis on limiting resources and erosion factors, indicate on the one hand that a further sub-division of the zones is required, but may also imply that more attention should be paid to technology transfer and to the *communication of experiences* between similar developing regions. In this connection it is suggested that an international agricultural research institute, or coordinating body, should focus specifically on all aspects of land degradation and soil and water conservation technology. Such an initiative was proposed during the 1994 ISCO conference in New Delhi, under the title of ISERI. We suggest that this should be changed to ILWERI (International Land and Water Environmental Research Institute). This institute could benefit from the important work undertaken by the WOCAT (World Overview of Conservation Approaches and Technologies) group. Clear links should be established with FAO and UNEP and with important institutes in the field of soil and water, such as IBSRAM, ISRIC and IIMI. It should have the same status as the international agricultural research centres of the CGIAR (Consultative Group for International Agricultural Research) with their different mandates, with regard to cropping, livestock and farming systems. The focus should be clearly on the coordination of research on land and water resources in agriculture, and not on more global environmental issues for which Fresco and Rabbinge (1996) made some organisational proposals recently.

12.3 Evaluating the evaluation methods

In a search for methods suitable for the evaluation of SCWD activities and projects, two major evaluation methods, *CBA* and *MCA*, were compared. The main advantages of CBA are that it constitutes a standard method, that all effects (costs and benefits) are expressed in only one (monetary) unit, and that it can deal with the time dimension of effects. Thus far, it has been the most often applied method in project appraisal in developing countries. However, the Indonesian case study shows that SCWD activities bring about various direct and indirect effects that are hard to quantify and value. The effects on the lifetime of the reservoir appear after such a long period that they are practically reduced to zero after discounting. That they still carry some weight in the CBA shows how important these effects are. MCA offers the advantage that it can incorporate more evaluation criteria, and that the attributes of these criteria can be given weights that reflect the preferences of the respective actors. It can give a better indication of where conflicts arise, and what incentives are required to reconcile these conflicts. Several MCA methods can also deal with qualitative data. These features of MCA are important for SCWD projects, which often have to deal with several groups of actors with different objectives, and engender multiple effects of which some can only be assessed in a qualitative way. The drawbacks of MCA are that the merits of a chosen project option cannot be compared with those of projects elsewhere in the economy, and that the method cannot easily deal with the time dimension.

Because of the difficult economic conditions of most developing countries, the *efficiency* criterion needs to carry much weight in project appraisal. Because of limited capital and skilled manpower resources, a ranking of all potential projects within the national economy on the basis of this criterion remains very important. Therefore emphasis is here first given to the use of CBA in the appraisal of SCWD projects, whereby much attention is paid to the *quantification and valuation* of all major effects on land and water resources and their impact on actors. The case studies have shown that such an exercise cannot be undertaken without extensive data collection. In the framework of the Konto River Project detailed hydrological and erosion research was undertaken that made such quantification of effects possible. However in other situations, such as in Jamaica, not enough data are available. In such cases CBA should be undertaken to assess the score of SCWD activities on efficiency and equity criteria and on the quantifiable attributes of the conservation criteria. MCA could then be applied, whereby the CBA results are used and the remaining attributes on the conservation criteria are expressed in their own quantitative or qualitative units. Van Pelt (1993) refers to this as integrated evaluation.

While CBA focuses on testing the efficiency of the best alternatives, MCA methods pay more attention to the 'ranking of alternatives' function of evaluation methods. It could therefore also play an important role in the preparation phase of SCWD projects, where alternative technologies and approaches need to be *screened*. It is suggested that more use of MCA and CBA be made in the early stages of the project cycle, in particular to assess which technologies and approaches are the most appropriate under different agro-ecological conditions and for different groups of actors (farm patterns).

As remarked already in Section 12.1, projects have often concentrated on a single technology and a similar approach for different zones and actors, where a differentiation would have been appropriate. This holds not only for the generalized application of terraces and earth bunds, but also for the focus on a particular tree crop variety or 'miraculously fast growing species'. The cases of coffee in Indonesia and tree crops in Tunisia show that a blanket approach may be successful in some areas, but less so in others. A preliminary screening by agro-ecological zone and by farm pattern with its resource utilization options and preferences, could have prevented failure in the latter zones.

An additional important problem in the ex post evaluation of SCWD projects, which may also affect project appraisal, is that project activities are only undertaken over a *short period*, whereas the total impact period is very long. It is then very difficult to assess the impact on stream flow, erosion and farm income with a sufficiently high probability, even when base and monitoring data are available. Besides, new activities are often superimposed on the original ones or objectives reformulated. This does not only happen after political changes, such as the one in Tunisia after 1969, but also after new scientific breakthroughs (e.g. green revolution) and the emergence of 'new solutions' (e.g. vetiver grass, rock phosphate). In long-lasting projects that consist of several phases, a reformulation often takes place after each phase. Because of new insights gained, such changes are understandable, but complicate ex post evaluation, unless clear monitoring procedures are followed. In the design of so-called 'programmatic' projects these changes have in fact been anticipated, allowing a project to change course. For an adequate assessment of the merits of SCWD projects it is suggested that much attention should be paid in the project preparation stage to the development of a comprehensive set of attributes on the evaluation criteria, and adequate procedures to be able to *monitor* these '*indicators*'. The base data for these indicators should be derived from surveys during the preparation stage.

The case study projects in Indonesia and Tunisia were terminated five and fifteen years ago, respectively. This allowed a realistic assessment of the long term impact of the tree planting and other investment activities, although subsequent developments have somewhat blurred the picture. Presentations of the project cycle generally pay insufficient attention to this (post-measures) impact phase. For SCWD activities the physical lifetime already exceeds twenty-five years, and the eventual impact therefore accrues largely to the next generation. Due attention should be paid to proposals for a separate analysis of the project results for the next generation. This could be done either by choosing a second date for discounting in CBA as already proposed by Walker (1982) and applied by de Janvry et al. (1994), or by considering the future generation as a separate group of actors with their own preferences, to be reflected in weight sets in MCA. Alternatively, the terminal values for the non- or semi-renewable resources (land, natural forest and water) can be included as additional attributes to the conservation criteria in MCA or in an integrated evaluation.

