Monitoring for impact:
Evaluating 20 years of soil and water conservation in southern Mali

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Cover photos:
Left: runoff and erosion in a cotton field, Koutiala region, Mali
Middle: Farmer evaluation meeting in Farakoro village, Mali
Right: Mr. Bagayogo installing a stone row in Farakoro village, Mali

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Table of Contents

Abbreviations

CMDT	Compagnie Malienne pour le Développement des Textiles (Malian semi-government organisation for cotton and rural development)
DDRS	Division Défense et Restauration des Sols (SWC Unit within the CMDT)
DED	Deutsche Entwicklungsdienst (German service for development co-operation)
DGIS	Directoraat Generaal voor Internationale Samenwerking (Directorate for International Co-operation, the Netherlands)
DRSPR	Division de la Recherche sur les Systèmes de Production Rurale (Farming Systems Research Group, within IER)
EC	Erosion Control
ESPGRN	Equipe Système de Production – Gestion Ressources Naturelles (Farming Systems – Natural Resource Management Research Group, ex-DRSPR, within IER)
IER	Institut d'Economie Rural (Agricultural Research Institute, Mali)
IOB	Inspectie Ontwikkelingssamenwerking en Beleidsevaluatie (Inspection of development co-operation and policy evaluation, ex-IOV, the Netherlands)
IOV	Inspectie Ontwikkelingssamenwerking te Velde (Field inspection of development co-operation, the Netherlands)
KIT	Koninklijk Instituut voor de Tropen (Royal Tropical Institute, the Netherlands)
M&E	Monitoring and Evaluation
NRM	Natural Resource Management
OECD	Organisation for Economic Co-operation and Development
PIRT	Projet d'Inventaire des Ressources Terrestres (Land resources inventory Project, Mali)
PLAE	Projet Lutte Anti Erosive (SWC project in southern Mali)
SE	Suivi Evaluation (Monitoring and evaluation department within the CMDT)
SF	Soil Fertility
SSA	Sub Saharan Africa
SWC	Soil and Water Conservation
VA	Village Associations, Mali

Chapter 1

Introduction

1 Introduction

1.1 Project monitoring and evaluation

Project evaluations serve three main purposes: to give timely feedback for improvements, to account for the expenses made and to learn lessons that can be used in future projects. An evaluation refers to a project plan and a project strategy, which describes how project inputs and activities contribute to project output, project purpose (outcome) and higher-level goal (impact). For example, the strategy of a plant breeding project is to use project funds for breeding work (activities), resulting in new plant varieties (output), resulting in farmer adoption of those varieties (outcome), contributing to improved food security (impact). This project plan and strategy is often presented in a logical framework, which will be discussed in Chapter 2.

Traditionally, monitoring and evaluation have been distinct activities. Monitoring was an ongoing internal comparison of achievements with plans, e.g. on a three-monthly basis. One step further in the analysis, considered monitoring by some but evaluation by others, is to aggregate annual to cumulative achievements that can be compared with long-term targets. Evaluation was often an external, more in-depth analysis of how project activities contributed to the higher-level goal, validating the project strategy. Typically, an evaluation was done at project appraisal (ex-ante), halfway through the project, and after project closure (ex-post) (Casley and Kumar, 1987; van de Putte, 1995).

In this thesis, monitoring and evaluation are defined as follows:

- Monitoring is the regular data collection and comparison of achievements with plans at any level in the logical framework.
- Evaluation is the analysis of the contribution of project activities to the higher-level goal. This includes, in two steps, the contribution of outputs to outcome and the contribution of outcome to impact.

Complete project evaluations, after project closure, typically look at the following five aspects (OECD, 2002):

- Effectiveness in the fulfilment of project objectives, up to the level of the project's purpose.
- Impact, which entails considering the intentional, unintentional, positive and negative effects at the level of the project's goal.
- Efficiency, comparing the project achievements with costs.
- Relevance, comparing project achievements with the needs and priorities of the beneficiaries, and with the country policy and the donor policy.
- Sustainability, assessing whether benefits will continue after project closure.

Considering these five aspects of evaluation, the effectiveness needs to be evaluated first, before something sensible can be said about impact, efficiency, relevance and sustainability.

In current discussions, the need is often expressed for more timely internal feedback during project implementation. This feedback should put less emphasis on the comparison of achievements with plans at the activity and project output level, emphasising instead the comparison of project outcome and impact with project purpose and goal. To do so, the project strategy itself, including the assumptions, should be regularly validated (Cameron, 1993). With the development of the Millennium Development Goals, with time-bound (up to 2015) and mostly quantitative targets at the goal level, evaluations are required of how individual projects and programmes contribute to these goals (Carvalho, 2003). Early impact assessment is not only valuable to improve the project strategy but also serves as a convincing extension tool (Nill, 2000). Different terms are used for this internal impact assessment: ongoing evaluation, impact monitoring (Vahlhaus and Kuby, 2001), impact monitoring and assessment (Herweg and Steiner, 2002) and performance measurement (Binnendijk, 2001). The need for a more timely and regular assessment of project outcome and, as far as possible, project impact, requires not only more in-depth analyses but also relatively simple methods that can be applied on a more regular basis during project implementation.

1.2 Evaluations of SWC projects in West Africa

Before discussing the evaluation of the SWC project in southern Mali, a few evaluations of other SWC projects in West Africa are reviewed, with the focus on how outcome (achievement of purpose) and impact (achievement of goal) are evaluated. In particular, I will examine whether the separate causes can be disentangled and how effects are attributed to a project. Evaluation studies vary from interesting mini case studies that are difficult to extrapolate, to large-scale impact studies in which it is difficult to attribute changes to project intervention.

Within the range of SWC measures, I will consider erosion control measures and soil fertility measures. Erosion control measures in West Africa include line interventions, gully interventions and area interventions. Examples of line interventions are stone rows, live fences, grass strips and earth bunds. Examples of gully interventions are check dams made from stones or from wood and crop residues. Examples of area interventions are crop residue mulching, cultivation along the contour and the *zai* planting technique; the latter entails digging plant holes and applying compost, which increases water infiltration. Soil fertility measures in West Africa include making compost in compost pits and collecting manure from improved cattle pens that confine cattle to a small, enclosed area (2-3 m^2 per head) in which crop residue litter is used as bedding.

The impact of stone rows was evaluated in Chad in a mini case study (Nill, 2000). Water run-off, soil erosion and crop yield were monitored. A useful aspect of this study was the introduction of thresholds (here: tolerated soil loss of 15 t ha^{-1} y^{-1}) below which the results for a certain indicator become less relevant and recommendations for SWC change. The results from one field with SWC and one field without SWC were extrapolated to costs and benefits. One of the conclusions was that the installation of stone rows is only worthwhile on fields steeper than 4%. Although the method itself is interesting, the limited number of fields monitored (two) forms too weak a basis for attributing effects to project interventions or for extrapolating to a larger area.

The impact of stone rows, *zai*, compost and mulching was evaluated in Niger where crop yields were monitored during three years in order to reduce the effect of fluctuating annual rainfall on the results (Schorlemer, 2000). Various combinations of different treatments and a control were monitored at several project sites. The extrapolation of increased crop yield to the costs and benefits of SWC, taking into account the lifespan of SWC measures, the installation costs and the annual maintenance costs, is interesting. However, the set-up of the experiment and the analyses did not allow the various causes to be disentangled. And the statistical significance of the effects was not tested.

In 1999 PATECORE, a large SWC project in Burkina Faso, evaluated the effects of stone rows and earth bunds by comparing crop yields in a zone from 10 m below to 30 m above the SWC measure with crop yields on fields without SWC (PATECORE, 2000). Interestingly, it was assumed that the area just above the SWC measure was expected to benefit most. For someone from southern Mali this may seem incomprehensible, because in southern Mali the cultivated area below stone rows is considered to be protected from erosive runoff coming from the plateau. However, PATECORE operated in an area that is drier than southern Mali, so water harvesting may have been more important than erosion control. A large number of fields were monitored, allowing statistical analyses of the effects of SWC measures. Interesting interactions with soil type and compost use were presented, but without statistical analyses; this made it difficult to distinguish the causes, especially as compost was used more often in fields protected from erosion than in unprotected fields. The crop yields, taken in small areas close to the SWC measures, may not have been representative and could not be extrapolated to large fields.

Kunze (2000) further explores the data from a study by PATECORE in Burkina Faso. She points out that not all impact can be attributed to project interventions: farmers who adopted SWC measures had more livestock and higher off-farm revenue, but this could not be attributed to the introduction of SWC. Whereas most studies focus on crop yield and revenue per hectare, Kunze also looks at revenue per household and return to labour. The effects at the household level were not as significant as the effects on field level, because only some of the fields were protected by SWC and because part of the land area had been taken up by SWC structures. The return to labour was found not to be significantly higher with SWC, because of the additional labour required for SWC.

Ouedraogo et al. (2001) evaluated the impact of the IFAD-funded Special SWC and Agroforestry Programme in Burkina Faso. Most emphasis was given to farmers' perception of impact. What is interesting in this study is that farmers were more positive about the impact than M&E staff. This is partly because M&E staff compared crop yields in fields with SWC with crop yields in fields without SWC, while according to the farmers, the fields with SWC only produced *because* of the SWC. Thanks to SWC, the farmers had rehabilitated unproductive land that would otherwise have been left abandoned. Another reason for a more positive view is that farmers look not only at cereal yield but also at many other impacts: e.g. vegetative regeneration, fruit trees, grasses and a higher water table. An important point is made about the sustainability of the programme: farmers can continue expanding the area under *zai* but are unable to install stone rows without project assistance in transport of stones.

Reij and Thiombiano (2003) did a large impact study in Burkina Faso. Their study is especially interesting because of the large scale, the wide view on impact and the long period over which changes were monitored. A participatory identification of impact and indicators was used, not limited by original project objectives and targets. The study entailed analysing changes in time and comparing villages with and without project assistance. The indicators included crop yield, cultivated area, crop diversification, food security, tree density, livestock number and intensification, water availability, and even migration and wealth. The effect on different sub-groups of beneficiaries was assessed, distinguishing poor, average and rich farmers and whether they were Fulani and / or women. Changes over time and differences between villages were attributed to SWC projects, increased rainfall and population pressure. The study gives a good and complete description of changes over time and convincingly concludes that the situation on the Central Plateau has improved in recent decades. However, isolating the causes and effects and attributing impact to the SWC project proved to be very difficult.

For evaluation of efficiency it is interesting to calculate the project costs per hectare of land protected by SWC. For PEBASO, a project promoting small dams in Burkina Faso, Traoré (2000) calculated the total costs per ha cultivated land of two dams, including expatriate and local staff, extension and construction; he compared these costs with the annual revenues from various cropping scenarios. Because of discouraging cropping possibilities, the internal rate of return was negative for both dams. This is one of the rare examples in the region of efficiency evaluation of an extension project.

1.3 The SWC project in southern Mali

The study area in southern Mali

The research described in this thesis focused on the cotton-growing area of southern Mali where the *Compagnie Malienne pour le Développement des Textiles* (CMDT) has been operating. The CMDT is a semi-government organisation: 60% is owned by the Malian government and 40% by the French company CFDT. Up to 2002, the CMDT had an integrated dual mission: a commercial mission to organise activities related to cotton (inputs on credit, extension, processing, export) and a public mission of rural development (e.g. literacy programmes, water supply), assigned to the Malian government. This meant that rural development was partly financed by cotton revenue, complemented with support from the Malian government and donor agencies: a public–private partnership. The CMDT had a dense, hierarchical network of extension workers. About 650 general extension workers covered 8-10 villages each. 33 district offices assisted the general extension workers and formed the link with the 6 regional offices, which were supervised by the National Directorate.

The CMDT area covers 125,000 km^2 and 5,000 villages, hosting a rural population of 3.1 million in 2002 (CMDT, 1996; Schrader and Wennink, 1996; MaliArp, 1999). Annual rainfall varies from 1200 mm at the southwest border with Guinea to 600 mm in the northeast (CMDT rainfall data 1991-2001, unpublished). An average farm family is composed of 17 persons and cultivates 10 ha of land (CMDT, 2003). Cotton is the main cash crop, grown in rotation with cereals. The soils are mainly loamy sand. The slopes in the cultivated fields are gentle: 0-2% in the central and eastern parts and 0-5% in the southern and western parts (Hijkoop et al., 1991). On cultivated fields, the annual soil loss from sheet and rill erosion is estimated to be 5 to 31 t ha^{-1} (Roose, 1985; Hallam and Verbeek, 1986; Bishop and Allen, 1989; Vlot and Traoré, 1994). Van der

Pol (1992) found negative nutrient balances of the cropping system, especially for nitrogen and potassium. More details on the study area are given in Chapter 3.

SWC activities between 1982 and 2003

The SWC activities can be grouped into six phases between 1982 and 2003.

In the pre-project phase, from 1982 to 1986, the Malian farming systems research group *Division de Recherche sur les Systèmes de Production Rurale* (DRSPR) had tested SWC approaches. DRSPR received Dutch funding (DGIS) and Dutch technical assistance (KIT). Following complaints by farmers about falling yields and water washing away their crops, trials were carried out in 1984 jointly with the CMDT.

The pilot project phase, from 1986 to 1989, followed the promising results from the trials. The SWC project *Projet Lutte Anti Erosive* (PLAE) was created within the CMDT structure in 1986, and also received Dutch funding and technical assistance. Collaboration between the SWC project, the CMDT, the DRSPR and two other (German-funded) SWC projects, assured a thorough testing and harmonisation of SWC measures and extension methods. By the end of 1989, the SWC project had reached 36 villages.

The promotion phase, from 1989 to 1996, was characterised by the large-scale capacity building of the CMDT extension staff. The targeted villages were spread out over southern Mali, in order to involve all extension staff and to maximise the exposure of neighbouring villages. By the end of 1996, the project had reached 1135 villages.

During the handing-over phase, from 1996 to 1998, the Dutch donor changed from a project to a programme approach, with the result that the CMDT also became responsible for the financial management of the SWC programme. In the remainder of this thesis, 'project' also refers to the 'programme' phase. By the end of 1998, the project had reached 1809 villages.

In the donor withdrawal phase, which lasted from 1998 to 2002, donors first withdrew their financial support to the CMDT and later also withdrew their technical assistance. By 2000, the project had reached 2562 villages. After 2000, SWC extension continued in a reduced intensity.

During the extension withdrawal phase, from 2002 onwards, the Malian cotton sector was being restructured and the CMDT had to abandon many of its former activities, including SWC extension.

The author worked as technical assistant at the SWC Unit of the CMDT from 1998 to 2002.

The overall goal of the SWC project, as stated in the first project document in 1986, was 'to reduce the degradation of the ecosystem and to intensify agriculture for increased agricultural production' (PLAE, 1986). The formulation of specific project purposes, outputs and activities has varied over the years but followed a similar logic, in which four main project purposes can be distinguished:

1. The extension service is capable of running a large-scale SWC programme.
2. The rural population is aware of land degradation and SWC.
3. The rural population is responsible (and will bear the costs) for natural resource management (NRM), in which a distinction is made between:
    - The adoption of SWC measures to protect agricultural land.

- A balance between agricultural, silvicultural and pastoral land uses.
- NRM of communal land by village institutions.

4. Experiences are monitored, evaluated, documented and disseminated.

The third purpose can be considered as the core purpose, while the others are supporting and necessary conditions for its success. Each project purpose was further defined with project outputs, activities and inputs (PLAE, 1989; van Mourik et al., 1993; CMDT, 1995).

The SWC extension approach targeted villages, rather than individual farmers. It consisted of awareness-raising meetings, training, demonstrations, field visits, planning and review meetings, and the provision of tools and planting materials for SWC. The approach is described in more detail in Chapter 5. One of the key activities was the installation and training of an 'SWC village team', a team of five to eight young farmers who received thorough training in SWC and served as intermediaries between the SWC project and the targeted village.

The SWC consisted of erosion control measures and soil fertility measures. The erosion control measures included line interventions (stone rows, live fences, grass strips), gully interventions (of stones, crop residues and wood) and contour cultivation. The soil fertility measures included improved cattle pens where crop residues are applied, and compost pits.

1.4 Evaluations of the SWC project in southern Mali

A number of evaluations of the SWC project in southern Mali are reviewed here, in order to identify their shortcomings. The evaluations address effectiveness, impact, efficiency, relevance and sustainability. The institutions involved in monitoring and evaluation, and the indicators, reference values and analyses will be discussed in Chapter 2.

Several evaluations proved the effectiveness of farmer training in increasing the adoption of SWC measures (Giraudy et al., 1996; CMDT, 2002). In some studies, 'adoption' merely referred to whether or not a farmer had installed a certain SWC measure. In others, 'adoption' also specified the number of the SWC measures. During the monitoring of SWC adoption, villages where SWC training had been given were distinguished from villages where training had not yet been given, thus facilitating the evaluation of effectiveness of training. The difference in adoption could be attributed to the training activities and could be extrapolated to southern Mali.

One aspect of the overall goal was to increase agricultural production. In one study, which I conducted in 2000 when still working at the SWC Unit, the impact of SWC measures on crop yield was evaluated (CMDT, 2002). It comprised a detailed internal field study looking at the effects of SWC on crop yields, plus an analysis of external annual survey results in order to relate cotton yield to the presence of SWC measures in general. Data from that study (Fieldwork 2000) were analysed further in the research for this thesis. Some of the preliminary results reported in 2002 are worth mentioning here. Despite using parameters related to erosion risk (slope etc.), erosion (erosion rills) and other factors influencing crop yield (fertilisation and rainfall), it was difficult to prove that SWC was having statistically significant positive effects. Only the effect of stone rows and compost use on cotton yield proved to be statistically significant. In the general annual surveys, the cotton yields on the fields of farmers who had adopted SWC measures were found to be systematically higher. However, it was difficult to attribute this effect to the SWC, because adoption of SWC correlated with other factors that may also influence crop yield, such as farm size or farm equipment.

Apart from increasing agricultural production, the overall goal of the SWC project included two other aspects: to reduce land degradation and to intensify agriculture. There has been no systematic monitoring of soil erosion and so it is impossible to say whether land degradation has or has not decreased. Between 1988 and 2000, farmers increased their use of chemical fertiliser and organic compost and therefore the nutrient balance has become less negative, which can be interpreted as agricultural intensification (CMDT, 2002).