12.4 Challenges

The problems of land degradation can be considered a major threat to the world. The effects of erosion and soil mining reduce food production potential in many developing countries and in particular in Africa. Rapid siltation of many multi-purpose reservoirs will have a major effect on water supplies in the coming decades, reducing irrigated crop production and hydroelectricity and leading to more flooding. The 'price' of soil erosion is high!

Many different *incentives* have been tried to stimulate land users to opt for more sustainable land use. In semi-arid zones this has to be done in the form of subsidies (in cash or in kind) since farmers are poor and are seldom eligible for credit. Unfortunately these countries seldom have the funds to provide subsidies at a substantial scale. In sub-humid mountainous zones, where farmers generally have more farm and non-farm income opportunities, credit could play some role and transfer payments to upland farmers could theoretically be recuperated from downstream beneficiaries, politicians permitting.

In both zones people abuse open access resources such as forests and pastures. Regulations seldom help since governments have insufficient means to enforce them. The focus is now on passing responsibilities on to the local or village level. However, local organisations often lack the necessary stronghold on all actors involved. Countries with mineral resources could consider investing the proceeds from these non-renewable resources in the management of their renewable resources. However, as the Indonesia case study shows, managing these resources is not an easy task. The management of natural resources will continue to require some regulations, considerable moral persuasion at the local level and economic incentives justified by considering the external benefits enjoyed by downstream and future land users.

As suggested in Chapter 2, a country should ideally have a national land capability and land use model, linked to a hydrological and water use model, to be used for the monitoring of the land and water resources utilisation space. From these models or masterplans (which should be able to deal with different responses of actors), policies and priorities for soil and water conservation could be derived, that would form the basis of national long-term SCWD programmes and projects.

The case studies show that projects have often worked too much in isolation and changed course. This has made it difficult to assess their effectiveness. SCWD activities and projects are hard to evaluate since neither their effects nor their beneficiaries can be easily detected. It is therefore suggested that, after a preliminary appraisal, SCWD projects should be preceded by a *preparatory* phase, during which three, partly separate and partly interlinked, activities need to be undertaken:

1. *socio-economic research* to identify existing farm patterns and other actors (also downstream) likely to participate in or to be affected by SCWD activities;
2. *hydrological and erosion research* (where possible from secondary sources and supplemented with primary data), to obtain a clear picture of land degradation problems under the different conditions of terrain, soils and land use;
3. small-scale *pilot implementation*, not only to test and compare the various technologies, but also to look into all organisational aspects of implementing SCWD projects, including the choice of incentives.

These activities will greatly benefit the subsequent preparation and appraisal of a large-scale SCWD implementation programme. The pilot implementation would provide the necessary information to undertake the comprehensive screening of alternative activities and of organisational requirements. The research activities will lead to more accurate impact assessment, whereby use can be made of farm patterns with their land use system, and of data on water, sediment and nutrient flows, and their on-site and downstream effects.

These three above-mentioned activities were undertaken by the FAO project in Jamaica. However, at the same time 'blue print' SCWD implementation plans had already been prepared by the forestry, agronomy and soil conservation sections, which later proved to be completely unrealistic. In the Indonesian Konto River Project pilot implementation was only undertaken after six years of inventories, research and planning. Hydrological and erosion research, were only initiated in the third phase. In semi-arid zones, where projects face low returns and high risks, these preparatory activities seem costly, but even there they may ultimately prove to be cost-effective.

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ANNEXE 1. INDICATORS FOR CASE STUDY COUNTRIES

Table A 1 *General development indicators for case study countries (1990)*

Countries	GNP per capita (US$) 1990	Life expect. (yrs) 1990	Calories per head per day 1989	Commerc. energy[2]/ head/day 1990	Adult illiteracy (%) 1990	External Debt (% of GNP) 1990	Official dev. aid (% of GNP) 1990
Burkina Faso	330	48	2,288	17	82	26	9.9
Tunisia	1,440	67	3,121	520	35	62	2.5
Indonesia	570	62	2,750	272	23	66	1.6
Jamaica	1,500	73	2,609	931	< 5	132	7.1
Developing 1) countries	**840**	**63**	**2,523**	**605**	**36**	**40**	**1.4**

Source: World Bank, 1992.
1) Countries with 1990 income per capita below US $ 7,000.
2) Commercial energy in kg of oil equivalent (excluding firewood)

Table A 2 *Demographic and agricultural indicators for case study countries (1990)*

Countries	Total popul. (mill.) 1990	Popul. growth (%) 80-90	Total area (mill. km2)	Popul. density pers/km2 1990	Urbanization (%) 1990	Agric. as % of GNP 1990	Annual growth (%) agric. 80-90
Burkina Faso	9.0	2.6	0.27	33	9	32	3.3
Tunisia	8.1	2.3	0.16	49	54	16	2.3
Indonesia	178.2	1.8	1.81	98	31	22	3.2
Jamaica	2.4	1.3	0.01	218	52	6	0.8
Developing countries	4,146.0	2.0	77.08	53	44	17	3.2

Source: World Bank, 1992.