A first attempt to evaluate the efficiency was made in the same impact study by comparing annual expenses on the SWC project with the estimated annual farmers´ revenues from the additional cotton yield attributed to SWC measures (CMDT, 2002). The annual benefits for farmers seemed to exceed annual expenditure on the SWC project. However, the basis of project impact on crop yield was weak.

To evaluate the relevance of the SWC project, its impact needs to be compared with the priorities of the beneficiaries, the national policy and the donor policy. In 2000 the Dutch inspectorate of development cooperation and policy evaluation (IOB) evaluated the Dutch policy and programme approach implemented in Mali between 1994 and 1998 (where, since 1996, the SWC activities had become part of a rural development programme implemented by the CMDT). They concluded that too little information was available about the impact on the environment and on the beneficiaries. The lack of information was partly due to the performance indicators chosen, even though these had been agreed on by the CMDT and Dutch embassy. The lack of information was also due the fact that the programme approach had been given too little time: from 1996 to 1998. There had been no good analytical comparison of Malian policy with Dutch aid policy in general. More specifically, the Dutch embassy had different ideas about the rural development programme’s overall goal, strategy and priorities than the CMDT implementing that programme (IOB, 2000).

One of the indicators that touches on several aspects of sustainability is the continuation of adoption of SWC measures by farmers without external support. In spite of decreasing SWC training activities and the withdrawal in 1998 of special credits (for donkey carts and wire mesh for improved cattle pens) that facilitated SWC adoption, adoption continued to increase steadily (CMDT, 2000a; CMDT, 2003).

In conclusion, at the time that donor support to the SWC programme stopped, no complete final evaluation had been undertaken, in spite of the lessons that should be learnt from this long-term and large-scale experience.

In 1999, when the impact study was initiated, there were some serious concerns about the project impact and its assessment. Firstly, some policy makers in Bamako were not convinced that the project had had sufficient impact, judgements that probably resulted from a lack of clear evidence. Secondly, coordinators and field staff involved in the SWC project, even though they were convinced about the positive project results, feared that it would be methodologically very hard to evaluate the impact because of the complexity and the many external non-project factors influencing impact. As discussed above, there were a number of shortcomings in the relationships between planning, monitoring and evaluation in the SWC project in southern Mali. These would not only complicate an ex-post evaluation but had also resulted in sub-optimal feedback about the impact during the project implementation.

1.5 Objectives and research questions

So far, the evaluations of SWC projects have rarely been convincing. They have been handicapped by the incompleteness of information in project planning (baseline, long-term targets), by limited information from specific SWC monitoring and evaluation reports and from general agronomic surveys, and by a poor attribution of change to project interventions.

The research described in this thesis focused on the evaluation of the effectiveness and intended impact of SWC projects, using the SWC project in southern Mali as a case study. Evaluating effectiveness and intended impact requires firstly the observation of indicators of change at the project outcome and project impact levels. Secondly, project achievements need to be compared with reference values: baseline data and targets. Thirdly, changes need to be attributed to project interventions. This requires analysing small-step cause–effect relations at different levels in the project's logical framework, with the inclusion of other influential, non-project factors, after which the results can be aggregated and extrapolated to impact.

The challenge for the evaluator is to complement the existing information with key information from specific case studies and to analyse in such a way that changes in outcome and impact can be attributed, at least partly, to project interventions.

The objective of the research was threefold:

1. To develop an ex-post impact evaluation methodology for the SWC project in southern Mali.
2. To evaluate the impact of the SWC project in southern Mali and to infer the lessons for future SWC activities in Mali and elsewhere.
3. To make recommendations for the planning, monitoring and evaluation of future SWC projects in order to have a more timely feedback on impact during project implementation.

The main focus was on 2) the evaluation of the actual impact of the SWC project in southern Mali.

These three objectives are reflected in the following specific research questions:

- What information is available from the SWC project and other sources, and what are the needs for additional research enabling an ex-post impact evaluation?
- What is the background of agricultural development in southern Mali against which the SWC project is evaluated?
- What was the effect of the SWC extension approach on the adoption of SWC measures, and which other factors influenced adoption?
- What was the effect of erosion control on soil erosion?
- What was the effect of erosion control on crop yield?
- What lessons can be learnt from the monitoring and evaluation system of the SWC project in southern Mali and which recommendations can be made for the planning, monitoring and evaluation of future SWC projects?

1.6 Thesis outline

The six research questions listed above will be answered in the following chapters.

Chapter 2 provides the plan of what to evaluate. It explains the relationship between planning, monitoring and evaluation and reviews the possibilities for analyses. It then identifies the evaluation shortcomings in southern Mali and proposes a number of additional analyses, based on the specific research questions. Chapter 3 describes how to evaluate. It describes the research area in southern Mali, the history of SWC activities, the available data from the CMDT, and the additional fieldwork done in 2000 and 2003. It further proposes the methods for the additional analyses to evaluate the impact of the SWC project southern Mali.

Chapter 4 describes the general trends in agricultural development that need to be understood before project impact can be evaluated. It analyses changes over recent decades in terms of expansion, intensification, production and sustainability.

Chapter 5 describes the SWC approach: the choice of simple and cheap SWC measures, the incorporation of SWC activities into an existing extension service, and the participatory village approach. It further analyses the dynamics of adoption over time, both within villages targeted by the SWC project and in neighbouring villages. It draws conclusions about the effectiveness and sustainability of the SWC extension approach. Chapter 6 analyses the factors influencing the adoption of SWC. Adoption is explained by a combination of SWC training as project activity and external factors (land pressure, cotton growing, possession of ploughing equipment and possession of a donkey cart).

Chapter 7 proposes simple erosion indicators that can be used by farmers and extension staff. In order to evaluate the effect of erosion control in an area where most fields do not have visible erosion gullies, the feasibility of using soil crust and deposit cover as an erosion indicator was evaluated. Chapter 8 analyses the impact of erosion control on soil erosion. In one case study, erosion in 2003 could be compared with a baseline from 1988. For ex-post evaluations without baseline data, two alternative methods were used: a reconstructed baseline and a virtual time series.

Chapter 9 analyses the impact of erosion control on crop yield, firstly by taking into account rainfall, fertilisation, crop management and field characteristics, and secondly by constructing a virtual time series.

Chapter 10 argues that monitoring should be linked to evaluation. It describes how information available from different monitoring sources was complemented with additional fieldwork, in order to evaluate effectiveness and impact. Recommendations are made for M&E systems of future SWC projects that allow for a more timely impact assessment during project implementation.

Finally, Chapter 11 provides a synthesis and presents the conclusions of the study, emphasises what is new, and presents the institutional and policy implications.

Chapter 2

Impact Evaluation Methodology for the Soil and Water Conservation Project in Southern Mali

2 Impact Evaluation Methodology for the Soil and Water Conservation Project in Southern Mali

2.1 Concepts in planning, monitoring and evaluation

2.1.1 Project planning

Logical framework

Evaluations refer to a project strategy and a project plan, which can be visualised in a logical framework, or logframe. The logframe was first developed in the late 1960s for USAID to facilitate monitoring and evaluation, but is later also much used and adapted by other organisations as a project-planning tool (USAID, 1980; GTZ, 1988; Crawford and Bryce, 2003).

There are variations in how the logframe is built up: some are composed of four horizontal levels, others of five. Some logframes have a lowest-level 'inputs' below the activity level, whereas others use 'inputs' and 'activities' as synonyms. What is considered as the 'goal' in the logframe of an individual project may be a 'purpose' in the logframe of a national programme. In spite of these differences, logframes follow the same logic. Table 2.1 presents as an example a simplified logframe for the SWC project in southern Mali, here with 4 columns x 4 rows.

Table 2.1. Example of a simplified logframe for the SWC project in southern Mali.

	Narrative summary	***Objectively verifiable indicators***	***Means of verification***	***Assumptions and risks***
Goal *(impact)*	Reduce degradation; Improve production	Soil erosion; Crop yield	National survey	No climate change
Purpose *(outcome)*	Fields protected from erosion	Area protected	Project survey report	No further deforestation
Output	Farmers enabled to protect fields	Number of farmers with knowledge and access to materials	Project survey report	Cash crop enables credit
Activity	Training sessions; Materials supply	Number of sessions held; Quantity of supplies delivered	Annual project report	Social cohesion in village

Vertically from the bottom row upward, the logframe presents the project strategy of how project activities contribute to project outputs, how these contribute to project purposes (outcome), and how these then contribute to the wider goal (impact). In the example above, one could imagine that a national programme would have an even higher level goal, for example improved farmer welfare. Differences between the four levels have been defined in terms of control and responsibility. Activities and outputs are under project control. Outcome is not under project control and depends also on other stakeholders, but still falls under the project responsibility. Impact is not under project control or under project responsibility (van Leeuwen et al., 2000; Guijt and Woodhill, 2002; Herweg and Steiner, 2002).

Going from the left column to the right, each narrative summary in the first column is accompanied by objectively verifiable indicators in the second column: impact indicators, outcome indicators, output indicators and activity indicators. These indicators are accompanied by reference values: baseline data describing the situation at the start of the project and targets describing the desired situation. The third column describes the means of verification: how is progress monitored and reported and by whom. The last column gives the assumptions and risks: conditions outside project control that need to be fulfilled for the project to succeed.

Project, programme and policy

The relations between project objectives, programme objectives and policy objectives cannot always be presented in a simple linear logframe. Three dimensions of objectives need to be understood: the specificity, the spatial scale and the time scale.

- A project deals with a limited number of specific objectives, has limited resources and is time bound (e.g. 3-5 years). Therefore, a project will avoid over-ambitious objectives and will operate in a defined target area (e.g. in a number of villages or districts).
- A programme coordinates activities but is broader than a project, has often more global objectives organised for the development of a region, a country or a sector. A programme has a longer time frame or is continuous and has therefore less-defined limits on resources. One programme can consist of several sub-programmes and / or several projects (McLean, 1988).
- A policy reflects priorities for example of national governments or donors, often without quantifying targets or resources. Programmes and projects need to be consistent with policies.

A constructive link between several projects under one programme is the cascading or interlocking logframe, in which the purpose of an individual project feeds the output of the overall programme. Because of the difference in timeframes, such a linkage will require setting intermediate targets for the programme objectives that can be compared with the project objectives (Farrington et al., 1997; MDF, 2003).

There is a tendency to set more quantitative and time-bound objectives at the programme and even at the policy level, for example as specified in the millennium development goals with targets for 2015 (UN, 2000). Because the time scale of 15 years exceeds the time scale of most programmes, it is recommended to specify intermediate targets for these quantified goals (Carvalho, 2003).

Indicators

Indicators give specific hold to objectives and enable monitoring progress in achieving those objectives. If for project planning the logical framework is used, indicators are chosen in relation to project goal (impact indicators), project purpose (outcome indicators), project output (output indicators), and project activities (activity or process indicators) (Binnendijk, 2001). If inputs form a lowest level under activities, corresponding indicators are chosen (e.g. budget, expenditure).

The choice of indicators also depends on who has to work with them: farmers, extension workers, researchers, funding agencies or policy makers. For example, erosion rills are an excellent visible indicator of soil erosion for farmers and extension workers but less suitable for funding agencies or policy makers, who prefer quantitative research results from for example models or remote sensing (Herweg and Steiner, 2002).

Indicators are useful only in combination with reference values. Reference values include baseline values – describing the situation at the start of the project – and targets – describing the desired situation after a defined period of time.

Generally, monitoring indicators at a higher lever (impact) is more difficult than monitoring indicators at the lower level (activity). Higher-level indicators are often the result of several project and non-project effects. More specifically for SWC projects, it is often easier to monitor outcome indicators (the adoption of practices) than to monitor impact indicators (the anticipated effects of those practices). Some projects assess impact by monitoring outcome and assuming relations between outcome and impact. The main disadvantage is that it does not verify the assumed relation between outcome and impact itself. Nor will it give room to improve practices or encourage new practices that are perhaps more effective in achieving the desired impact (Hayo and van der Werf, 2002). A compromise is to complement large-scale monitoring of outcome (e.g. adoption of SWC) with more in-depth evaluations of impact (e.g. soil erosion, crop yield) in the form of case studies (Casley and Kumar, 1987).

On the one hand there is a trend to develop subjective indicators in a participatory way, which is a good method for a one-time process and learning exercise, e.g. during project design or during ex-post evaluations of intended and unintended impact (Vahlhaus and Kuby, 2001; Lopez-Ridaura et al., 2002). On the other hand there is a trend to develop more uniform and objective indicators, which enables comparing results from different evaluations, e.g. comparing different projects within the same sector, or comparing results from the same project at different times during implementation. For accountability, quantitative objective indicators are preferred (Dumanski and Pieri, 2000).

Baseline data

Baseline data describe the situation at the time the project starts. For all indicators at different levels in the logframe, quantitative baseline values are presented in a baseline report. Baseline data can be general, giving an average value for a whole region, or they can be specific, distinguishing values for the project group and the control. Eventually one may want to compare changes over time between villages with and without project assistance. If the indicators are related to the selection criteria for targeting villages, then specific baseline data will be needed from both targeted and untargeted villages.

Baseline data may already be available, for example from a national statistics institution. Often, such data are not village-specific but averaged per region or country. In cases where the baseline indicator is not related to the selection criteria for project intervention, such average baseline data can be used.

If baseline data are not available before the start of project interventions, there are a number of simple alternatives to determine baseline data in targeted villages:

- 'First measurement at starting point'. This combines the collection of baseline data with the first project activities, e.g. during the first meeting in a village. These village baseline data can be aggregated to a baseline report for a whole region (Guijt and Woodhill, 2002).
- 'Rolling baseline'. This is similar to first measurement at starting point, but takes into account that different activities may start at different times (Guijt and Woodhill, 2002).
- 'First measurement at first annual review'. The first review of achievements can serve as baseline data for the subsequent project period.
- 'Assumed baseline'. In the case of the introduction of new practices one may assume that adoption was negligible before the project started.

Collecting specific baseline data in non-targeted villages may be problematic. A project going into a village, collecting baseline data and subsequently withholding project assistance will frustrate the villagers. One option is to use villages during the period between baseline survey and project intervention as a control group. This is an option for projects that increase the number of villages for assistance each year. Such projects can do one baseline study at the start of the project in all villages that will eventually be targeted (James, 2001).

Targets

Targets are set for indicators at different levels in the logframe, but usually less detailed targets are set at higher levels. By the definitions used for the logframe, the inputs, activities and outputs are under control of the project: quantitative targets are set for which the project will be held accountable. The outcome (achievement of the project purpose) is not under control of the project, so the project will not be held accountable for quantitative outcome targets. However, the project is responsible for its contribution to outcome, so even if no quantitative outcome targets are set, progress should be made. The achievement of the goal is not under control or the responsibility of the project, so in most cases no quantitative targets for impact are set.

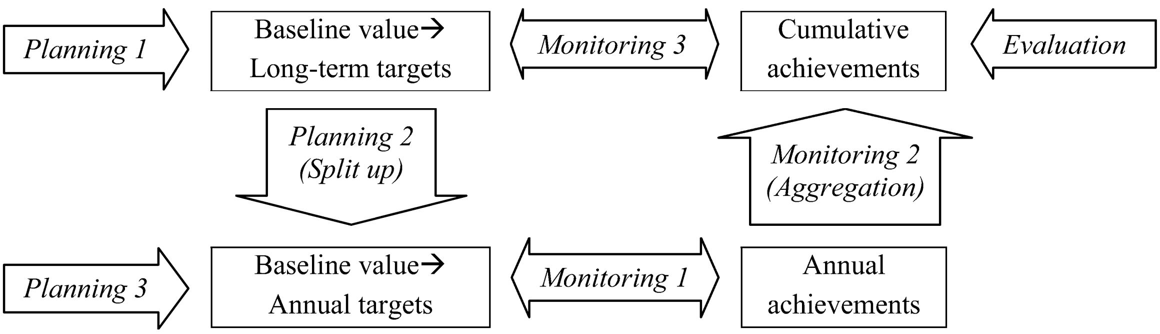


Figure 2.1. Functions of planning (P), monitoring (M) and evaluation (E) and the relation with targets and achievements.

A schematic overview of how planning relates to monitoring and evaluation is shown in Figure 2.1. A distinction is made between annual targets and achievements (bottom row) and long-term targets and cumulative achievements (top row). Long-term targets are set at the start of the project (Planning 1). Annual targets, often limited to the activity and output level, can be derived by dividing long-term targets over several years (Planning 2), or they can be determined by the capacity of the project (budget and personnel) and the participation of beneficiaries (Planning 3).

2.1.2 Project monitoring

Project monitoring is normally an internal project instrument to follow project inputs, activities and outputs. It involves collecting data and comparing achievements with targets. One can distinguish (Figure 2.1): the regular comparison of annual achievements with annual targets (Monitoring 1), the aggregation of annual to cumulative achievements (Monitoring 2) and the comparison of cumulative achievements with long-term targets (Monitoring 3). Project monitoring is more frequent at the input, activity and output levels, where timely corrective actions are needed, and less frequent, if at all, at the outcome and impact level.

External organisations or institutes may monitor indicators, for example in the framework of a national policy, that are related to the project purpose and goal. In that case, it may be wise for an individual project to link up with such an external monitoring institute. An external monitoring institute may provide data to the project enabling timely evaluations of outcome and impact without having to spend many resources on extensive internal monitoring at the purpose and goal level.

2.1.3 Project evaluation

Effectiveness, impact, efficiency, relevance and sustainability

Project evaluations can include various aspects, depending on the project phase and the objective of the evaluation. Complete project evaluations, after project closure, typically look at the following five aspects: effectiveness, impact, efficiency, relevance and sustainability (OECD, 2002).

Evaluating effectiveness is defined by some as comparing targets and achievements within one horizontal level in the logframe (Binnendijk, 2001; Guijt and Woodhill, 2002). In the light of a changing approach in which outcome and impact become more important than the comparison of achievements with plans, I prefer the definition of effectiveness as the contribution of project achievements towards a higher-level objective in the logframe (van Leeuwen et al., 2000; MDF, 2003). In most cases, evaluation of effectiveness stops at the outcome level: the achievements of the project purposes.