Table A 3 *Natural resource use indicators for case study countries (1982-90)*

Countries	Land use Distribution (%) Crop land	Past-ure	For. Wood	Other land	Deforestation[1] (% per year)	Fertil. use[2] (kg/ha) 1990	Irrigation (% of arable)	Water resources infrastructure Dams 1982	Capacity[3] 1000 m3/s
Burkina Faso	13	37	24	26	1.7	6	0	2	3
Tunisia	30	19	4	47	1.7	23	6	30	37
Indonesia	12	7	63	19	0.5	117	34	36	20
Jamaica	25	18	17	40	3.0	116	13	2	n.a.
Developing countries	11	28	29	32	0.6	83	(25)	26,000	n.a.

1) Deforestation rates differ considerably by source.
2) Total of plant nutrients per ha of arable land.
3) Total maximum discharge capacity of spillways (in 1000 m3/sec)
Sources: FAO, 1987; Ewing & Chalk, 1988; World Bank, 1992; World Resources Institute, 1989; ICOLD, 1984.

ANNEXE 2. CURRENCY CONVERSION FACTORS

Table A 4 *Foreign exchange rates and price indexes for case study countries (1972 - 1994)*

	Exchange rates (currency per US$)				**Consumer price index** (1987 = 100)			
	Burkina Faso	Indonesia	Jamaica	Tunisia	Burkina Faso	Indonesia	Jamaica	Tunisia
Year:	CFAF	Rupiah	J$	DT				
1972	252	415	0.77	0.48	31	13	8	33
1973	223	415	0.91	0.42	34	16	9	35
1974	240	415	0.91	0.44	37	23	12	36
1975	214	415	0.91	0.40	43	28	14	40
1976	239	415	0.91	0.43	40	33	15	42
1977	245	415	0.91	0.43	52	37	17	45
1978	226	442	1.41	0.42	56	40	23	47
1979	213	623	1.77	0.41	64	46	30	51
1980	211	627	1.78	0.41	72	54	38	55
1981	272	632	1.93	0.49	78	61	43	61
1982	329	661	1.99	0.59	87	67	45	69
1983	381	909	2.15	0.68	94	75	51	75
1984	437	1026	3.94	0.78	99	83	65	82
1985	449	1111	5.56	0.83	105	86	81	88
1986	346	1283	5.48	0.79	103	92	94	93
1987	301	1644	5.49	0.83	100	100	100	100
1988	298	1685	5.49	0.86	104	108	108	106
1989	319	1770	5.75	0.95	104	115	124	114
1990	272	1843	7.18	0.88	103	124	151	122
1991	282	1950	12.12	0.93	103	135	228	132
1992	265	2029	22.96	0.88	101	145	404	139
1993	283	2089	24.55	1.00	n.a.	n.a.	n.a.	n.a.
1994	528	2181	33.28	0.98	n.a.	n.a.	n.a.	n.a.

Source: World Bank, 1995; n.a. = not available.

GLOSSARY OF TERMS

Actor

Farmers and other economic operators (private and public), who play a role in the management of the local environment and ideally assume certain responsibilities for it (adapted from Bäck; in Savenije and Huijsman, 1991).

Appraisal See evaluation.

Attribute

Attributes are characteristics, factors, qualities, performance indices or parameters of alternatives in decision-making. Alternatively it is a measurable aspect of judgment by which a dimension of the various decision variables or alternative management schemes under consideration can be characterized (In: Bogardi and Nachtnebel, 1994).

Carrying capacity

The maximum level of exploitation of a renewable resource imposing limits on a specific type of land use, that can be sustained without causing irreversible land degradation in an area.

Conservation

In an economic sense Ciriacy-Wantrup considered conservation as a way of redistributing use rates in the direction of the future (van Kooten, 1993). In this research it is often an abbreviation for soil and water conservation.

Cost-benefit analysis (CBA)

A tool of economic analysis, used in project evaluation, in which the actual and potential costs of various economic decisions are weighed against actual and potential benefits (Todaro, 1977). A distinction is made between economic CBA, undertaken for society as a whole (ECBA), social CBA, which also considers equity aspects (SCBA), and financial CBA, undertaken for the respective actors or entities concerned (FCBA).

Criteria

Criteria are standards, rules or tests on which judgements or decisions can be based. In decision-making theory they may represent either an attribute or an objective (In: Bogardi and Nachtnebel, 1994).

Desertification

Desertification is a process of sustained land degradation in arid-, semi-arid and dry sub-humid areas, caused at least partly by mankind. It reduces productive potential to an extent which can neither be readily reversed by removing the cause nor easily reclaimed without substantial investment (Nelson, 1988).

Effect

A process set in motion or accelerated by man's actions (as used by Munn (1975) for environmental effects). In economic terms positive effects could be seen as benefits and negative effects as costs. Soil conservation and watershed development activities can bring about on-site effects, and these effects may subsequently engender downstream effects.

Effectiveness

The results of an activity compared with its aim(s).

Efficiency
The overall benefits of an activity compared with its costs.

Environmental functions
The capacity of natural processes and components to provide goods and services that directly or indirectly contribute to human welfare (de Groot, 1992).

Equity
The relative importance of benefits of an activity for different groups of actors.

Erosion See soil erosion.

Evaluation
Evaluation is a process for determining systematically and objectively the relevance, viability, effectiveness and impact of activities in the light of their objectives (adapted from UN, 1984). Evaluation can take place prior to (ex-ante evaluation or appraisal), during or after the expiration (ex-post) of a project.

External effect or externality
Effect of a project that falls outside the project (area), or accrues to groups not belonging to the target population.

Farm household
An organized social and economic unit, the members of which undertake agricultural and non-agricultural activities (communally or complementarily) aimed at satisfying the material needs of the group and at creating material conditions to fulfil non-material needs (Huijsman, 1986).

Farm pattern
A group of typical farm households that show similarities in resource availability and resource use.

Farm type
A group of typical farm households that show both similarities in resource availability and resource use, and in personality factors leading to specific farming styles.

Farming style
A group of typical farm households that show similarities in personality factors, leading to specific farming objectives and attitudes. Or: a way of farming generally accepted by a certain group of farm households.