Evaluating impact looks at changes at the goal level. Although the achievement of the goal in absolute figures is not the responsibility of the project, the project is responsible for validating the assumption that project outcome contributes to the goal (van Leeuwen et al., 2000; Guijt and Woodhill, 2002). A full impact assessment also looks at unintended impact, which may be positive and negative (OECD, 2002). By definition, unintended impact cannot be captured by predefined indicators in the original project plan. An impact evaluation requires thus a participatory assessment in which beneficiaries identify possible impacts and indicators, without losing sight of the original project objectives.

Evaluating the efficiency includes a comparison of costs with output, outcome or impact (de Graaff, 1996; Guijt and Woodhill, 2002; OECD, 2002). In the last case this is also called a cost-effectiveness analysis. A distinction is made between financial efficiency, from the viewpoint of a participant, and economic efficiency, from the viewpoint of a society as a whole (Casley and Kumar, 1987).

Evaluating the relevance includes the comparison of impact with the needs and priorities of beneficiaries, with the country policy and with the donor policy. It may thus happen that a successful sectoral project (successful from an effectiveness, efficiency and impact point of view) is stopped because donor policy changes from a sectoral to an integrated development approach.

Evaluating sustainability assesses whether benefits continue after external project support has stopped. Different aspects of sustainability are distinguished (World-Bank, 2001; MDF, 2003):

- Policy support: Does the country policy allow for continuation?
- Technology: Are beneficiaries capable of using the chosen technology after outside support has ceased?
- Environment: Is continuation of environmental protection guaranteed?
- Socio-cultural: have measures been taken to ensure ongoing participation of all members of target group?
- Institutional: have measures been taken during project to ensure future functioning of organisations?
- Economic and financial benefits: will in the long run the benefits continue to be higher than the costs, which will now have to be entirely borne by the target group itself?

Effectiveness and intended impact need to be evaluated before unintended impact, efficiency, relevance and sustainability can be evaluated. Evaluating effectiveness and intended impact requires that changes can be attributed to the project. Attributing change at the goal level to project activities requires three actions:

- Splitting the long cause-effect chain between project activities and goal into smaller cause-effect steps.
- Attributing effects to causes in each step.
- Aggregating and extrapolating results of small-step analyses to impact.

Splitting the cause – effect chain in smaller cause – effect steps

One may try to explain an effect at the goal level (e.g. crop yields) by a cause at the activity level (e.g. farmer training). This large-step analysis increases the risk of overlooking other influencing factors and lacks the possibility to evaluate the different pathways between cause and effect. Douthwaite et al. (2003) argue that the evaluation requires more detailed cause-effect steps than usually presented in the four-level logframe and propose an 'impact pathway evaluation'. A large-step analysis can be split up into several small-step analyses.

- By analysing a sequence of smaller cause-effect steps (e.g. farmer training – adoption of erosion control – reduced erosion – increased crop yield).
- By analysing several parallel cause-effect steps (e.g. training – erosion control; training – compost use; erosion control – crop yield; compost use – crop yield).

Attributing effects to causes

The attribution of effects to causes requires a comparison of 'before-after' project intervention and a comparison 'with-without' of project intervention.

Before-after comparisons depend on baseline data from the time when project intervention started. A special case is the interrupted time series from before to after project intervention, in which the trend is clearly affected by the project intervention. Time series are more useful than a comparison of only two moments when indicators are affected by fluctuating non-project factors (e.g. crop yields by rainfall). If changes over time without project intervention can be neglected, no control would be needed.

With-without comparisons depend on a control group without project intervention. If the project group and control group are not equivalent, it will be necessary to include non-project factors in the comparison (Casley and Kumar, 1987). A special case is the regression analysis in which project intervention and non-project factors can be continuous variables. If the baseline values for impact indicators of the project group and the control group can be assumed the same, no baseline data would be needed.

In some cases the changes over time in the control group cannot be neglected and the baseline values for impact indicators of the project group and the control group cannot be assumed the same. Hence the evaluation will need a combination of a 'before-after' and a 'with-without' comparison, with specific baseline data for the project group and the control group (Casley and Kumar, 1987; Guijt and Woodhill, 2002).

In ex-post evaluations one may be confronted with the lack of documented baseline data. I describe here two creative options: to reconstruct a baseline and to create a virtual time series.

A baseline can be reconstructed in different ways. For example, in fields one may observe not only the current active erosion gullies, but also the reclaimed gullies indicating erosion in the past. The number of total gullies, active and reclaimed, can be used as reconstructed baseline for a better comparison between fields. As another example, farmers may recall the year they received training and the year they installed erosion control measures. By gathering information from several farmers, one can reconstruct an interrupted time series (Figure 2.2 A). Such interrupted time series presents the moment of project intervention (dotted vertical line in 1988) and the number of farmers adopting erosion control measures (up to 3 farmers in 1992). If training sessions in different villages were held in different years (Figures 2.2 A, B and C), the time series for the different villages could be transposed to one zero-point of project intervention on the x-axis (Figure 2.2 D). The transposed interrupted time series presents the moment of project intervention (x=0) and the trend line of cumulative number of farmers adopting erosion control measures (up to 10 farmers 4 years after project intervention).

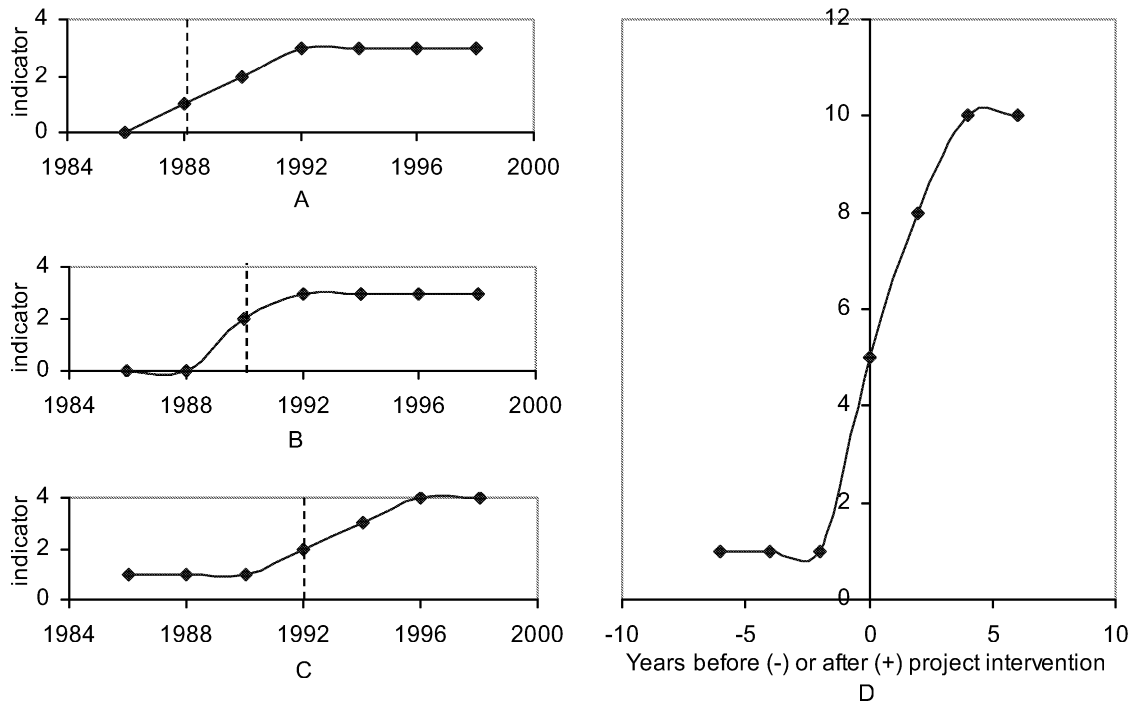


Figure 2.2. Transposed time series. 3 individual time series (A, B and C) with different years of project intervention are transposed to one point of project intervention (D).

A virtual time series presents the current situation as a function of different periods since project intervention (Figure 2.3). For example, erosion in fields with older erosion control measures (12 years old; installed in 1988) may be lower than erosion in fields with recently installed erosion control measures (less than 1 year old; installed in 2000). A special case is where erosion was a criterion for project intervention. In that case a control field (horizontal control reference line) may show less erosion than a field with recently installed erosion control measures, but more erosion than a field with older erosion control measures.

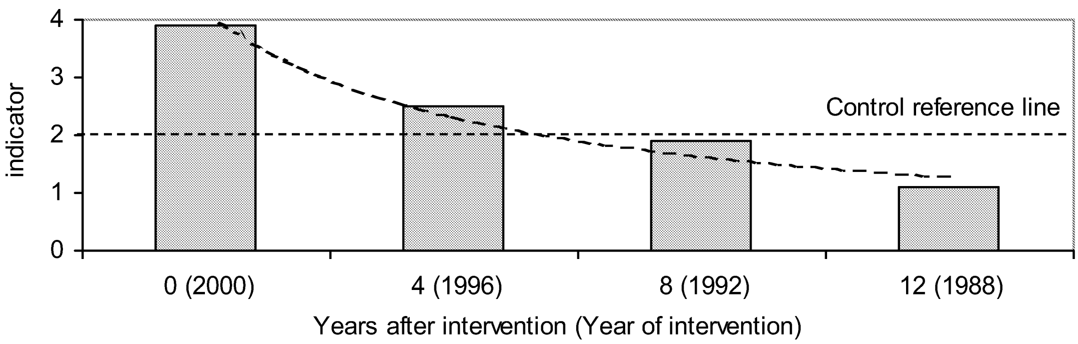


Figure 2.3. Virtual time series: Indicator, measured in 2000, as function of years after intervention. Control presented as horizontal reference line.

Aggregation of results and extrapolation to regional impact

The results of the various small-step cause-effect analyses can be aggregated to a longer cause and effect chain between project intervention and impact at the field and the farmer level. For example, the training in SWC may have resulted in a higher compost production and in the installation of erosion control measures, of which the combined effect is a certain yield increase.

The impact at the field and farmer level is extrapolated to a larger region or district, taking into account the percentage of farmers and the percentage of fields positively affected by the project. For example, the yield increase found in the previous step is extrapolated using the percentage of farmers that have been trained, the percentage of fields that receive compost and the percentage of fields protected with erosion control measures.

Attribution gap between the evaluation of an individual project and the evaluation of higher development goals

The question that comes up when evaluating effectiveness and impact is: what part of outcome or impact can be attributed to the project, since other factors influence the outcome and impact as well? This attribution problem becomes more problematic the further away one moves from project control (activities and outputs) and the closer one comes to the project purpose and goal.

Vahlhaus and Kuby (2001) and Herweg and Steiner (2002) argued that one should not expect from individual projects to evaluate the impact they have on the achievements of the higher-level development goal. They suggest, in what they call the GTZ model, two evaluation steps: one from project activity upward, the other from higher development goal downward (Figure 2.4).

Higher-level development progress (eg improved agricultural production)
↓
Direct causes of impact (eg increased fertiliser use)
↓
ATTRIBUTION GAP
↑
Direct benefits of project outcome (eg increased yield on fields with SWC)
↑
Project outcome (eg adoption of SWC)
↑
Project outputs (eg farmers trained and supplied with materials)
↑
Project activity (eg training sessions)
↑
Project input (eg money, personnel, materials)

Figure 2.4. The attribution gap between the upward evaluation of direct benefits of project outcome and the project-independent downwards evaluation of direct causes of impact (adapted from Valhaus and Kuby, 2001).

On the one hand, project evaluations should be limited to the highest level of outcomes that can unambiguously be attributed to the project: the direct benefits experienced by beneficiaries who use the project outputs. These direct benefits are also called farm-level effects (van de Fliert and Braun, 2002). In the example of a SWC project, the project would thus evaluate, for example in case studies, whether adopters of SWC experience a reduction in erosion and / or an improvement of crop yields, without assessing land degradation and / or agricultural production at the regional or national level.

On the other hand, impact at the higher goal level should be assessed in larger project-independent evaluations, for example in national or regional surveys on agricultural production. In some cases, underlying factors are monitored that affect impact, e.g. rainfall or fertiliser use. Underlying factors related to national or regional programmes may be included in the monitoring in order to evaluate their impact. However, the monitoring is normally not set up to attribute impact to a specific or locally operating project.

The gap between the upward evaluation and the downward evaluation is called the 'attribution gap' (Vahlhaus and Kuby, 2001). Douthwaite et al. (2003) suggest that this attribution gap may be bridged by the evaluator identifying 'plausible links' between project outputs and higher-level development changes. Although they acknowledge the importance of bridging the attribution gap during project implementation, they consider this as an ex-post impact assessment. The World Bank recognises this attribution gap and proposes to complement the upward effectiveness evaluation of individual projects and the downward evaluation of country or sector programme goal with a side view on how individual projects have contributed to the programme results (World-Bank, 2001).

There are different ways to go about this attribution problem. One may simply ignore the higher-level goal. One may extrapolate outcome to impact by using the assumed relations between outcome and impact, without validating them. Or, one may validate these assumptions by additional case studies. In the ideal situation, the downward monitoring system and the upward monitoring system match in such a way that a certain impact can be attributed to project activities.

2.2 Planning, monitoring and evaluation in practice

2.2.1 Planning the SWC project in southern Mali

This study is not a complete evaluation of the SWC project in southern Mali but will focus on the effectiveness and impact of a number of SWC measures that have been promoted since the project started in 1986. The adoption of SWC measures is taken here as a core purpose to visualise how planning, monitoring and evaluation are linked to the logical framework of the SWC project. Although the logical framework was initially not used during the design of the SWC project in southern Mali, the project documents followed a similar logic. In 1996, the Dutch donor changed from project approach to programme approach. The Dutch embassy and the CMDT agreed on a set of nine performance indicators for the SWC component of the programme, at the goal, purpose, and output level. This set of performance indicators, meant to inform the donor, did not replace the more detailed internal planning and monitoring by the CMDT (Lanser, 1997; Schrader, 1997).

Planning at the goal level

The goal of the SWC project in southern Mali was composed of three aspects (PLAE, 1986; PLAE, 1989; CMDT, 1995):

- To reduce land degradation
- To intensify agriculture
- To increase agricultural production

When the SWC project continued as SWC programme in 1996, the overall goal changed slightly: to contribute to economic and ecologic sustainable development in southern Mali.

Initially no quantitative targets were set at the goal level. The rationale behind this was that attribution of change to the project would be too difficult because many other, non-project factors affect the indicators at the goal level. In 1993, propositions for a new monitoring and evaluation system were made, based on a logical framework, but no impact indicators were included either (van Mourik et al., 1993). Following the three aspects of the original goal, I examine the availability of indicators, baseline data and targets.

Land degradation was not covered by indicators in the project or programme planning. Baseline data on land degradation are scarce. Jansen and Diarra (1992) have undertaken a qualitative study on trends in land use and land degradation in a few villages in southern Mali between 1952 and 1987. A detailed mapping of soils and vegetation was done (PIRT, 1983) but this was not translated into an erosion risk mapping. The SWC project targeted villages with more severe erosion problems. Hence, specific baseline data on land degradation would be needed from targeted and non-targeted villages. No targets were set on how much land degradation should be reduced.

Agricultural intensification was covered by two of the performance indicators (agreed on in 1996): cotton fertiliser dose and cultivated area per person. The values for 1996 served as baseline data and targets were set for 1997 and 1998. The cultivated area per person should not increase any further, and chemical fertiliser doses on cotton should increase.

Agricultural production was not covered by indicators in the project or programme planning, so no baseline values or targets were set by the SWC project. Because crop yields were probably lower in targeted villages, specific baseline crop yields would have been needed.

Planning at the purpose level

The core project purpose was the management of natural resources by the rural population. This included the adoption of SWC measures, a balance between agro-, sylvo- and pastoral land use, and the management of communal land by village institutions. Supporting project purposes were capacity building of the extension service, awareness raising of the rural population for natural resource management, and documenting project experiences (PLAE, 1989). The focus in the remainder of this research will be on the adoption of SWC measures: erosion control and soil fertility management.

For each recommended erosion control measure, indicators were the quantity (number or length) installed, the number of farmers and the number of villages involved. The adoption of erosion control measures was negligible when the project started and the baseline adoption was assumed zero. At the overall project level, there was no erosion risk inventory specifying for example the percentage of land that should be protected from erosion. Hence no long-term targets were set for erosion control. Only annual targets, based on a participatory village planning, were documented.

For each recommended composting measure, indicators were the number of measures installed, the number of farmers and the number of villages involved. The adoption of composting measures was substantial before the project started. The adoption, monitored after the first year project intervention, served as baseline value for the subsequent project period. Long-term targets were that all farmers would produce compost in a pit and that all farmers with at least two oxen would install an improved cattle pen.

The performance indicators at the purpose level, agreed on in 1996, emphasised the composting measures (percentage of farmers producing compost, percentage of farmers having a compost pit, percentage of farmers having an improved cattle pen), and only briefly covered erosion control (percentage of villages engaged in erosion control). For these performance indicators, the adoption in 1996 served as baseline and targets were set for 1997 and 1998.

Planning at the output level

The indicator that reflects best the project output in relation to erosion control is the number of villages with a ‘SWC village team’. The SWC village team consisted of five to eight voluntary farmers, of which at least two literates, that served as a relay between the extension service and the other farmers in the village. The installation and 5-day training of this SWC village team was, together with other activities, part of the SWC village extension approach. Initially, no villages had a SWC village team. The long-term target was that all villages in the CMDT area of southern Mali would have a SWC village team. Annual targets were based on the capacity of the extension service and the available budget.

A second indicator for project output, related to soil fertility management, was the number of villages where an additional training on soil fertility management was given. This specific 5-day training was given, from 1995 onwards, in villages where a SWC village team had already been installed. However, this training targeted interested farmers directly, not via the SWC village team. Initially, none of the villages had received this training. The long-term target was that this training would be given in all villages. The performance indicators, agreed on in 1996, included one indicator related to project output: the percentage of villages where the soil fertility training was given. The 1996 value served as baseline; targets were set for 1997 and 1998.

Planning at the activity level

The SWC extension approach consisted of a series of activities at the village level, including awareness meetings, the installation of a SWC village team, the distribution of equipment and plant materials, planning and review meetings, and specific credits. Annual planning of activities followed the annual planning of the number of villages to be targeted by the SWC project. Activities will be discussed in detail in Chapter 5.