Impact
Outcome of activities: net effect of activities on economic, social and ecological status.

Impact assessment
The assessment of the net change in well being of people (and their ecosystems), resulting from certain effects (Munn, 1975).

Incentive
Any stimulus positively influencing the willingness and/or potential of an individual or organization to undertake a 'desired' action, or abandon an 'undesired' action (Campen, 1993).

Inter- and intra-generational equity See equity.

Land and water utilisation space (LWUS)
The maximum level of sustainable exploitation of land and water resources in a certain area (e.g. watershed), whereby these do not (yet) lose their functions (see also carrying capacity).

Land degradation
Net change in the land resource base (soil and vegetation) that results in the reduction of the productivity and/or stability of a land use system.

Land unit
A uniform tract of land defined by its physical characteristics, and in particular by weather, landform and soiltype (van Rheenen and Efdé, 1993).

Land use system and technology (LUST)
A more or less uniform combination of human activities on a specific land unit. It may be typified by certain crop, livestock or other enterprises and combinations, and by the application of certain management or technology (e.g. with regard to soil and water conservation).

Monitoring
Periodic or continuous surveillance of project activities by participants, management or donors (FAO, 1988).

Multi-criteria analysis (MCA)
MCA constitutes a group of decision-making or evaluation methods or tools, whereby the decision maker(s) can pursue multiple objectives (criteria) in choosing between an array of feasible options (adapted from Romero and Rehman, 1989).

Nutrient balance (at field level)
The difference between the amount of plant nutrients exported from cultivated fields and those added or imported (van der Pol, 1992).

Off-site (downstream) and on-site effects See effect.

Opportunity cost (in production)
The benefit foregone by using a scarce resource for one purpose instead of for its next best alternative use (Gittinger, 1982).

Production situation
The conditions that determine the levels of production that can be achieved; at a certain location the condition is determined by physical factors such as climate, soil quality and water availability (van Rheenen and Efdé, 1993).

Productivity
The output of a product valued per unit of resource input (Conway and Barbier, 1990).

Project
A project constitutes a discrete package of investment, policies and institutional and other actions designed to achieve a specific development objective (or set of objectives) within a designated period (Baum & Tolbert, 1985).

Scenario
One of several possible and likely development paths, to be taken into consideration in the planning and/or appraisal of long term projects.

Sediment yield
The soil delivered to point in the stream under evaluation. It gives an indication of the net rate of soil erosion.

Soil degradation
Net change in the soil resource base that results in the reduction of its inherent productivity.

Soil erosion
The gross amount of soil moved by raindrop detachment and/or run-off (Barrow, 1995).

Soil conservation
Soil conservation measures can be technically defined as: any set of measures intended to control or prevent soil erosion, or to maintain fertility (Stocking et al., 1989).

Stability
Constancy of productivity in the face of small disturbing forces that arise from normal fluctuations and cycles in the surrounding environment (Conway and Barbier, 1990).

Sustainability
The capacity to maintain productivity of certain resources over a long period of time.

Sustainable development
Sustainable development is 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland, 1987).

Water balance
The difference between on the one hand the precipitation and inflow of water and on the other hand the evapotranspiration and outflow of water. It provides an approximate overview of water conditions in a field or a larger area.

Watershed development
The process of formulating and carrying out activities involving natural, agricultural and human resources within a watershed, in order to provide resources that are desired and suitable to society, but under the condition that sustainable use is made of soil and water resources. The social, economic and institutional factors, operating within and outside the watershed must be considered (after Gregersen et al., 1987).

Watershed management
The management of the natural resources of a drainage basin, primarily for the production and protection of water supplies and water-based resources, including the control of erosion and floods, and the protection of the aesthetic values associated with water (Society of American Foresters, 1944, quoted by Hewlett, 1982).

SUMMARY

Soil erosion by water is the principal cause of land degradation, and a major constraint to agricultural development in developing countries. Soil erosion greatly reduces the functions of land, water and vegetation resources. Natural resource accounting for a dozen developing countries shows that annual costs of resource degradation range from 1 to 17% of GNP.

Since the 1930's large scale erosion control investment activities have been undertaken in many countries. Because of high initial costs, slowly emerging benefits and important downstream effects, public organisations have often taken the initiative and borne the brunt of the costs. Despite a few success stories, many of these top-down attempts have failed. Since the 1980's new soil conservation approaches have focused more on local technologies and farmer participation. Measures must reduce on-site soil, water and nutrient losses, which affect farm production and in semi-arid zones result in 'soil mining' and desertification hazard. In sub-humid mountainous zones soil erosion also leads to accelerated siltation of reservoirs and other downstream effects. The feasibility of soil and water conservation activities then need to be assessed within the framework of the development of the watershed.

Soil conservation and watershed development (SCWD) activities are hard to evaluate since neither their effects nor their beneficiaries are easily to detect. The on-site and downstream impacts of land degradation are part of social costs of agricultural production. These costs are routinely neglected by farmers and policy makers, due to numerous market and policy failures in developing countries that mask the full cost of degradation to society.

In the preparation and appraisal of SCWD projects one has to find out what effects the project activities will bring about and which groups of actors will be affected, either as beneficiaries or otherwise. The appraisal of these project activities is usually carried out using cost-benefit analysis (CBA), but this evaluation method cannot easily deal with less quantifiable effects and their impact on actors, and it is largely focused on one criterion (efficiency). Methods such as multi-criteria analysis, that can deal with qualitative effects and multiple objectives of different actors, could constitute valid alternatives.

This research was therefore aimed at improving methods for the preparation and appraisal of SCWD projects, and was directed to the following major objectives:

- To develop a method for distinguishing groups of actors likely to participate in or to be affected by SCWD activities, and to use the analysis of impacts on these groups of actors as a starting point for the overall project evaluation.
- To develop methods for incorporating an analysis of on-site and downstream effects of erosion and soil and water conservation measures into impact assessment.
- To investigate which economic evaluation methods are most useful and appropriate for the appraisal and evaluation of SCWD activities or projects.

Decisions with regard to soil and water conservation activities and their on-site effects are primarily taken by farm households. The participation of households in SCWD activities differs by type of household, depending on their location, their resources and resource utilization, and their objectives and attitudes. To assess participation rates a method has been devised to construct or select a number of representative farm patterns on the basis of farm survey data. The financial analysis can show under which conditions (e.g. incentives) these farm patterns will participate. These financial results can be aggregated to obtain an overall picture of the costs and benefits of the respective SCWD investment activities.

Since this financial analysis should be based on actual impact of SCWD activities on the actors, a detailed analysis of on-site and downstream effects of SCWD activities should be undertaken in project preparation and appraisal. For this purpose impact assessment spreadsheet modules were developed. With these modules the yield response to on-site changes in water and nutrient balances, due to SCWD activities, can be calculated. A watershed level multiple-spreadsheet model was developed to assess downstream effects of SCWD activities on sedimentation and streamflow, affecting functions of reservoirs.

To assess their suitability for appraising SCWD projects with these multiple effects, the two evaluation methods CBA and MCA were compared and applied in the case studies.

The thesis is divided into three parts. After an introductory chapter, part I explores land degradation problems, decision-making in land and water use and evaluation methods. The above mentioned methodologies for impact assessment are developed in part II, which concludes with a framework for the preparation and appraisal of SCWD projects.

Because of differences in land degradation types and effects between semi-arid and sub-humid mountainous zones, the framework has been tested on two case studies, in part III. The first concerns the financial analysis of stone rows and fertilization measures, the major soil conservation activities in Burkina Faso. This situation is compared with that in a semi-arid zone in Tunisia, where the emphasis is on land use conversion and water conservation. The second case study concerns a watershed development project in Indonesia, where reforestation, coffee planting and terracing were undertaken, not only to increase local productivity but also to reduce sedimentation and streamflow fluctuations downstream. The case is compared with that in a more or less similar sub-humid mountainous zone in Jamaica. Lastly the incentives used in these projects are discussed and final conclusions are drawn.

The case studies show that different SCWD strategies are followed in the four countries. The focus on erosion factors varies, and different incentives are used. This shows on the one hand that problems and solutions are diverse, but it may also imply that more attention should be paid to technology transfer and to communication of experiences between similar regions.

Future SCWD projects and programmes should first be screened on the basis of 'national land and water resource inventories', showing the resource utilisation space. After a preliminary appraisal, a preparatory phase can start, and should include three main activities:

1. socio-economic research, to identify participating farm patterns and other actors;
2. hydrological and erosion research, to assess erosion problems and their multiple effects;
3. small scale, pilot implementation, to test technologies, organisations and incentives.

These activities will greatly benefit the subsequent preparation and appraisal of larger scale SCWD implementation programmes. The pilot implementation is important for the right choice of SCWD activities and their organisation. The socio-economic and erosion research activities will lead to more accurate impact assessment, in which use is made of farm patterns with their land use systems and technology (LUST's) and of data on water, sediment and nutrient flows, and the on-site and downstream effects of changes in these flows.

The evaluation methods CBA and MCA appear to complement each other very well in project preparation and appraisal. Efficiency can be assessed using CBA, where effects can be quantified and valued. MCA can be used to assess scores on non-monetary attributes of the criteria, and can show how conflicting objectives of different actors affect the scores. Both methods can also perform a useful function in screening alternative technologies.

SOMMAIRE

L'érosion du sol par l'eau est la principale cause de dégradation de terre, et représente une contrainte majeure dans le développement agricole des pays en voie de développement. L'érosion réduit considérablement les fonctions des ressources en terre, eaux et végétation. Selon des calculs de ressources naturelles, les coûts annuels de dégradation de ces ressources dans une douzaine de pays en voie de développement s'élèvent de 1 à 17% du Produit National Brut (PNB).

Depuis les années 30 des essais de grands travaux de lutte anti-érosive ont été entrepris dans de nombreux pays. Dû aux coûts initiaux élevés, au peu de bénéfices obtenus et aux effets importants en aval, les organisations publiques prennent souvent l'initiative et en assument les coûts. Bien qu'il y ait eu certains succès, la plupart de ces tentatives ont échoué. Depuis les années 80 de nouvelles tentatives de CES se sont plus spécialement concentrées sur les technologies locales existantes et la participation des agriculteurs.

Les mesures doivent réduire les pertes en sol, eau et éléments nutritifs sur les sites érodés qui affectent la production agricole, et qui dans les régions semi-arides conduisent à la dégradation du sol et à la désertification. Dans les zones montagneuses sub-humides l'érosion conduit aussi à un rapide envasement des réservoirs et à d'autres effets en aval. La faisabilité des activités de CES doit être jugée dans le cadre du développement de tout le bassin versant.

Les activités de conservation des eaux et du sol et du développement des bassins versants (SCWD) sont difficiles à évaluer puisque leurs effets et leurs bénéficiaires ne peuvent être que difficilement décelés. L'impact sur les sites et en aval de la dégradation de terre fait partie des coûts sociaux de la production agricole. Ces coûts ne sont généralement pas pris en considération par les agriculteurs ni les politiciens dû au non-fonctionnement du marché et de la politique des pays en voie de développement, qui masque les coûts totaux de la dégradation pour la société.