2.2.2 Monitoring the SWC project in southern Mali

It should be recalled that the Malian Government had consigned many tasks of agricultural and rural development in southern Mali to the CMDT. For the monitoring of the SWC project in southern Mali, three structures within the CMDT were relevant. The SWC Unit, under the CMDT Directorate of Rural Development, was responsible for the SWC activities. The Statistics Unit and the M&E Unit, both under the CMDT Directorate of Programming and Management Advice, were independent from the SWC project.

Internal project monitoring by the SWC Unit

The SWC Unit collected data through the specialised SWC personnel at regional and district level, assisted by the general extension workers. From 1986 to 1995, only targeted SWC villages were monitored, but from 1996 onwards, all villages were monitored. The SWC Unit monitored indicators related to activities (SWC training), output (villages with SWC village team) and outcome (installation of SWC measures) as were presented in the annual work plan. They did not monitor indicators related to impact: land degradation, agricultural production or intensification. They monitored what had been achieved in that year, not the cumulative achievements from previous years. Annual achievements were systematically compared with annual targets, which were reported in the annual SWC activity reports.

Aggregation of annual achievements to cumulative achievements was sometimes difficult. For example, the number of farmers or villages from annual reports could not be added up to a cumulative number of farmers or villages without risking double counting. Because of incomplete data, cumulative achievements could not always be compared with baseline data or long-term targets.

External monitoring by the Statistics Unit and Monitoring & Evaluation Unit

The Statistics Unit collected agronomic data, with a strong focus on cotton, in all villages of southern Mali involving all extension staff. They monitored the area under each crop, all farm operations including fertilisation and crop yields. Data were aggregated in averages per district, region and CMDT area. Information on SWC had a low priority and the Statistics Unit normally extracted summary data from the detailed annual activity reports of the SWC Unit.

The M&E Unit monitored in a sample of 54 villages, through enumerators who were not involved in extension or logistical work of the CMDT. They monitored more detailed information on crop management and performance but also about farmers and villages. They monitored a few indicators related to SWC: whether the village had been targeted by the SWC project and whether the farmer had adopted SWC measures. The M&E Unit monitored the cumulative installation of SWC measures up to that year, not what was installed in one year. Some indicators related to the goal of the SWC programme, which were not monitored by the SWC Unit: crop yields, fertiliser use and cultivated area per person. Data were entered in a spreadsheet in an un-aggregated way so that more complex analysis and evaluations could be made upon demand.

Because both the SWC project and the M&E unit were under the same CMDT umbrella and both structures had already collaborated in a joint evaluation study in 1996, the M&E unit was willing to adjust their monitoring format to enable the evaluation of certain SWC activities. From 1996 onwards, the M&E Unit monitored indicators on the adoption of SWC measures at the farmer level. From 2000 onwards, the presence of SWC measures at the field level was also monitored.

The relations between the logical framework (simplified to the core purpose of SWC adoption), the indicators, and the data available from planning and monitoring, are summarised in Table 2.2. Note that the information gaps, identified afterwards, should not be read as criticism on the project planning or monitoring but help additional data collection for further evaluation.

Table 2.2. Logical framework, indicators and data from planning and monitoring of the SWC project of southern Mali.

Logical framework	***Indicator***	***Planning***			***Monitoring***	
		Baseline data	Long-term targets	Annual targets	Annual achievements	Cumulative achievements
Goal:						
▪ Reduced degradation	(Erosion, erosion risk)	-	-	-	-	-
▪ Agricultural intensification	Fert. dose, area per person	96	96	96	e	e
▪ Improved production	Crop yield	e	-	e	e	e
Purpose:						
▪ Adoption erosion control	Quantity, farmers, villages	i	-	i	i	i+e
▪ Adoption composting	Quantity, farmers, villages	i	i	i	i	e
Output:						
▪ Farmers capable in SWC	Villages with SWC village team	i	i	i	i	i+e
Activity:						
▪ Training sessions, etc.	Sessions, participants, villages	i	i	i	i	i

-: not available
96: baseline set only in 1996 and targets set only for 1997 and 1998
e: available from external structures (CMDT annual plan, Statistics Unit, M&E Unit)
i: available from internal project plan and monitoring.

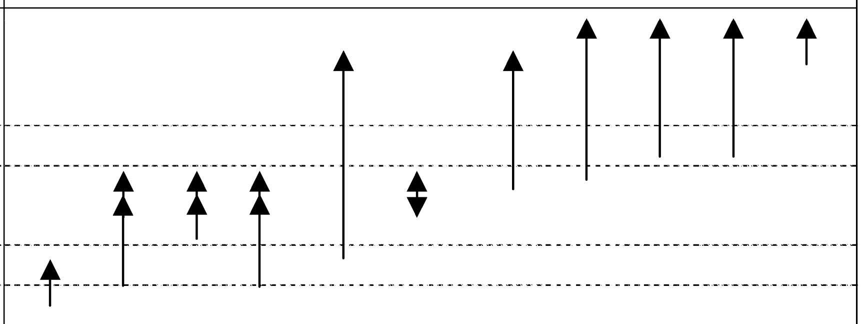
2.2.3. Evaluating the SWC project in southern Mali

Evaluations depend on the data available from planning, monitoring and additional studies, and on the possibility to make comparisons of 'with – without' and 'before – after' project intervention.

Two main evaluations have been done so far. The first, 'Survey on SWC techniques' (Giraudy et al., 1996), evaluated the impact of the SWC programme on farmer knowledge and SWC adoption, comparing villages where SWC training had been given with untargeted villages. The second, 'Impact of the SWC programme on agricultural sustainability in southern Mali' (CMDT, 2002), evaluated the relation between training, erosion control, erosion, and crop yield in a sample of representative villages (targeted and untargeted) and in a sample of villages with high SWC adoption.

From these two evaluations, an inventory is made of the various analyses (a total of 11). Analyses 1, 2 and 3 come from the first evaluation; the other analyses come from the second. For each analysis, the step between cause and effect along the logframe and the type of analyses is indicated. The type of analysis is described in different criteria: whether a 'with – without' or a 'before – after' comparison has been made, whether other factors influencing the effect have been taken into account, and whether results have been supported by statistical tests (Table 2.3). The result for each analysis is briefly described hereunder.

Table 2.3. Inventory of available evaluations, indicating for each analysis (1-11) the step on the logframe and the type of analysis.



Logframe indicators		*Analyses* 1	2	3	4	5	6	7	8	9	10	11
Impact	Yield											
	Fertilisation											
	Area / person											
	Degradation											
Outcome	Erosion control											
	Compost prod.											
Output	Knowledge											
Activity	Training											
Type of analysis												
	Comparison with-without	+	+	+	+	+	+	+	+	+	+	+
	Comparison before-after	-	-	-	+	+	-	-	-	-	-	-
	Other factors included	o	o	o	-	-	-	-	-	-	+	+
	Statistical test	-	-	-	-	-	+	+	+	-	+	+
Evaluation source		1	1	1	2	2	2	2	2	2	2	2

Type of analyses criteria: + yes; o partly; - no.

Evaluation source: 1: Giraudy 1996; 2: CMDT, 2002

Analyses 1, 2 and 3

In the targeted villages, awareness of erosion and knowledge of SWC was higher (1) and adoption of SWC measure was higher (2). Among the non-adopters, knowledge of SWC was considered one of the main reasons for non-adoption (3). Two other factors were considered: region, giving an indication of land pressure, and type of farmer, defined by the number of ploughing equipment and cattle. All three analyses were with-without comparisons including other factors, not supported by statistical analyses.

Analysis 4

During a second evaluation by the CMDT (2002),. From interviews with farmers, several time series of SWC adoption could be reconstructed, showing a clear increase in SWC adoption during the period of SWC training and showing different trends for trained and untrained farmers. This was a reconstructed time series with control, not supported by statistical analysis.

Analysis 5

A comparison was made between fertilisation in 1988 (van der Pol, 1992) and fertilisation in 1999 (CMDT, 2002). Both chemical fertiliser doses and compost doses had increased between 1988 and 1999. In 1999, farmers trained in SWC applied higher fertiliser and compost doses than untrained farmers. This was a with-without comparison with one average baseline value, not supported by statistical analysis.

Analysis 6

A strong and significant correlation was found between adoption of erosion control measures and adoption of composting methods (CMDT, 2002).

Analyses 7 and 11

A comparison was made between farmers with a traditional cattle pen and farmers with an improved cattle pen in which crop residues are applied. Farmers with an improved cattle pan produce more compost, apply higher compost doses to cotton (7) and obtain higher cotton yields (11). The average number of cattle was for both types of cattle pen the same, but no other factors were considered. Both analyses were with-without comparisons, without other factors, supported by statistical analyses (CMDT, 2002).

Analyses 8, 9 and 10

In a first simple analysis, using the data from the M&E Unit from 1997 to 2000, crop yields of farmers with and without erosion control measures were compared. Farmers with erosion control measures obtained systematically higher cotton yields (9). This was a with-without analysis, without other factors, not supported by statistical analysis.

In more detailed analyses, using additional fieldwork data from 2000, crop yields were explained as a function of erosion control measures and compost use. Other factors included rainfall and chemical fertiliser dose. From all SWC measures, only compost (8) and stone rows (10) had a significant effect on crop yield, and only on cotton, not on other crops. These two analyses were with-without comparisons, with other factors, supported by statistical analyses.

2.2.4 Additional evaluation needs

The analyses overview points at four methodological problems and six missing analyses.

The following methodological improvements can be made:

- Attribution of effects to causes can be improved by adding a 'before-after' comparison to the 'with-without' comparison.
- To evaluate impact, specific baseline data are needed when comparing targeted with untargeted fields, farmers or villages.
- Analyses can be more conclusive by including other influencing (non-project) factors.
- Results can be founded by statistical analyses.

Based on the research questions formulated in chapter 1, the need for six additional analyses was identified. These analyses complete the different steps in the cause – effect chain between project output and project impact.

(1) Relation between production, fertilisation, cultivated area and sustainability
(2) Effect of SWC extension and non-project factors on adoption
(3) Effect of erosion control on erosion
(4) Relation between erosion control, fertilisation and cultivated area per person
(5) Effect of erosion on crop yield
(6) Effect of erosion control on crop yield

These analyses will be described in more detail in Chapter 3, in Material and Methods (Section 3.3), after a general description of the research area.

Chapter 3

Material and Methods

3 Material and Methods

3.1 Study area

Area boundaries

This research focuses on the cotton growing area of southern Mali where the *Compagnie Malienne pour le Développement des Textiles* (CMDT) operates. This area of about 125,000 km^2 overlaps with four administrative regions: the whole region of Sikasso, the southern part of Segou, the eastern part of Koulikoro and the south-eastern part of Kayes. The cotton-growing area south of Bamako, in the region of Koulikoro, is covered by a second (government) cotton and rural development organisation: Office de la Haute Vallée du Niger (OHVN) and is not part of the research area (Figure 3.1).

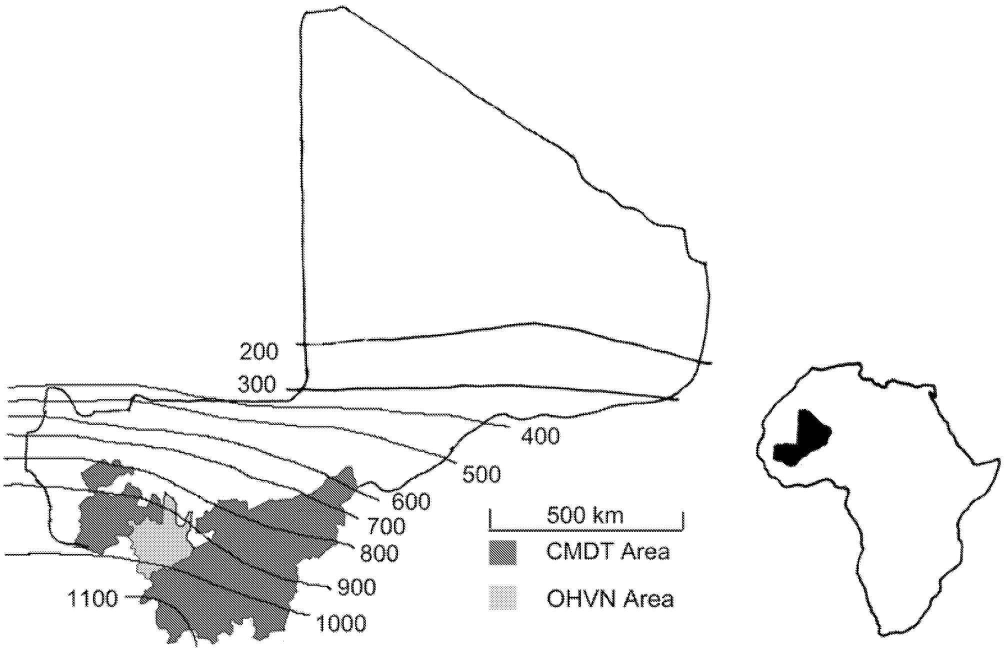


Figure 3.1. The CMDT area and the OHVN area in southern Mali, and rainfall isohyets (mm annual rainfall, average 1991-2001; CMDT data). On the right: Mali's location in Africa.

Climate

Annual rainfall in the cotton growing area varies from 1200 mm at the southern border with Guinea to 700 mm in the north, which limits cotton cultivation. The CMDT area includes also a small non-cotton growing area in the northeast, where cotton used to be grown until the beginning of the 1980s when rainfall was more favourable. Annual rainfall in this non-cotton growing area now varies from 600 to 700 mm. Rainfall is unimodal and falls between May and December (Figure 3.2). Average temperature varies from 24 °C in December to 30 °C in April.

Soils

Soils are mainly loamy-sand. In the central and eastern part, the mother material was fragile sandstone, resulting in very gentle slopes of 0-2% in cultivated fields. In the southern and western part, the mother material also included schist and granites, resulting in slightly steeper slopes of 0-5% in cultivated fields. Altitude varies between 200 and 400 m.a.s. About 42% of the land is suitable for agriculture (Hijkoop et al., 1991).

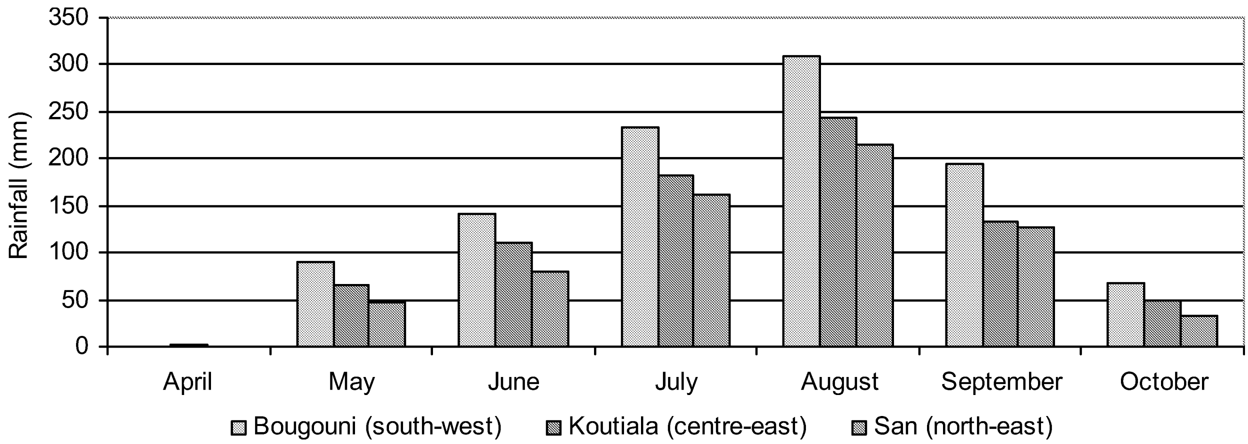


Figure 3.2. Average rainfall per month for the regions of Bougouni, Koutiala and San in southern Mali, from 1991 to 2002.

Population

The study area hosts over 5,000 villages. Rural population in the CMDT area in 2002 is estimated at 3.1 million, growing with about 2.2% per year. Average population density varies from 18 persons km^{-2} in the south and west to 37 persons km^{-2} in the centre and east (extrapolated from CMDT, 1996; MaliArp, 1999). With an annual per capita income of US$240 in 2003, Mali is one of the poorest countries in the world. Agriculture and livestock together account for nearly 50 percent of the country's GDP (World-Bank, 2003).

Farming system

An average farm family is composed of 17 persons and cultivates 10 ha of land, or about 0.6 ha per person. 77% of the farm families have at least 1 plough and 2 oxen; 64% of the farm families have a donkey cart. On average, one farm family has 10 cattle (including 3 oxen), 4 sheep, 5 goats and 20 chicken (CMDT, 2003).

Cotton is the main cash crop grown by 81% of the farm families mostly in a 2 or 3-year crop rotation with cereals. About 29% of the land area is under cotton, 22% under sorghum, 18% under millet, 13% under maize, 9% under groundnuts, 4% under rice and 5% under other crops and associations of crops (CMDT, 2003).

Land degradation

Data on run-off and soil erosion are scarce in southern Mali. Some are derived from the USLE model; others were measured on small erosion plots. On cultivated fields, the run-off coefficient is estimated at 7% to 40%. Sheet and rill erosion is estimated to lead to an annual soil loss of 5 to 31 t ha^{-1} (Roose, 1985; Hallam and Verbeek, 1986; Bishop and Allen, 1989; Vlot and Traoré, 1994).

Van der Pol (1992) calculated nutrient balances for the cropping system in 1988 in southern Mali and found negative balances, especially for nitrogen and potassium, even under the optimistic scenario. In the probable scenario, agricultural land loses 25 kg N and 20 kg K per hectare each year, and soil acidification is expected.

Jansen and Diarra (1992) compared land use and land degradation using aerial photographs from 1952 to 1987 in 3 villages in southern Mali. In the more densely populated areas farmers have started taking marginal land under cultivation. Land degradation had increased under all land uses but the increase was more severe in the communal forest and pastures than in the agricultural fields.

3.2 Data collection

Based on the research questions formulated in Chapter 1 and the inventory of the evaluations done so far, presented in Chapter 2, additional evaluation needs have been identified (Section 2.2.4). To complete the impact evaluation, additional analyses were done using four different data sources: the already available information from 1) the SWC Unit, 2) the M&E Unit, and from 3) the fieldwork in 2000. Besides, 4) additional fieldwork was done in 2003.

Data from the SWC Unit

The annual activity reports of the SWC Unit, available for 1986 to 2000, included data about SWC activities all villages (targeted, and from 1996 onwards also untargeted).
The information used in this research include:

- The number of villages with SWC village team.
- Annual adoption of SWC, specifying for each measure the quantity installed, the number of farmers and the number of villages involved in that particular year.
- Cumulative adoption of erosion control measures, expressed in quantity installed.

Data from the M&E Unit

The annual status reports of the M&E Unit were available for 1993 to 2002. Raw data files were available for 1999 to 2002. The 54 villages in the sample (the number varied over the years) were spread out over the 33 CMDT districts and represented the different agro ecological zones. Each year, part of the sample was renewed. The information used in this research include:

- Information at the village level: whether the village had been targeted by the SWC project.
- Information at the farm level: farm size, household composition, farm equipment, and adoption of SWC. The M&E Unit indicates with 'adoption' whether or not a farmer has installed a certain SWC measure. The M&E Unit indicates cumulative adoption and does not distinguish SWC measures installed in that particular year from measures installed before.
- Information at the field level: details about all farm operations, from sowing date to crop yield, and presence of erosion control measures.

Fieldwork in 2000

This fieldwork was prepared in 1999 by the author who worked at the SWC Unit of the CMDT from 1998 to 2002. The actual fieldwork was undertaken in 2000 by field staff of the SWC Unit and the M&E Unit of the CMDT. The main objective was to evaluate the impact of SWC measures on crop yield.

Observations were done on type, age and quality of erosion control measures. Because erosion control measures are more often installed on fields with high erosion risk where crop yields are expected to be lower, indicators related to erosion risk (slope, soil type) and related to erosion (rills) were included in the field observations. Details on field observations are found in the Material and Methods Sections of Chapter 7 and 8. Crop yields were not measured during the survey but farmers were asked what yields they had obtained. Because cotton production and area were well documented by farmers, cotton yield data were more accurate than yield data from other crops.

In order to have both representative data and enough data from fields with erosion control measures, two different samples were used, both covering the whole CMDT area. One representative sample was taken of 82 farmers (in 30 villages), out of the regular sample used by the CMDT M&E Unit. One selective sample was taken of 216 farmers in 30 other villages with high SWC adoption. A total of 298 farmers in 60 villages were interviewed and 841 fields were visited (two or three fields per farmer).

Interviews with farmers provided also qualitative information about their perception of the erosion severity, the effects of erosion control measures, yield trends since the SWC programme had started, the assistance by extension workers, and their plans for installing SWC measures next year.

Fieldwork in 2003

A second fieldwork was undertaken in 2003 in Koutiala, southern Mali, supported by the Erosion and SWC Group of the Wageningen University. The main objective was to complement missing data on erosion and erosion risk, gaps that were identified after preliminary data analyses of the fieldwork in 2000.

More precise field observations were done on erosion risk (slope, land use upslope, soil texture, structure and resistance) and erosion (rills, crusts and sediment). Cotton yield data collected by the M&E Unit in 2002 were related with field observations done in 2003. Details are found in the Material and Methods Sections of Chapter 7 and 8.

In 8 villages around Koutiala, chosen from the regular sample of the M&E Unit, 56 farmers were interviewed. From each farmer, one field was visited were in 2002 cotton was grown and from which farmer management and crop yield had been monitored by the M&E Unit.

Group discussions and individual interviews revealed the farmers' perception of causes and effects of erosion, erosion symptoms, and trends in land degradation. It also provided insight in their appreciation of the SWC extension approach, the perceived costs and benefits of erosion control measures, reasons for non-adoption, their plans to install SWC in the future, the effect that a change in cotton, fertiliser and labour price would have on SWC adoption, and recommendations for future SWC projects.

One village, Kaniko, where an inventory of erosion rills was made in 1988 and where many SWC measures have been installed, was revisited to see whether erosion had decreased or increased in these 15 years.

Data reliability

The reliability of data varies per source and per type of data. During the years that I have worked closely with staff involved in data collection, I have come to the following judgement about data reliability.

Generally, agronomic data for cotton (yield, fertilisation, crop management) are more reliable than for other crops. The CMDT had a great interest in accurate figures in order to plan the logistics of cotton inputs and processing. The agronomic data from the M&E Unit, collected by enumerators living in the sample villages, are very accurate and more reliable than data from the Statistics Unit or from the fieldwork in 2000. The M&E Unit has received long-term (French) technical assistance. A comparison of data from the M&E Unit with data from the Statistics Unit showed only minor differences. Besides agronomic data, the M&E Unit provided also reliable data about the farm type: farm and family size, crops grown, history, availability of farm equipment and oxen, etc.

We found only a few, non-systematic inconsistencies in the SWC data of M&E Unit during our fieldwork in 2003. But data related to SWC did not have a high priority for the M&E Unit. Most reliable data related to SWC come from either the annual reports of the SWC Unit or from the field work in both periods. Data on erosion symptoms and erosion risk are only available from fieldwork. Data from the fieldwork in 2003 are more complete and more accurate than the data from the fieldwork in 2000.

There is a trade-off between data accuracy and the number of sampling units. Field observations done in 2003 are more accurate than those done in 2000, but the larger number of fields monitored in 2000 often allowed better statistical analyses. In spite of certain inaccuracies in the SWC-related data from the M&E Unit, the large number of farmers and fields monitored and the number of years that data were available for allowed good statistical analyses.

3.3 Data analyses

There were four specific features in the analyses, which have been discussed in Chapter 2:
a) The evaluation was split up in smaller cause-effect steps, according the logical framework.
b) Data from different sources and covering a longer period of time were combined.
c) The ‘reconstructed baseline’ method was used.
d) The ‘Virtual time series’ method was used.
The latter two methods were applied to overcome the problem of incomplete baseline data.

Based on the research questions formulated in Chapter 1 and the inventory of evaluations done so far presented in Chapter 2, six additional analyses are identified (Table 3.1).

Table 3.1. Identification of additional analyses, indicating for each analysis the step on the logframe and the type of analyses.

Logframe indicators		*Analysis* 1	2	3	4	5	6
Impact	Yield						
	Fertilisation						
	Area / person						
	Degradation						
Outcome	Erosion control						
	Compost prod.						
Output	Knowledge						
Activity	Training						
Type of analysis							
	Comparison with-without	-	+	+	+	+	+
	Comparison before-after	+	-	+	-	-	+
	Other factors included	+	+	+	-	+	+
	Statistical test	+	+	+	+	+	+

Type of analyses criteria: + yes; - no.

Hereunder, the six additional analyses are elaborated, describing the several sub-analyses and the data sources used. If other factors or statistical analyses were included this is indicated as well.

(1) Relation between expansion, intensification, production and sustainability

Trends in agricultural development were described, which served as background against which project impact could be compared.

- Time series were presented for agricultural expansion, intensification, production and sustainability. The analyses were based mainly on various CMDT data from 1988 to 2002.
- Trends in crop yield were explained by trends in fertiliser use and rainfall. The regression analyses were based on CMDT M&E data from 1993 to 2002 and included other factors and statistical analyses.

The results hereof are presented in Chapter 4.

(2) Effect of SWC extension and non-project factors on adoption

The extension approach and the adoption in targeted and untargeted villages were described.

- The relation between year of training and year of adoption was presented in a reconstructed transposed interrupted time series. Analyses were based on fieldwork data from 2000.
- The relation between the year of training and adoption of erosion control measures in 2002 was presented in a virtual time series. Analyses were based on CMDT M&E data from 2002 and included statistical analyses.
- Adoption in targeted and untargeted villages was compared for different years. Analyses were based on CMDT M&E Unit data from 1997 to 2002 and included statistical analyses.

Results are presented in Chapter 5.

In addition to SWC training, a number of other factors were considered to explain adoption of SWC measures.

- Adoption of each SWC measure was explained by land pressure, the possibility to grow cotton in the area, the possession of ploughing equipment and donkey cart, and SWC training. Regression analyses were based on fieldwork data from 2000 and included other factors and statistical analyses.

The results hereof are presented in Chapter 6.

(3) Effect of erosion control on erosion

First of all the use of soil crusts as erosion indicator was evaluated.

- The relations between erosion gullies, soil crusts, erosion risk and cotton yield were analysed. Regression analyses were based on fieldwork data from 2003 and included other factors and statistical analyses.

Te results hereof are presented in Chapter 7.

Then the effect of erosion control measures on soil erosion was analysed using three different methods.

- Erosion in Kaniko village in 1988 was compared with erosion in 2003, after erosion control measures had been installed. The comparison was based on an erosion map from 1988 and field visits in 2003.
- Erosion was explained by the presence of erosion control measures, taking into account a reconstructed baseline. The baseline erosion was reconstructed by adding up active gullies and reclaimed gullies. Analyses were based on fieldwork data from 2000 and included statistical analyses.
- The effectiveness of erosion control measures was presented in a virtual time series. Erosion observed in 2000 was explained by the year of installation of erosion control measures. Analyses were based on fieldwork data from 2000 and included a control and statistical analysis.

The results hereof are presented in Chapter 8.

(4) Relation between erosion control, fertilisation and cultivated area per person

The relation between the adoption of erosion control measures and agricultural intensification was analysed.

- Fertiliser doses and cultivated area per person were explained by the presence of erosion control measures. Regression analyses were based on CMDT M&E data from 2000 to 2002 and included statistical analyses.

The results are included in Chapter 9.

(5) Effect of erosion on crop yield

The effect of erosion on crop yield was evaluated.

- Crop yield was explained by the presence of erosion gullies and soil crusts. Regression analyses were based on fieldwork data from 2000 and 2003 and included other factors and statistical analyses.

The results are included in Chapter 7.

(6) Effect of erosion control on crop yield

The effect of erosion control on crop yield was analysed.

- Crop yields were explained by the presence of erosion control measures, rainfall, fertilisation, and crop management. Regression analyses were based on the CMDT M&E data from 1999 to 2002 and fieldwork data from 2000 and included other factors and statistical analyses.
- Crop yield was explained by the age of erosion control measures and by the year of SWC training in two virtual time series. Data were based on fieldwork data from 2000 and on CMDT M&E data from 2000 to 2002 and included statistical analyses.

The results hereof are presented in Chapter 9.

Before evaluating the actual impact of the SWC project, the next chapter will first present the general agricultural development in southern Mali over the last decades.

Chapter 4

Agricultural Development in Southern Mali: A Closer Look at Expansion, Intensification, Productivity and Sustainability

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Submitted to Land Use Policy

4 Agricultural Development in Southern Mali: A Closer Look at Expansion, Intensification, Productivity and Sustainability

Abstract

Agricultural development in southern Mali is described in terms of expansion, intensification, productivity and sustainability. The cultivated area per person increased from 0.44 ha in 1988 to 0.61 ha in 2002. Meanwhile, farmers have intensified farming: they grow more cash crops (cotton and maize) and have almost doubled chemical and organic fertiliser doses. In spite of intensification efforts, cotton and maize yields have decreased with 10% and 17% between 1993 and 2002, partly due to decreasing rainfall and cultivation on more marginal land. However, expansion compensated declining crop yields so production per person increased. The nutrient balance, expressed in kg N+P+K ha^{-1} y^{-1}, has become only a little less negative in 2002 (-40) than it was in 1988 (-58). Further intensification is needed to increase both productivity and sustainability.

Key words: agricultural development, expansion, intensification, productivity, sustainability, southern Mali

4.1 Introduction

The modernisation of agriculture in southern Mali is connected with the expansion of cotton cultivation in the region. Various authors have been interpreting the evolutions in the area, coming to different conclusions. More in general, there are two contrasting views on agricultural development: the pessimistic land degradation narrative and the optimistic intensification counter-narrative (Gray and Kevane, 2001). A brief synthesis of the two narratives provides ideas on how to evaluate agricultural development in southern Mali.

The pessimistic land degradation narrative

The general picture of countries in Sub Saharan Africa shows an alarming relation between on the one hand increased population pressure and reduced fallowing of land, and on the other hand increasingly negative nutrient balances (Drechsel et al., 2001). Fact is that per capita food production decreased in Sub Saharan Africa between 1980 and 1995 (Sanchez and Leakey, 1997). Breman, et al. (2001) conclude from the negative nutrient balances the need for additional inorganic fertilisers and the development of international markets.

In Mali cotton cultivation is considered to cause degradation of natural resources. The introduction of ox ploughs enabled a rapid increase of the agricultural area at the expense of pasture and forest areas. Rural immigration and increased livestock numbers aggravated the pressure on land resources. The increased exploitation of the decreasing area under forest and pasture have resulted in degradation of the sylvo-pastoral zone, while the agricultural area is degraded by soil erosion and soil fertility depletion (Berthe et al., 1991; Hijkoop et al., 1991; Jansen and Diarra, 1992). Considering the negative nutrient balances under the current farming, without intensification a further degradation is expected (Stoorvogel and Smaling, 1990; van der Pol, 1992).

The optimistic intensification counter-narrative

History shows that population growth and increased land pressure can lead to agricultural intensification (Boserup, 1965). In the example of Machakos District in Kenya, population growth and agricultural intensification have even reduced land degradation (Tiffen et al., 1994). The degree of intensification is determined by many other factors: the shift from self-sufficiency to commercial farming, farming profitability, market proximity and secure land rights (Zaal and Oostendorp, 2002). Mazzucato and Niemeijer (2000), however, show that farmers in Burkina Faso have intensified farming and increased production with indigenous practices, a development not determined by external inputs or commercial farming. Similarly, Mortimore and Adams (2001) describe successful intensification in north-east Nigeria, and have confidence in the high adaptability of people in the Sahel and in the indigenous development of local markets. Based on an inventory of 70 empirical studies, Templeton and Scherr (1999) identified a U-shaped relationship between the ratio land : labour costs—the result of increasing population pressure—and land productivity, visualising how a region passes through a phase of environmental degradation before agriculture is intensified up to a more sustainable level and increased productivity. Cour (2001) underscores that the Sahel passes through a difficult transition phase in a ‘silent agricultural revolution’ and stresses that rural development can not be seen separately from migration and urbanisation, which triggers agricultural intensification.

For southern Mali, van der Pol and Giraudy (1993) estimated that intensification as practiced by farmers would lead to more positive nutrient balances, and thus would help in achieving sustainable agricultural development. Other authors point at the facts that crop yields in southern Mali have spectacularly increased up to 1975 and have stabilised since. Besides, soil fertility of old agricultural land is not any worse than recently reclaimed land or fallow land (Gigou, pers. com; Benjaminson, 2001). Moreover, the conversion of forest and pasture into agricultural land is not considered as degradation by farmers (Benjaminsen, 2001).

The complexity in evaluating agricultural development

The criticism on the land degradation narrative reveals the difficulty to evaluate agricultural development and to draw conclusions from apparent simple indicators as soil fertility, crop yield and nutrient balances.

Firstly, if land were degrading, why is this not supported by soil fertility analyses? The problem is that nutrient stocks are high and their variability between fields is large compared to the annual change in soil fertility (Gachimbi et al., 2005). This makes nutrient stocks relatively insensitive indicators. Even when researchers have compared current soil fertility with the results from soil analyses done decades ago by others (Mazzucato and Niemeijer, 2000), the results have not convincingly proved sustainability, soil degradation or soil improvement. An alternative indicator for declining soil fertility would be an increasing crop yield response to fertiliser (Elias and Scoones, 1999), but this relationship is undermined if soil fertility decline is accompanied by soil structure deterioration. Another alternative is the spatial analogue method, comparing fields under long-term cultivation with recently cleared fields, fallow fields and natural vegetation (Gigou, pers. com; Benjaminson, 2001). However, farmers are selective in the choice of land, clearing the best fields first. Fairhead and Scoones (2005) give examples where the cultivation in the forest-savannah transition zone resulted even in a soil improvement. Farm practices 'ratchet up' biomass and accelerate its turnover, bringing soils into fertility. It must be noted that these examples concern complex agroforestry systems, not continuous annual cropping. Nevertheless, it becomes clear that, to cite Mortimore and Harris (2005) 'soil resources […] can be managed for profit or subsistence, for growth or neglect, for investment or mining'.

Secondly, if land were degrading, why are crop yields not declining? On the contrary, crop yields have increased in Mali (Gigou et al., 1998) and Burkina Faso (Mazzucato and Niemeijer, 2000) between the 1960s and the 1990s. This is a good argument and relevant for farmers, but such analyses will need to take other factors into account including fertilisation and rainfall, before drawing conclusions.

Thirdly, the conclusion that land is degrading is partly based on results from simplified nutrient balances, which have been criticised by various authors. Nutrient balances made for the regional or national level use extrapolations of site-specific data, for example erosion from small runoff plots, which can often not be justified (Scoones and Toulmin, 1998). Nutrient balances are not very useful without knowledge of the nutrient stocks (Lesschen et al., 2004). A nutrient balance is a snapshot approach that does not capture long-term dynamic processes (Scoones and Toulmin, 1998; Roy et al., 2003). However, the main criticism is perhaps not so much the use of nutrient balances as such, but the resulting simplified policy recommendations, without recognising the diversity between farmers and fields, and—even worse—leaving little room for farmer experimentation and innovation (Scoones and Toulmin, 1998). Without recognising the long-term process of adaptations farmers make in a response to changing soil conditions, there is no justification of describing sustainability using nutrient balances based present practices (Ramisch, 2005).

Objective

The objective of this study is to describe the agricultural development in southern Mali, using quantified indicators for expansion, intensification, productivity and sustainability. From this description, we should be able to position the situation between the land degradation and the intensification narratives, and to identify a future trend for agricultural development in southern Mali.

The focus in this study is on the cultivated area, emphasising the period from 1988 to 2002, of which sufficient data were available. However, we acknowledge and livestock, pasture, forest and wood consumption have undergone important changes as well and influence land quality and land degradation of southern Mali as a whole. We also acknowledge that a period of 14 years is relatively short to determine trends.