Dans la préparation et l'évaluation des projets de SCWD, on doit trouver les effets que les projets apporteront et les groupes d'acteurs qui seront affectés comme bénéficiaires ou autrement. L'évaluation de ces activités est normalement entreprise avec l'analyse coûts-bénéfices (CBA), mais cette méthode d'évaluation ne peut pas facilement traiter les effets non-quantitatifs et leurs impacts sur les acteurs, et elle est largement basée sur un seul critère: l'efficience. Des méthodes telles que l'analyse à multiples-critères (MCA), qui peuvent traiter les effets qualitatifs et les nombreux objectifs des différents acteurs, peuvent constituer des alternatives valables.

Cette recherche avait donc pour but d'améliorer les méthodes de préparation et d'évaluation des projets de conservation des eaux et du sol et de développement des bassins versants (SCWD) en visant les principaux objectifs suivants:

- Développer une méthode pour distinguer les groupes d'acteurs prêts à participer ou être touchés par les activités SCWD, et utiliser l'analyse d'impacts sur ces groupes comme point de départ de l'évaluation des projets.
- Développer des méthodes aptes à inclure dans l'analyse d'impacts les effets sur les sites et les effets en aval des activités SCWD.
- Déterminer quelles méthodes d'évaluation économique sont les plus utiles et les plus appropriées pour l'évaluation des activités ou des projets de SCWD.

Des décisions à propos des activités de CES et de leurs effets sur les sites sont principalement prises par les agriculteurs. Leur participation dans les activités de SCWD diffère selon le genre d'entreprise agricole et dépend de leur situation géographique, de leurs ressources et de l'utilisation de ces ressources, et de leurs objectifs et attitudes. Afin d'estimer le taux de participation, une méthode a été retenue en sélectionnant un nombre 'd'agriculteurs-types' représentatifs suivant les données d'enquêtes agricoles. L'analyse financière pour ces agriculteurs-types montre les conditions (par exemple incitations) sous lesquelles les agriculteurs participeront et ces résultats financiers pourront être cumulés pour obtenir les coûts et bénéfices totaux des activités SCWD.

Puisque cette analyse financière doit être basée sur l'impact actuel des activités SCWD sur les acteurs, une analyse détaillée des effets sur les lieux érodés et en aval des activités de SCWD devrait être entreprise pour la préparation et l'évaluation des projets. A cet effet, des 'modules' avec un logiciel tableur pour les analyses d'impacts ont été développés. Avec ces 'modules' on calcule les effets des activités de SCWD sur la production, en calculant les changements effectués par ces activités dans le bilan d'eau et le bilan de nutriments du sol. Avec un logiciel multiples tableurs, un modèle à l'échelle des bassins versants a été développé pour analyser les effets en aval des activités de SCWD comme la sédimentation et les changements en débits fluviaux affectant les fonctions des réservoirs.

Les deux méthodes d'évaluation CBA et MCA ont été comparées et appliquées aux études de cas afin de déterminer leur aptitude à évaluer des projets SCWD avec les multiples effets de ceux-ci.

La thèse est divisée en trois parties. Après l'introduction, la première partie attire l'attention sur les problèmes de dégradation du sol, la prise de décisions sur l'utilisation du sol et de l'eau et sur les méthodes d'évaluation. Les méthodologies mentionnées ci-dessus pour l'analyse d'impacts sont développées dans la deuxième partie, qui se termine par un schéma de préparation et d'évaluation des projets de SCWD.

A cause des différences de dégradation et des effets entre les zones semi-arides et sub-humides montagneuses, le schéma a été testé sur deux études de cas dans la troisième partie. La première étude concerne une analyse financière de cordons pierreux et de mesures de fertilisation, représentant les activités de CES les plus importantes au Burkina Faso. Cette situation est comparée avec une autre dans une zone semi-aride en Tunisie, où l'accent a été mis sur le changement de l'utilisation de la terre et sur la conservation des eaux. La deuxième étude de cas concerne un projet de développement de bassins versants en Indonésie, où on s'est occupé du reboisement, des plantations de caféiers et des terrasses de CES, non seulement pour augmenter la production locale, mais également pour diminuer la sédimentation et les fluctuations des débits fluviaux en aval. Ce cas est comparé avec celui d'une zone sub-humide montagneuse similaire en Jamaïque. Ensuite les différents types d'incitations, appliqués dans ces projets sont discutés, avant de présenter les conclusions finales.

Les études de cas montrent que chaque pays suit sa propre stratégie de SCWD, avec un accent différent sur les facteurs d'érosion et un choix différent d'incitations. Cela indique que d'un côté les problèmes et les solutions sont divers, mais il se peut aussi que plus d'attention doive être accordée au transfert de technologie et de communication des expériences entre régions semblables.

Des projets et programmes SCWD futurs devraient être sélectionnés d'abord sur la base 'd'inventaires nationaux de ressources en terre et en eaux', en montrant les limites et les possibilités d'utilisation de ces ressources. Après une évaluation préliminaire, une phase préparatoire pourrait démarrer avec trois activités principales:

1. recherche socio-économique, pour identifier les agriculteurs-types, qui pourraient participer, ainsi que les autres 'acteurs';
2. recherche hydrologique et d'érosion, afin de déterminer les problèmes d'érosion et leurs effets multiples;
3. réalisation à petite échelle, pour tester les technologies, les organisations et les moyens d'inciter les agriculteurs à participer.

Ces activités pourraient être très utiles pour la préparation et l'évaluation des programmes SCWD à grande échelle qui suivront. La réalisation pilote sera importante pour la sélection des activités SCWD et pour leurs modes d'organisation. Les activités de recherche socio-économique et d'érosion mèneront à une analyse d'impacts plus précise. Dans cette analyse on se basera sur des 'agriculteurs-types' avec leurs systèmes d'utilisation de terre et de technologie (LUST's) et sur des données concernant les flux d'eau, de sédiments et d'éléments nutritifs, ainsi que les effets des changements dans ces flux sur les sites et en aval.