4.2 Material and methods

4.2.1 Research area

This research focuses on the cotton-growing area of southern Mali where the Compagnie Malienne pour le Développement des Textiles (CMDT) has been operating (Figure 4.1). The CMDT area covers 125,000 km^2 and 5,000 villages, hosting a rural population of 3.1 million in 2002 (CMDT, 1996; Schrader and Wennink, 1996; MaliArp, 1999). Annual rainfall varies from 1200 mm at the southwest border with Guinea to 600 mm in the northeast (CMDT rainfall data 1991-2001, unpublished). An average farm family is composed of 17 persons and cultivates 10 ha of land (CMDT, 2003). Cotton is the main cash crop, grown in rotation with maize—grown also as cash crop—, sorghum, millet and groundnuts. Population density varies from 18 persons km^{-2} in the South and West to 37 p km^{-2} in the Centre and East. This explains why rotational fallowing is still common in the South and West and cultivation is more permanent in the Centre and East. The soils are mainly loamy sand. The slopes in the cultivated fields are gentle: 0-2% in the central and eastern parts and 0-5% in the southern and western parts. Soils are characterised by their position on the 'toposequence': the plateau with shallow gravely soils, the steep and stony escarpment, the glacis with well-drained sandy soils, the stream embankment, and the clayey valley bottoms (Hijkoop et al., 1991). On cultivated fields on the glacis, the annual soil loss from sheet and rill erosion is estimated to be 5 to 31 t ha^{-1} (Roose, 1985; Hallam and Verbeek, 1986; Bishop and Allen, 1989; Vlot and Traoré, 1994).

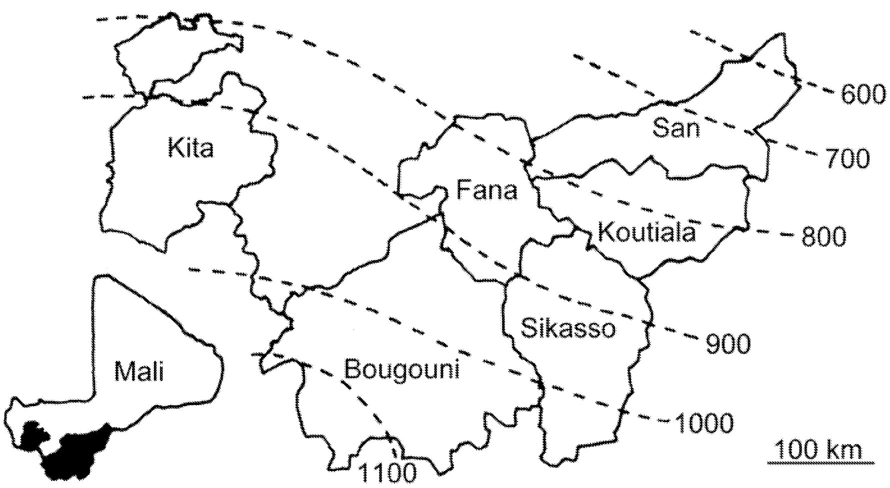

Figure 4.1. The six CMDT regions in southern Mali and rainfall isohyets (mm annual rainfall); inset on the left: Mali with the CMDT area in black.
Source map: CMDT 2003; source rainfall data: CMDT 1991-2001.

4.2.2 Concepts used

Changes in agriculture over the last decades in southern Mali are described in terms of expansion, intensification, productivity, and sustainability. The following concepts and indicators are used in this research.

Expansion is the increase of total cultivated area. Indicators used to present trends are rural population, total cultivated area, and cultivated area per person. The cultivated area per person is further explained by the available farm equipment.

Intensification is the increased use of inputs (materials and labour) per unit area, in order to increase the outputs per unit area. Indicators used to present trends are the portion of cultivated area devoted to cash crops, mineral fertiliser doses, compost doses and crop residue management. Labour input could be expressed in available active persons per ha cultivated land, but is not included as indicator for intensification because the cultivated area per person (inversely related to available labour per hectare) is already used as indicator for expansion.

Productivity is the agricultural output, either expressed in kg crop produce or in crop value. Productivity can be expressed in output per ha, the aim of intensification, or in output per person, the aim of both intensification and the increase of cultivated area per person. Productivity could also be presented per unit capital invested, which in some cases explains much better the current farmer practices than that productivity per unit land area does (Kunze, 2000). However, this indicator is not applied here because of unavailability of data.

Sustainability has been simplified here to: the likelihood that productivity will sustain in the future. Two indicators are used. 1) Trends in crop yields, taking into account other factors influencing yield, such as rainfall and fertilisation. 2) Nutrient balances of inputs and outputs, expressed in kg nutrient per ha per year. Partial nutrient balances consider chemical and organic fertilisation as inputs, and crop yield and harvested crop residues as outputs. Complete nutrient balances also include atmospheric deposition, biological N-fixation, weathering and sedimentation as inputs; and soil erosion, leaching and gaseous losses as outputs. The nutrient balances presented here consider the cultivated area without fallow land.

4.2.3 Data used

Most data used in this study come from two sources within the semi-public organisation for cotton and rural development CMDT (Compagnie Malienne pour le développement des Textiles). The Statistics Unit monitors agronomic data since the 1960s. Data are aggregated to district, region and CMDT level. The Monitoring and Evaluation (M&E) Unit collects data from a sample of 41 - 55 villages, representative for the different agro ecological zones of southern Mali, since 1993. Enumerators interview over 4000 farm families and measure field sizes and yields in a sub-sample of over 800 farm families. In this study, only the sub-sample of 800 'measured' farms is used, and therefore results differ slightly from the published CMDT M&E annual reports. Data are available in a non-aggregated way that allows more complex analyses.

National agronomic data for whole Mali are aggregated and presented in the FAO on-line statistical database (FAO, 2004).

An inventory was made on land suitability (PIRT, 1983), which was later used to evaluate land pressure: suitable land per person and cultivated land per person (CMDT, 1996).

Some data come from two additional studies on the impact of a SWC programme implemented by the CMDT since 1986. The first study was done in 2000 in collaboration with the M&E Unit and the SWC Unit of the CMDT where the corresponding author worked at that time. One sample of 30 representative villages and one sample of 30 villages with high adoption of SWC measures were used, visiting 298 farmers and 740 fields. The second study, a complement to the study in 2000, was done in 2003 for the Wageningen University in collaboration with the CMDT, and was limited to 6 representative villages in the region of Koutiala, in the old cotton zone. Interviews were done with 56 farmers, 1 field per farmer was visited.

Because the Kita region, in the West of southern Mali, has only become part of the CMDT cotton area since 1995, this region is left out in the presentation of times series and analyses.

4.2.4 Analyses

After presenting time series of various indicators, a number of analyses are presented to evaluate various aspects of sustainability.

The relations between trends in crop yield, rainfall and fertilisation were analysed using a univariate general linear model. Two data sets were used: 1) cotton and maize yield, fertiliser use and rainfall data from 1993 to 2002 from the CMDT M&E Unit, and 2) cotton yield and rainfall data at the district level from 1995 to 2002 from the CMDT Statistics Unit.

The effect of land pressure on intensification and crop yields was analysed. The indicator for land pressure was the number of years fields had been under cultivation since last fallow (which was monitored by the CMDT), using one average value per village. This indicator correlates well (Pearson 2-tailed: 0.621; Sig.: 0.000) with the land pressure per district as presented in the land suitability and land pressure inventory (CMDT, 1996).

The effect was analysed that cultivation of more marginal land had on intensification and crop yields. Based on the assumption that newer fields in the village are the more marginal fields, we used the number of years a field had been under cultivation since last fallow as indicator. However, in the high land pressure areas (more permanent cultivation in the Centre and East), all fields—marginal as well as not marginal—fields have been cultivated longer than in the low land pressure areas (rotational fallowing in the South and West). Therefore we calculated a new variable ‘relative field age’: the number of years a field had been under cultivation compared with the average for all fields in that village. This means that in each village, both ‘old’ and ‘new’ fields are considered. Yields from old and new fields are corrected for differences in fertilisation and rainfall by incorporating the latter two indicators these as covariates in the analyses.

Partial and complete nutrient balances for the cultivated are were recalculated for 1988 and 2002 using the ‘Integrated Environmental and Economic Accounting’ Excel workbook (FAO – KIT, in preparation). The comparison of 1988 and 2002 is more relevant than the absolute values.

4.3 Agricultural expansion

4.3.1 Population growth, expansion and cultivated area per person

While traditionally millet and sorghum have been the main crops in the region, cotton became an important export cash crop about 50 years ago, at first around Koutiala, which is now the old cotton area. The more southern provinces were initially unsuitable due to vectors of human and livestock diseases. This effect is part of the "historical footprint" found in the more humid areas of the Sahel (Wardell et al., 2003). With the widespread introduction of ploughing with oxen, the expansion of cotton followed a typical pattern. Initially, farmers started to follow the technical recommendations of the CMDT. In a subsequent phase, with the increasing mastering of the oxen ploughing technique and when farmers became aware that land could become scarce, farmers cultivated even more land to claim and assure land for future use.

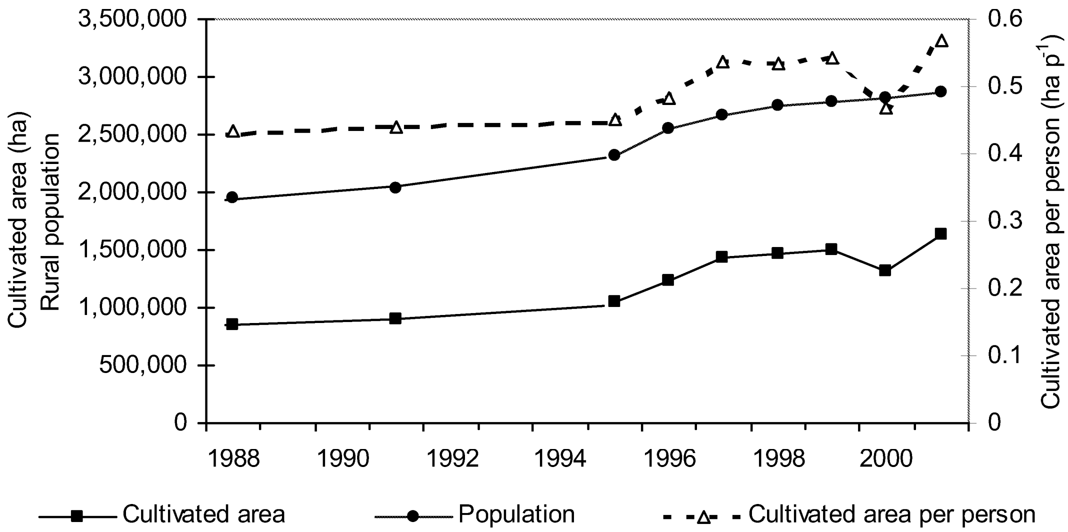

Figure 4.2. Total cultivated area, rural population and cultivated area per person in southern Mali between 1988 and 2001. Source: Stat. Unit, CMDT.

The Statistics Unit of the CMDT monitored rural population and total cultivated area (Figure 4.2). Rural population increased on average with 3.1% per year between 1988 and 2001. This population growth is higher than the 2.2% found for the period 1976-1991 (Schrader and Wennink, 1996) and could be due to immigration by people from the North. Between 1988 and 2001, the total cultivated area increased on average with 5.2% per year, with a sharp increase after the devaluation of the currency in 1994. Note the dip in cultivated area in 2000 when a farmers' strike reduced the area under cotton. According to the PIRT land inventory, about 42% of the 10.580.000 ha in southern Mali, or 4.443.600 ha, is suitable for agriculture (PIRT, 1983; Hijkoop et al., 1991). This means that the occupation of agricultural land by crops has increased from 19% in 1988 to 37% in 2001. The cultivated area per person increased on average with 2.1% per year. The M&E Unit found a similar increase of cultivated area per person of 2.4% per year between 1993 and 2002.

Trends in the occupation of agricultural land by crops vary considerably from one village to another. Jansen and Diarra (1992) compared developments in actual land use between 1952 and 1987, using aerial photographs, with land suitability. Three villages were studied: Minso-Sokoro in a drier area just north of the cotton zone, Kaniko in the centre of the old, saturated cotton zone, and Fonsebougou in the southern, more humid part of the cotton zone (Figure 4.3). The village boundaries indicated by the villagers may exclude some unclaimed land in-between villages and thus underestimate the area suitable for agriculture. In the period from 1952 to about 1978, the average increase in area under crops was slightly inferior to population growth, but from 1983 to 1987 the area under crops increased faster than population growth. In the dryer zone (Minso-Sekoro) the agricultural area did not increase. Some unused land was cultivated, but a similar area was left for long-term fallow. In the more favourable southern zone, the cultivated area increased beyond the suitable land. In the old cotton zone (Kaniko), all suitable agricultural land had been actually cultivated in 1987. Much degraded land had to be left to long-term fallow to restore its fertility. Some of the unsuitable land, e.g. on the plateau, had become more interesting to farmers than some of the suitable land, which points at land degradation in the suitable area.

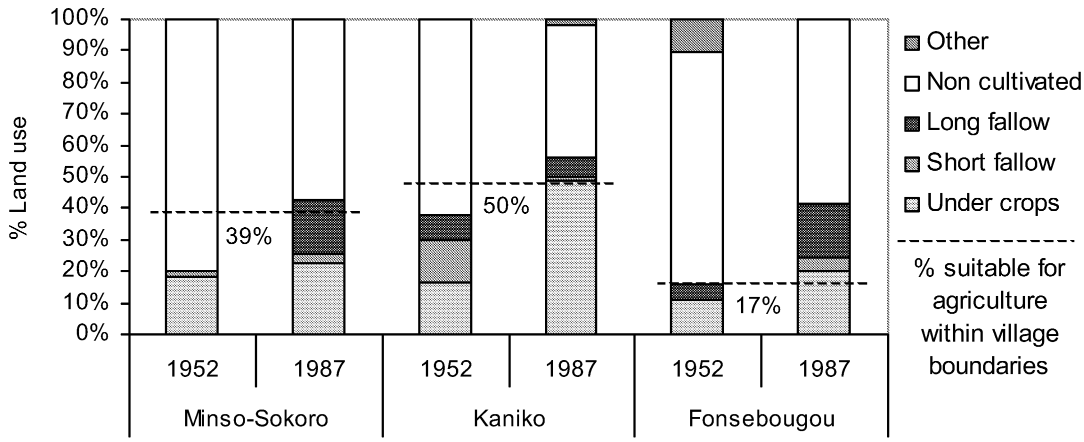

Figure 4.3. Evolution of land use in 3 villages in southern Mali, between 1952 and 1987.
Source: Jansen and Diarra, 1992. Suitable land according to the land inventory (PIRT, 1983).

Regional differences in available and cultivated land per person are important as well. Total land, land suitable for agriculture and cultivated area - per person - were calculated for the 5 CMDT regions in southern Mali in 1988 (Hijkoop et al., 1991) and recalculated for 2002 (Table 4.1).

At first sight, the relation between available land and cultivated land seems paradoxical: in the region with most available land per person (Bougouni) less land is cultivated per person. This is explained by the spatial pattern of cotton introduction. In Bougouni, cotton was introduced relatively late, and so were the connected credit schemes for ox ploughs, which enabled farmers to cultivate larger areas.

In San, where farmers cultivated small areas and suitable land was hardly available in 1988, expansion was high (3.9% yr^{-1}) and even took place into more marginal land. On the contrary in

Fana, where farmers cultivated large areas and suitable land was more abundantly available in 1988, expansion was low (1% yr^{-1}).

Table 4.1. Evolution between 1988 and 2002 of total land, land suitable for agriculture, and cultivated land per person (ha p^{-1}), for 5 regions in southern Mali.

	1988			2002		
Region	Total*	Suitable*	Cultivated*	Total**	Suitable**	Cultivated***
Bougouni	8.33	4.58	0.23	5.91	3.25	0.54
Fana	5.56	2.78	0.61	3.60	1.80	0.70
Sikasso	4.76	1.33	0.31	3.86	1.08	0.50
Koutiala	3.85	1.15	0.61	2.90	0.87	0.72
San	3.45	1.21	0.45	1.92	0.67	0.72
Zone CMDT	5.26	2.21	0.44	3.62	1.52	0.61

Sources: * Hijkoop, 1991, based on PIRT, 1983 ** recalculated with population data from CMDT Statistics Unit; *** CMDT M&E Unit (total cultivated area / total population in sample).

4.3.2 Farm equipment: oxen, ploughs and donkey carts

The area one active person can cultivate is determined by farm equipment. The area cultivated per active person correlates strongest with the number of oxen per person (CMDT M&E data 2002: Pearson 2-tailed: 0.268; Sig. 0.000).

Since 1970, ox ploughing was encouraged by subsidies on equipment. However, in 1980 subsidies were removed as part of the structural adjustment program. Later, credits for equipment were organised between the bank and the CMDT who deducted reimbursement from cotton payment (Berthe et al., 1991). The percentage of the farm families with at least one complete set – 2 oxen and one plough – increased from 69% in 1988 to 83% in 2002. The percentage of farm families with a donkey or ox cart increased from 50% in 1994 to 65% in 2002 (Hijkoop et al., 1991; Doucouré and Healy, 1999; CMDT, 2000a) (M&E data 2002).

Table 4.2. Availability of oxen ploughs and carts per family, per person and per ha cultivated land in southern Mali, in 1991 and 2002.

	Per family		Per person		Per ha cultivated land	
	1991	2002	1991	2002	1991	2002
Oxen	2.4	3.2	0.15	0.19	0.35	0.31
Ploughs	0.7	1.4	0.05	0.08	0.11	0.13
Carts	0.4	0.8	0.03	0.04	0.06	0.07
Persons	15.4	17.6	-	-	2.3	1.7
Ha cultivated	6.8	10.7	0.44	0.61	-	-

Note: because of the available aggregated weighed averages for 1991, weighed averages for 2002 are presented here that are different from the un-weighed averages for 2002 presented earlier.
Source: CMDT; 1991: Statistics Unit; 2002: M&E Unit.

The availability of oxen, ploughs and carts per family and per person has increased between 1991 and 2002 (Table 4.2). As expected, the number of oxen and ploughs per ha cultivated land has not really changed: farmers adjust the cultivated area to the available oxen. Trends in the relation between available oxen per person and cultivated area per person, for the five regions, follow a fairly linear pattern (Figure 4.4).

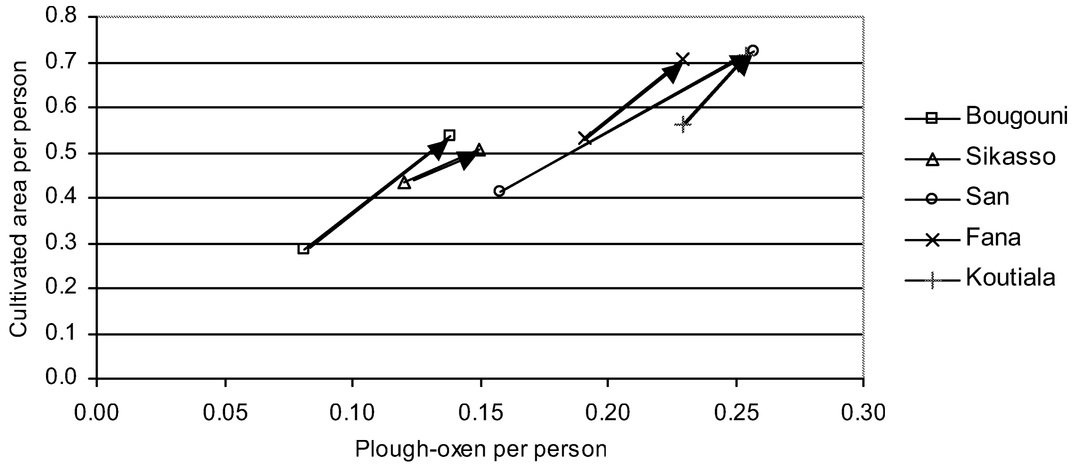

Figure 4.4. Trends in the relation between available oxen per person and cultivated area per person for the five regions in southern Mali, between 1991 and 2002.

Due to increased availability of farm equipment, farmers have expanded their cultivated area on marginal land. Expansion has slowed down in the high land pressure areas but did not completely stop. Gradually, farmers will come in a situation where intensification is the only option to increase productivity.

4.4 Agricultural intensification

The most extensive form of agriculture, cultivation of food crops during a few years alternated with long fallow periods, still exists in the most southern and western parts of southern Mali. Reduction of the fallow period, eventually leading to permanent cultivation, is considered as a first step in agricultural intensification. Unfortunately, there has been no regular systematic monitoring of area under fallow. Only the earlier mentioned study of Jansen and Diarra (1992) concludes that short fallow had reduced between 1952 and 1987, while long fallow had increased. From the other available data, no clear trends in area under fallow could be extracted. Other processes of intensification are the introduction of cash crops, accompanied fertiliser use and the use of compost and crop residues to improve soil quality in the absence of fallows.

4.4.1 Cultivation of cash crops

In southern Mali, the proportion of cultivated land under cash crops, cotton and maize, has increased from 29% in 1988 to 43% in 2002 (Figure 4.5). Note the strong dip in 2000 when a farmers' strike reduced the area under cotton. The portion of cultivated area under cash crops increased on average with 2.8% per year. However, from 1997 onwards, this fraction remained more or less stable.

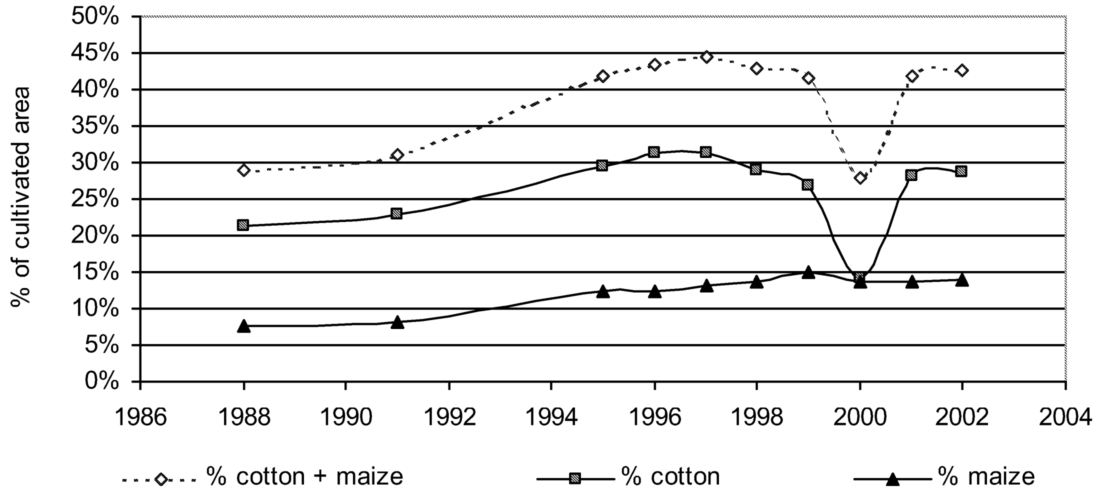

Figure 4.5. Percentage of cultivated area under the cash crops cotton and maize in southern Mali between 1988 and 2002.
Source: 1988-2001: Stat. Unit; 2002: M&E Unit, CMDT.

4.4.2 Mineral fertiliser use

Mineral fertilisers are mainly used for the cash crops cotton and maize (96% in 2002).

Fertiliser doses on cotton increased up to 1980 when fertilisers were heavily subsidised. Fertiliser doses decreased between 1980 and 1988 when subsidies were removed as part of the structural adjustment program (Berkmoes et al., 1990). Doses increased again slightly from 1988 onwards with an improving price ratio and limited fertiliser subsidies by donors in 1988-1993 (Coulibaly et al., 1993). The devaluation of the local currency in 1994 made the cotton price go up immediately while fertiliser prices followed the year after. Farmers negotiated a fertiliser subsidy with the CMDT and the Malian government in 1997, which resulted in a favourable price ratio in 1997-1998 (Benjaminsen, 2001). Not the absolute fertiliser dose, but the change in fertiliser dose strongly correlates with the price ratio and changes in the price ratio cotton / complex fertiliser, between 1974 and 2002 (Pearson 2-tailed: 0.589 resp. 0.628; sig: 0.000) (Figure 4.6). The presented fertiliser doses in the 1980s tend to be overestimated by an underestimated area under cotton (Gigou et al., 1998). The fertiliser doses monitored by the M&E Unit from 1993 onwards give a more reliable picture.

Fertiliser doses on maize followed a similar trend. Doses increased between 1982 and 1989 during the CMDT 'Maize Project' with guaranteed maize prices. When the Maize Project stopped in 1989, maize prices dropped and fertiliser doses decreased drastically. From 1993 to 2002, doses steadily increased again. Unlike the other cereals sorghum and millet, maize is also grown as an important cash crop in southern Mali.

When all crops are taken into account, the total mineral fertilisation has increased between 1988 and 2002 (Table 4.3). The change in formulas of complex cotton fertiliser resulted in a stronger increase for N and K than for P. The total mineral fertiliser dose (kg N+P+K ha^{-1}) increased on average with 3.5% per year.

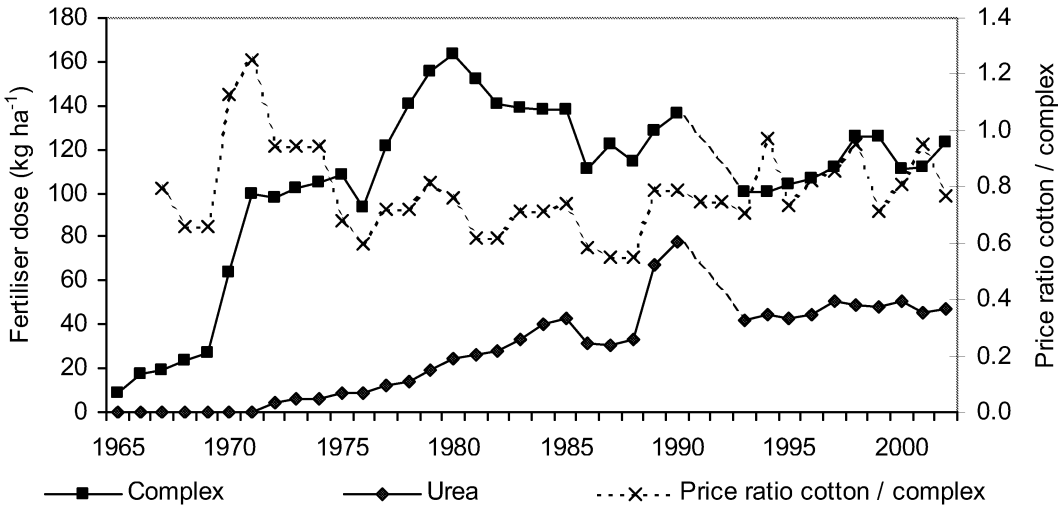

Figure 4.6. Fertiliser doses on cotton in relation with the price ratio cotton / complex fertiliser in southern Mali between 1965 and 2002.

Source: 1965 - 1990: Stat. Unit; 1993 - 2002: M&E Unit, CMDT.

Table 4.3. Mineral fertiliser doses (kg ha^{-1} yr^{-1}) for different crops in southern Mali, in 1988 and 2002.

	1988				2002			
	Area (%)	N	P	K	Area (%)	N	P	K
Cotton	21	31.1	10.9	11.4	29	41.4	10.5	16.5
Maize	8	44.1	6.0	6.2	16	34.6	4.7	8.0
Sorghum	25	0.3	0.2	0.2	22	1.5	0.3	0.5
Millet	30	0.3	0.2	0.2	20	2.7	0.2	0.3
Rice	2	11.6	2.3	2.4	4	9.4	1.0	1.8
Groundnut	5	1.0	0.7	0.7	7	0.2	0.0	0.1
Cow pea	5	0.0	0.0	0.0	0	0.8	0.2	0.3
Other*	5	0.0	0.0	0.0	3	0.0	0.0	0.0
Total	100	10.4	3.0	3.1	100	18.5	3.9	6.3

* Other crops are assumed to be unfertilised.

Sources: 1988: CMDT, cited by Van der Pol, 1992; 2002: M&E Unit, CMDT.

4.4.3 Compost use

Compost can be classified according to its ingredients: animal manure, crop residues, animal manure mixed with crop residues, and household waste.

Traditionally, cattle were kept at night and part of the day, attached with rope to a wood log, often without enclosure and without a bedding of crop residues. Household waste was piled up in a heap. A large part of the crop residues were burnt, because of lack of transport and because cotton stalks left in the field caused phytosanitary problems.

Several improvements have been proposed and adopted to increase the quantity and to improve the quality of the compost. An enclosure around the reposing cattle, giving 2-3 m^2 per animal, concentrates the manure in a thicker and more humid layer, decreasing oxidation and improving humification. The addition of crop residues with high C/N ratio to manure with low C/N ratio reduces N losses, improves decomposition and increases the quantity of compost of good quality. Household waste deposited in a pit decomposes better than in a heap. The phytosanitary problems of cotton stalks can be resolved without burning, as long as the stalks are cut and removed from the field (Van Campen, pers. comm.). Farmers lacking transport or animal manure can compost crop residues in a pit in or next to the field. Compost production is strongly related to the possession of donkey carts and ox carts.

Most compost is applied to cotton and maize: 82% in 1988 (van der Pol, 1992) and 84% in 2002 (CMDT M&E data). The total area receiving compost has increased from 15% to 24%, or an average annual increase of 3.0%. This means that the area receiving compost has increased in the same pace as the area under the cash crops cotton and maize.

There has been no systematic monitoring of compost doses applied. Table 4.4 shows a summary of the available data on compost doses, distinguishing southern Mali from Koutiala region, where compost use is relatively high. Some original data were recalculated using an average of 140 kg dry compost per cart. Therefore, values presented here may differ from original publications.

Table 4.4. Annual compost production per farm family and application per hectare (tons dry weight) in southern Mali and in Koutiala region, between 1988 and 2003.

Zone	Unit	1988 1)	1993 2)	1994 3)	1999 4)	2001 5)	2002 6)	2003 7)
S. Mali	t $farmer^{-1}$	2.2			7.8		7.7	
	t ha^{-1}	0.4			1.0		0.7	
Koutiala	t $farmer^{-1}$		6.0	9.2	10.9	17.5	12.6	14.4
	t ha^{-1}		0.7	1.0	1.1	1.6	1.1	1.2

Sources: 1) CMDT data, cited by Van der Pol, 1992; 2) Vierstra, 1994, 9 villages ; 3) Camara, 1995, 12 villages; 4) Fieldwork 2000, 26 M&E villages; 5) Kanté, 2001, 2 villages; 6) CMDT M&E data 2002 combined with fieldwork 2000; 7) Fieldwork 2003, 6 M&E villages.

The average annual compost dose per ha cultivated land increased from 0.36 ton in 1988 to 0.73 ton in 2002, or an average annual increase of 5.2%. The compost dose is given as an average per ha per year. In reality farmers apply compost in larger quantities, on average 3 tons ha^{-1} per application (found in fieldwork done in 2000), but only once every 3 to 6 years. Assuming a nutrient content of

1.1% N, 0.2% P and 1.3% K (van der Pol, 1992), the average compost application in 1988 contained 4.0 kg N, 0.7 kg P and 4.7 kg K per ha cultivated land per year. In 2002, the amount of nutrients applied with compost increased to 8.9 kg N, 1.6 kg P and 10.5 kg K per ha cultivated land per year.

4.4.4 Crop residue use

Key in soil fertility management and related to compost production is crop residue use. Crop residues are left in the field to be browsed by livestock, eaten by termites, burnt, or ploughed under. Residues are also collected to be used as fodder, bedding in improved cattle pens or composted in compost pits. Minor amounts are collected and burnt for potash. There has been no systematic monitoring of crop residue use but trends can be derived from a few studies. Van der Pol (1992) reviewed studies done in Mali, Burkina Faso and Senegal. Camara (1996) and Kanté (2001) studied crop residue use in 12 and 2 villages respectively, in Koutiala and North Sikasso region, where compost use is relatively high. During the fieldwork in Koutiala in 2003, crop residue use and adoption of composting methods were evaluated in 6 villages.

There are a few clear trends: more crop residues are collected as fodder, as bedding in improved cattle pens, or are composted in pits. Even cotton stalks, which are more often burnt than other crop residues, are rarely burnt nowadays (Figure 4.7). Increased collection of crop residues will result in a reduced 'direct' restitution of crop residues left in the field. From the available data it is difficult to quantify trends in the amount of crop residues left in the field.

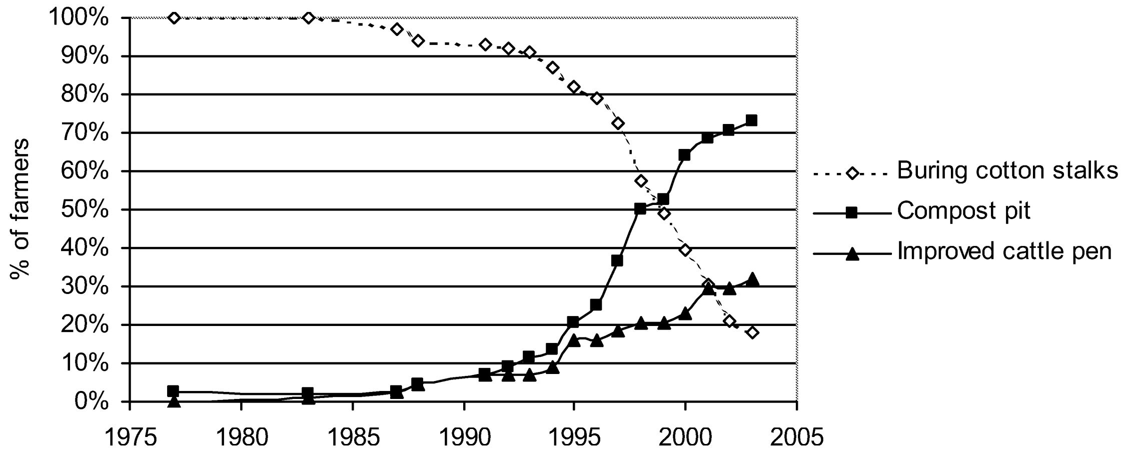

Figure 4.7. Burning of cotton crop residues and adoption of compost pits and improved cattle pens in Koutiala region between 1977 and 2003.
Source: Fieldwork 2003.

During interviews in Koutiala in 2003, farmers explained that nowadays fields need more compost to produce the same yield. They are obliged to collect the maximum of crop residues, grasses and weeds, to produce the maximum amount of compost. The availability of donkey carts or ox carts appear to be the limiting factor for crop residue collection and compost production.

4.5 Agricultural productivity

Agricultural productivity per ha may increase with intensification. Agricultural productivity per person, the combined result of intensification and expansion of cultivated area per person, may increase even if intensification has not increased productivity per ha.

4.5.1 Cotton and maize yields

Crop yield data are more reliable for cotton than for other crops, because cotton is the most accurately monitored crop. Yield data from the Statistics Unit and from the M&E Unit hardy differ. Cotton yield increased spectacularly up to 1982, remained stable between 1982 and 1992, but then decreased slightly between 1992 and 2002 (Figure 4.8). Optimum rainfall for cotton is between 800 and 1150 mm; cotton yield is not as much affected by rainfall as maize is.

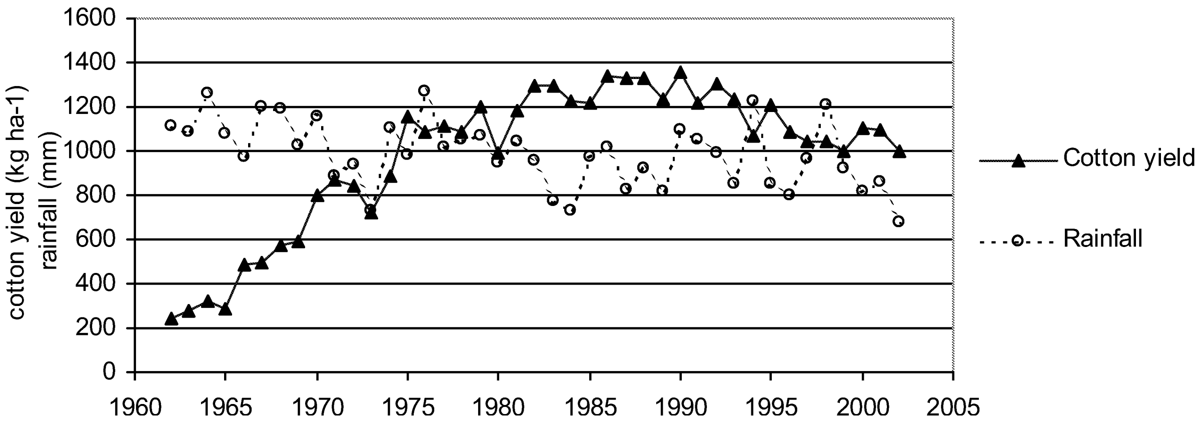

Figure 4.8. Cotton yield in southern Mali and rainfall in Sikasso and Koutiala regions (averaged) between 1962 and 2002.
Sources: Statistics Unit, CMDT; Nat. Dir. for Meteorology.