Les méthodes d'évaluation, CBA et MCA, semblent très bien se compléter dans la préparation et l'évaluation des projets. Avec CBA on peut déterminer l'efficience, là où les effets peuvent être quantifiés et valorisés. MCA peut être appliquée pour déterminer les scores des attributs non-monétaires des différents critères, et peut montrer comment des objectifs contradictoires de différents acteurs influencent les scores. Ces deux méthodes peuvent jouer un rôle important dans la sélection des différentes technologies.

SAMENVATTING

Bodemerosie door water is de belangrijkste oorzaak van landdegradatie, en een belangrijke beperkende factor in landbouwontwikkeling in ontwikkelingslanden. Bodemerosie beperkt in hoge mate de functies van de hulpbronnen land, water en vegetatie. In een twaalftal ontwikkelingslanden bedroegen de jaarlijkse kosten van degradatie van natuurlijke hulpbronnen tussen 1 en 17 % van het Bruto Nationaal Produkt.

Vanaf de jaren dertig zijn grootschalige erosiebestrijdingswerken uitgevoerd in vele landen. Vanwege de hoge investeringen, laat optredende baten en belangrijke benedenstroomse effecten, hebben overheidsorganisaties veelal het initiatief genomen en ook het leeuwendeel van de kosten gedragen. Afgezien van een aantal succesgevallen, zijn veel van deze van bovenaf geregelde activiteiten mislukt. Sinds de jaren tachtig geven nieuwe benaderingen van bodemconservering meer aandacht aan lokale technologieën en participatie van de boeren. De maatregelen moeten de lokale verliezen van bodem, water en nutriënten terugdringen, die de produktie beperken en in droge klimaten bodemuitputting en gevaar voor desertificatie tot gevolg hebben. In regenrijke bergachtige gebieden leidt bodemerosie ook tot het versneld dichtslibben van stuwmeren en andere benedenstroomse effecten. De effectiviteit van bodem- en waterconserveringsactiviteiten moet dan bezien worden op het niveau van stroomgebieden.

Activiteiten op het gebied van bodemconservering en stroomgebiedsontwikkeling (SCWD) zijn moeilijk te evalueren, aangezien noch de effecten, noch de belanghebbenden gemakkelijk kunnen worden bepaald. De lokale en benedenstroomse effecten van landdegradatie maken deel uit van de sociale kosten van landbouwproduktie. Deze kosten worden doorgaans genegeerd door boeren en beleidsmakers, aangezien zij door het falen van de markt en van het beleid geen totaalbeeld van de kosten van degradatie verkrijgen.

In de voorbereiding en beoordeling van 'SCWD'-projecten moet men nagaan welke effecten projectactiviteiten teweeg zullen brengen en welke groepen 'actoren' daarbij in het geding zijn, als begunstigden of anderszins. Deze activiteiten worden meestal beoordeeld d.m.v. kosten-baten analyse (CBA), maar deze evaluatiemethode kan niet goed uit de voeten met minder gemakkelijk te kwantificeren effecten en de invloed daarvan op actoren. De methode is bovendìen vooral op één criterium (efficiency) gericht. Methoden zoals multicriteria analyse (MCA), die met kwalitatieve effecten en met meervoudige doeleinden van verschillende actoren kunnen omgaan, kunnen een bruikbaar alternatief vormen.

Dit onderzoek was daarom gewijd aan het verbeteren van methoden ter voorbereiding en beoordeling van SCWD-projecten, en was gericht op de volgende hoofddoelstellingen:

- De ontwikkeling van een methode om groepen actoren te onderscheiden die betrokken zullen raken bij SCWD-activiteiten, om nadien bij de projectbeoordeling uit te kunnen gaan van de impactanalyse van de activiteiten op deze actoren.
- Methoden te ontwikkelen om in de analyse van effecten op actoren terdege rekening te houden met lokale en benedenstroomse effecten van erosie en bodem- en waterconservering.
- Na te gaan welke economische evaluatiemethoden het best bruikbaar zijn en toegepast kunnen worden voor de beoordeling en evaluatie van SCWD-activiteiten en -projecten.

Beslissingen t.a.v. bodem- en waterconservering en de lokale effecten daarvan worden vooral door agrarische huishoudens genomen. De participatie van huishoudens in SCWD-activiteiten verschilt per type huishouden, afhankelijk van lokatie, aanwezige produktiefactoren en gebruik daarvan, en van doelstellingen en gedragslijnen. Ten einde de participatie te beoordelen is een methode ontwikkeld om op basis van bedrijfsonderzoeksgegevens een aantal representatieve 'bedrijfspatronen' te construeren of te selecteren. De financiële analyse van deze bedrijfspatronen kan aangeven onder welke voorwaarden ze in bepaalde activiteiten zullen participeren. De financiële resultaten van de diverse 'patronen' kunnen geaggregeerd worden om totale kosten en baten van de SCWD-investeringsactiviteiten te kunnen bepalen.

Aangezien deze financiële analyse gebaseerd moet zijn op de feitelijke invloed van SCWD-activiteiten op de actoren, zal in de projectvoorbereiding en -beoordeling een gedetailleerde analyse van de lokale en benedenstroomse effecten van SCWD-activiteiten ondernomen moeten worden. Rekenbladen-modules werden ontwikkeld voor de analyse van deze effecten en om de opbrengstreactie op lokale veranderingen in de water- en nutriëntenbalansen als gevolg van SCWD-activiteiten, te kunnen berekenen. Daarnaast werd een meervoudig-rekenblad-model op stroomgebiedsschaal ontwikkeld om te kunnen inschatten wat de benedenstroomse effecten van SCWD-activiteiten zijn op sedimentatie en debieten, die de functies van reservoirs beïnvloeden.

Om hun bruikbaarheid voor de evaluatie van SCWD projecten, met hun diversiteit aan effecten, te toetsen, werden de twee evaluatiemethoden CBA en MCA vergeleken en toegepast in de case-studies.

De dissertatie is verdeeld in drie delen. Na een introductie, besteedt deel I aandacht aan land-degradatieproblemen, aan besluitvorming in land- en watergebruik en aan evaluatie-methoden. De hierboven omschreven methoden voor de analyse van effecten worden ontwikkeld in deel II, dat afgesloten wordt met een schema voor de voorbereiding en beoordeling van SCWD-projecten.

Vanwege verschillen in degradatievormen en -effecten tussen semi-aride en sub-humide, bergachtige gebieden, is het evaluatie-schema in deel III uitgetest in twee case-studies. De eerste studie betreft de financiële analyse van stenen rijen en bemestings-maatregelen in Burkina Faso. De analyse van deze maatregelen wordt vergeleken met die van landgebruiksveranderingen in een soortgelijk gebied in Tunesië. De tweede case-studie betreft een stroomgebiedontwikkelingsproject in Indonesië, waar herbebossing, koffie-aanplant en terrassering centraal stonden, niet alleen ter verhoging van de produktie maar ook om de sedimentatie en debietfluctuaties benedenstrooms te verminderen. Een vergelijking is gemaakt met soortgelijke activiteiten in een bergachtig gebied in Jamaica.

Vervolgens wordt aandacht besteed aan de stimuleringsmaatregelen die een rol speelden in deze projecten. Tenslotte worden conclusies getrokken.

De case-studies tonen aan dat er verschillende SCWD-strategieën gevolgd worden in de vier landen. De aandacht voor de diverse erosie-factoren verschilt en het gebruik van 'incentives' loopt uiteen. Dit geeft aan de ene kant aan dat de problemen en oplossingen variëren, maar het kan ook betekenen dat er meer aandacht geschonken moet worden aan de uitwisseling van technologieën en ervaringen tussen vergelijkbare gebieden.

Toekomstige SCWD-projecten en -programma's moeten eerst worden geselecteerd op basis van 'nationale land- en water-inventarisaties', die de milieu-gebruiksruimte moeten aangeven. Na een voorlopige beoordeling zou een voorbereidingsfase kunnen starten, die de volgende activiteiten zou moeten omvatten:

1. sociaal-economisch onderzoek, om de deelnemende bedrijfspatronen en andere actoren te identificeren;
2. hydrologisch en erosie-onderzoek, om de erosieproblemen en de veelheid aan effecten daarvan te kunnen bepalen;
3. kleinschalige implementatie, om technologieën, organisatievormen en stimuleringsmaatregelen uit te testen.

Deze activiteiten zullen een belangrijke bijdrage leveren aan de voorbereiding en beoordeling van grootschalige projecten en programma's, die hierop volgen. De kleinschalige implementatie is van belang voor de juiste keuze van technologieën en organisaties. Het sociaal-economische en erosie-onderzoek zal leiden tot een verbeterde effect-analyse, waarbij gebruik gemaakt wordt van de bedrijfspatronen met hun landgebruikssystemen en technologieën (LUSTen) en van data t.a.v. water-, sediment- en nutriëntenstromen, en de lokale en benedenstroomse effecten van veranderingen in die stromen.

De evaluatiemethoden CBA en MCA blijken elkaar erg goed te kunnen aanvullen in projectvoorbereiding en -beoordeling. Efficiëntie kan worden bepaald met CBA, voor de effecten die kunnen worden gekwantificeerd en gewaardeerd. MCA kan worden gebruikt voor niet-monetaire attributen van de evaluatie-criteria, en kan laten zien hoe conflicterende doeleinden van verschillende actoren de uitkomst van de evaluatie beïnvloeden. Beide methoden kunnen een nuttige rol vervullen in het selecteren van alternatieve technologieën.

CURRICULUM VITAE

Jan de Graaff was born in The Hague, The Netherlands in 1948. He received his secondary education at schools in Den Helder and Bilthoven and obtained the Gymnasium-β certificate in 1967. At the Agricultural University in Wageningen he began his studies in land and water management, but after changing he graduated in 1974 with a major in development economics, and minors in land and water management, general economics and transport economics (at Erasmus University).

After graduating, he joined the Food and Agricultural Organisation from 1974-1982. He worked first for an agricultural project in Tunisia and for a marketing development project in Kenya. He then worked for the Agricultural Services Division (AGSP) and the Commodity Division (ESCB) at FAO headquarters in Rome. In this period he undertook consultancy missions to Burma and southern Africa. In 1980 he went back 'to the field', joining a soil conservation and watershed development project in Jamaica.

From 1982-1984 he worked for the Department of Development Economics of the Wageningen Agricultural University. Apart from teaching farm economics, he undertook research on the economics of tropical crops, for which he visited several countries in Latin America and Africa. This research led to publication of a book on the economics of coffee.

In 1984 he joined the Royal Tropical Institute (KIT) in Amsterdam. His duties comprised research and consultancies in food strategy studies and environmental management, and in the formulation of agricultural research and development projects.
From 1986-1990 he worked for the bilateral Konto River watershed project in Malang, Indonesia. He was responsible for the monitoring and evaluation of the various watershed development activities, and developed and supervised two large agro-economic surveys in the framework of the Brantas watershed planning. After his return to KIT headquarters, he wrote a book about soil conservation and sustainable land use.

Now a specialist in the economics of soil and water conservation, he returned in 1991 to Wageningen Agricultural University as lecturer in the Department of Irrigation and Soil and Water Conservation. Besides several teaching assignments he is involved in the inter-university research project on the Management of Natural Resources in the Sahel, and his PhD research allowed him to look back at the results of projects in Tunisia, Jamaica and Indonesia.