Maize yields monitored by the Statistics Unit show a similar trend but less drastically: an increase from 1400 kg ha^{-1} in 1972 to 1800 kg ha^{-1} in 1983 followed by a stable yield between 1983 and 2001. However, maize yields monitored by the M&E Unit are significantly lower than yields monitored by the Statistics Unit and show a significant decrease from 1500 kg ha^{-1} in 1993 to 1200 kg ha^{-1} in 2002.

4.5.2 Production per ha cultivated land

By combining crop yields and use of inputs with the relative area occupied per crop and crop prices, the gross margin per ha cultivated land can be calculated. The situation in 1988 is compared with the situation in 2002 (Table 4.5).

In 2002, the increased occupation of the high value cotton and high yielding maize compensated for the decreased crop yields. Total gross margin (crop value minus fertiliser, insecticide and herbicide costs) increased slightly between 1988 and 2002. Total cereal production, expressed in kg maize, sorghum, millet and rice per ha, decreased from 594 to 535 kg ha^{-1}.

Table 4.5. Gross margins in current prices from the 7 most important crops, per ha cultivated land, in southern Mali in 1988 and 2002.

	1988				2002			
	Area (%)	Yield (kg/ha)	Price (€/kg)	Contribution to gross margin (€)*	Area (%)	Yield** (kg/ha)	Price (€/kg)	Contribution to gross margin (€)*
Cotton	21	1,307	0.26	52	29	1,021	0.28	56
Maize	8	1,731	0.14	13	16	1,201	0.15	21
Sorghum	25	739	0.15	28	22	762	0.19	31
Millet	30	835	0.15	37	20	718	0.19	27
Groundnut	5	644	0.15	5	7	668	0.23	10
Rice	2	1,731	0.21	5	4	1,024	0.28	9
Cowpea	5	400	0.15	3	0	411	0.23	0
Total	95			143	97			156

* Gross margin in current prices: area*yield*price, with deduction of fertiliser, insecticide and herbicide costs.
**Crop yields presented for 2002 are 3-year averages from 2000-2002.
Sources: 1988: CMDT, cited in Van der Pol, 1992; 2002: M&E Unit, CMDT.

4.5.3 Production per person

Production per person has increased significantly due to the expansion of the cultivated area per person from 0.44 ha in 1988 to 0.61 ha in 2002. This expansion increased total gross margin from 63 € p^{-1} in 1988 to 95 € p^{-1} in 2002. These current prices are not corrected for inflation, so farm purchasing power may not have improved. Total cereal production increased from 261 kg p^{-1} to 326 kg p^{-1}.

4.6 Sustainability

Even though agriculture has intensified, crop yields have gone down, and the question comes up whether the agricultural system in 2002 has become more sustainable. Two methods to answer this question are presented. First, trends in crop yield between 1993 and 2002 are evaluated, taking rainfall and fertilisation into account. Especially the relation between yield reduction and declining rainfall is considered. Also the effect of land pressure and cultivation on more marginal land are considered as possible causes for yield decline. Secondly, following the nutrient balance calculated for 1988 by Van der Pol (1992), partial and complete nutrient balances are recalculated for 2002.

4.6.1 Trends in crop yields explained by rainfall and fertilisation

As shown in Figure 4.6, trends in crop yield depend on the period you are looking at. For the period between 1993 and 2002, the relation between trends in rainfall, fertiliser use and crop yield is analysed here. This time series is short, but the advantage is that data from the M&E Unit are reliable and includes detailed information on fertiliser use.

First, trends are analysed for each individual parameter in a linear regression analysis. The average annual change is presented in mm and kg ha-1, and in percentage of the projected value in 1993 (Table 4.6). The decline in rainfall did not turn out significant. For cotton, the increase in the complex fertiliser dose and the yield decline are significant. For maize, the increase in the urea dose and complex fertiliser dose, and the yield decline are significant.

Table 4.6. Trends in rainfall, fertiliser doses and crop yields, for cotton and maize, in southern Mali between 1993 and 2002.

		Annual change		Projected values		
		β	%	1993	2002	Sig.
Rainfall (mm)		-15.5	-1.8%	917	778	0.102
Cotton	Complex dose (kg ha^{-1})	+2.7	+2.4%	101	126	0.000
	Urea dose (kg ha^{-1})	+0.6	+1.2%	44	49	0.129
	Yield (kg ha^{-1})	-12.7	-1.2%	1125	1011	0.090
Maize	Complex dose (kg ha^{-1})	+2.2	+4.5%	41	61	0.055
	Urea dose (kg ha^{-1})	+2.9	+8.3%	25	51	0.000
	Yield (kg ha^{-1})	-29.1	-2.0%	1568	1306	0.071

Source: M&E Unit, CMDT. Values for 1993 and 2002 are projected using the constant and the coefficients from linear regression analyses.

Then, crop yield is analysed in the following regression model:

$$Crop\ yield = rainfall + rainfall^2 + N\ dose + year$$

For rainfall, a quadratic term was included. The complex fertiliser and urea doses were converted into nitrogen dose (kg N ha^{-1}). No significant interactions between fertiliser doses and rainfall were found. Data on compost use were available but compost use had no significant correlation with crop yield, probably because compost is applied on fields with relatively low soil fertility. Year is included as a linear term, allowing the regression model for a linear yield trend independent from rainfall or fertiliser dose (Table 4.7).

Rainfall is the most determinant factor. When the rainfall trend (Table 4.6) is entered in the regression model, the decline in rainfall would contribute to a yield decline of 9.9 kg ha^{-1} cotton and 74.4 kg ha^{-1} maize between 1993 and 2002. Compared with the actual yield decline between 1993 and 2002, reduced rainfall explains 9% of the cotton yield decline and 30% of the maize yield decline.

The N-dose has a significant effect on crop yield, especially on maize. When the projected N-doses for 1993 and 2002 are entered in the regression model, the increase in N-dose should contribute to a yield increase of 60 kg ha^{-1} cotton and 229 kg ha^{-1} maize between 1993 and 2002.

There is a significant yield decline, in spite of increased fertiliser doses, that cannot be attributed to decreased rainfall. This average annual yield decline is 15 kg ha^{-1} for cotton and 40 kg ha^{-1} for maize. Compared with the yield in 1993, this corresponds with an average annual yield decline of 1.3% for cotton and 2.5% for maize.

Table 4.7. Linear regression of cotton and maize yield on rainfall, N-dose and year, in southern Mali between 1993 and 2002.

	Cotton		Maize	
	β	Sig.	β	Sig,
Rainfall (mm)	+2.2	0.002	+3.8	0.002
Rainfall^2	-0.0013	0.003	-0.0019	0.008
N-dose (kg ha^{-1})	10.6	0.095	15.3	0.002
Year	-15.1	0.072	-39.5	0.034
R^2adj.	0.233		0.541	

Source: M&E Unit, CMDT.

This picture is more or less confirmed by the analysis of an independent data set on the average cotton yields in the 28 CMDT districts that compose the studied region (CMDT Statistics Unit, 1995-2002). Variability within each region was used to estimate slopes of the yield-rainfall curves and the 95% reliability interval. With these slopes and the actual rainfall trends, the yield decline that could be attributed to rainfall decline was estimated and compared with the actual yield decline (Table 4.8).

Table 4.8. Analysis of CMDT district data for cotton over the period 1995-2002

Zone	Effect rain on yield (kg ha^{-1} mm^{-1})	Rain trend (mm y^{-1})	Yield trend explained by rain (kg ha^{-1} y^{-1}) Average	95% range	Actual yield trend (kg ha^{-1} y^{-1})
South: Bougouni / Sikasso	0.03 ± 0.11	-12	0	-3 - +2	-7
Centre: Fana / Koutiala	0.28 ± 0.13	-32	-9	-17 - -1	-20
North: San	1.39 ± 0.20	+3	+4	3 - 5	3

Source: CMDT statistics Unit

The quadratic character of the yield-rainfall curves is clearly shown for the various zones. In the South (Bougouni and Sikasso), rainfall is relatively abundant and lower rainfall will depress yields in some cases while it will increase yields in other. Declining average yields are not at all explained by declining rainfall in this zone. In the centre (Fana and Koutiala), there is a positive relation between rain and yield that could explain about half of the actual yield trend. In dryer North (San), the relation between rainfall and yield is very strong, but rain trends as well as yield trends are not significant during the 1995-2002 period. Although this analysis gives in certain zones some more weight to rainfall decline in the explanation of yield declines, the overall picture remains that the significant yield declines in foregoing years cannot be attributed fully (about 29%) to decreased rainfall.

4.6.2 Trends in crop yields explained by land pressure

With the increasing population and expansion of cultivated area per person, land pressure has increased over time. Comparing the current situation in low land pressure areas with high land pressure areas may give insight in changes that have occurred over time. The indicator for land pressure is the number of years that fields have been under cultivation since last fallow, averaged per village.

Farmers in high land pressure areas, where cotton and ox-ploughing were introduced earlier, have more oxen, more ploughs and more carts, which enables them to cultivate more land: 0.68 ha p^{-1} compared to 0.52 ha p^{-1} in low land pressure areas (2002). Farmers grow more sorghum and millet. Low land pressure areas are located in the South, where rainfall is more favourable for growing maize and rice. The area under cotton is not different between low and high land pressure areas.

Chemical fertiliser use in the high land pressure areas is higher for cotton, sorghum, millet and cowpea. Total fertilisation is not different from low land pressure areas, where more fertilised maize is grown. Overall compost use is significantly higher in high land pressure areas where 27% of the fields receive compost, against 18% in low land pressure areas.

There is no clear effect of the factor land pressure on crop yields. In higher land pressure areas, crop yields are higher for cotton and millet but lower for maize, rice and groundnuts. We can thus not explain general trends in crop yields by the factor land pressure.

4.6.3 Trends in crop yields explained by expansion into marginal areas

Another effect of the increasing population and expansion is that new, often more marginal land is taken in cultivation. Comparing yields on new fields and old fields may give insight in changes that have occurred in time. The indicator for 'field age' used here is the number of years a field has been under cultivation since last fallow, compared with the average for all fields in that village. In each village, an equal number of old and new fields is considered. From fieldwork carried out in 2000, we found that newer fields are often further away from the village, are positioned higher on the glacis towards the plateau, and have coarser textured soils.

The occupation per crop on new fields is different from the occupation on old fields. Farmers tend to grow the more demanding crops - cotton and maize - on the older fields, and the less demanding crops - millet and groundnuts - on the newer fields (Table 4.9).

This confirms that fields under cultivation for a longer time are the more favourable fields. The fertiliser doses applied for each crop do not differ between old and new fields. However, because of the lower occupation by fertilised crops on new fields, overall fertiliser doses are about 12% lower on new fields. Similarly, compost use per crop is not different but overall compost use is about 10% lower on new fields. Crop yields of cotton and maize are respectively 5% and 11% lower on new fields (Table 4.9). In conclusion, the cultivation on more marginal fields could partly explain the general yield decline over time.

Table 4.9. Area per crop and crop yield* on old and new fields in southern Mali in 2002.

	Old fields		New fields		
	Area (%)	Yield (kg ha^{-1})*	Area (%)	Yield (kg ha^{-1})*	
Cotton	30	1,054	27	999	**
Maize	18	1,268	14	1,134	**
Sorghum	22	766	23	758	
Millet	18	726	20	716	
Rice	2	1,041	3	1,025	
Groundnut	5	643	7	681	
Cow pea		477	1	379	
Total	97		96		

*Crop yields are 3-year averages 2000-2002, corrected for differences in fertilisation and sowing date.
**Significant difference at 0.01 level;
Source: M&E Unit, CMDT.

The total cultivated area has almost doubled from 843,000 ha in 1988 to 1,630,000 ha in 2002. Let us assume that the old fields in 2002 correspond to the fields already under cultivation in 1988, and that the new fields correspond to the more marginal fields that have been taken in cultivation between 1988 and 2002. In that case, a yield decline of 28 kg ha^{-1} for cotton and 67 kg ha^{-1} for maize can be attributed to the effect of taking marginal land in cultivation (half the yield-difference between old and new fields). Spread out over a period of 14 years, this corresponds with an average annual yield decline of 0.15% and 0.28%. Compared with the observed average yield decline between 1993 and 2002, about 14% of both the cotton and maize yield decline can be attributed to the effect of taking marginal land in cultivation.

4.6.4 Nutrient balances

A negative nutrient balance, where nutrient output exceeds nutrient input, indicates an unsustainable agricultural system.

By comparing nutrient input from mineral fertiliser and compost with total nutrient uptake by crops, some interesting differences can be seen (Figure 4.9). This partial nutrient balance has certainly become less negative in 2002. In 1988, only 38% of nutrient crop uptake was replaced by fertiliser and compost; in 2002, this has increased to 82%. Partial nutrient balances are more or less in equilibrium for N and P but is still negative for K (-10 kg ha^{-1} yr^{-1}). The partial nutrient balances are more favourable in the high land pressure areas and on the older fields.

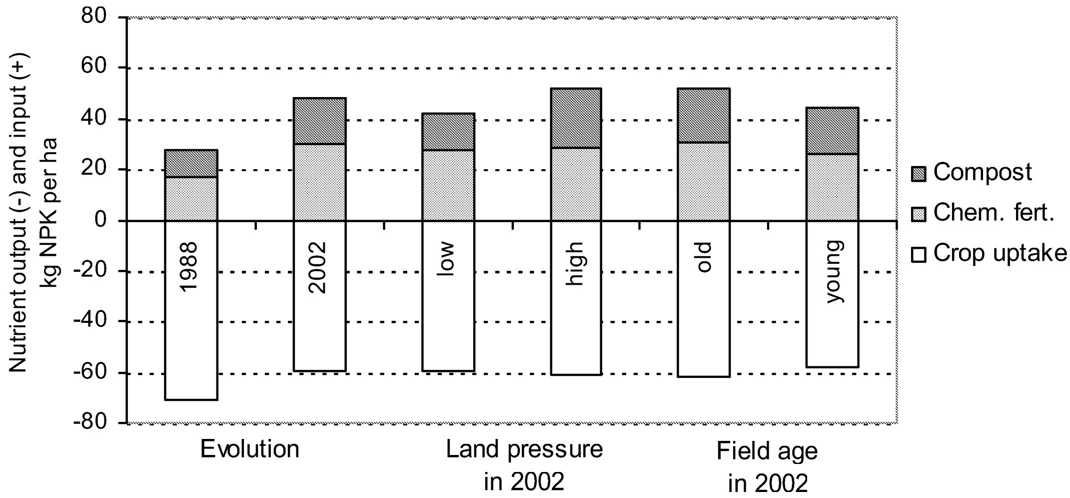

Figure 4.9. Partial nutrient balances (in kg N+P+K) of output (total uptake by crops) and input (mineral fertiliser and compost) for the cultivated area in southern Mali, comparing 1988 with 2002, low with high land pressure areas in 2002, and old with new fields in 2002.

In order to draw stronger conclusions about the sustainability, we need to calculate the full nutrient balance for cultivated land, including losses from leaching, erosion and gaseous losses, and natural inputs from atmospheric deposition, N-fixation, weathering and sedimentation. We suppose that the natural inputs did not change since 1988 and that increased fertiliser doses resulted in proportionally higher fertiliser losses. Because more crop residues are composted, less crop residues are left in the field. The full balances for N, P and K are estimated at -23, +1 and -18 kg/ha. With respect to nitrogen, these estimates are consistent with the data presented above on the carbon cycle (0.13 g OM loss with 5%N), indicating that the actual balance should be of the order of -15 to -30 kg N/ha/year. For N and K the balances for cultivated land are still negative, although less negative then in 1988 (Table 4.10).

Table 4.10. Estimated nutrient balances (kg ha^{-1} y^{-1}) in southern Mali in 1988 and 2002*.

	1988 including fallow	1988 cultivated land	2002 cultivated land
Area (ha)	1,223,000	872,000	1,630,000
N-Balance	-25	-33	-23
P-Balance	+1	0	+1
K-Balance	-20	-25	-18

* Analyses using the Integrated Environmental and Economic Accounting Excel workbook (FAO-KIT, in preparation), with estimated total losses on N, P, K fertilizer of resp. 45, 10 and 25%.

4.7 Discussion and conclusion

By interpreting agricultural expansion, intensification, productivity and sustainability, we should be able to place the situation in southern Mali along the continuum between the pessimistic land degradation narrative and the optimistic intensification counter-narrative, and to identify a trend for future agricultural development in southern Mali. Some indicators of agricultural development in southern Mali are compared with the average agricultural development in Sub-Saharan Africa (SSA), for the same period from 1988 to 2002, as presented by the FAO in their agricultural databases (FAO, 2004).

Expansion

Agricultural expansion between 1988 and 2002 in southern Mali was higher than the average for SSA. Annual rural population growth, including immigration, was higher: 3.1% against 2.0% in SSA. Annual expansion of the cultivated area was higher: 5.2% against 1.0% in SSA for all arable land and 2.4% in SSA for cotton, maize, sorghum, millet and groundnut together. The cultivated area per person increased annually with 2.1% to 0.61 ha p^{-1}, against an annual decrease of – 1.8% to 0.49 ha p^{-1} in SSA.

The high agricultural expansion in southern Mali is partly due to the relative abundance of land but is even more determined by farm equipment. The proportion of farm families with at least two oxen and one plough increased from 69% in 1988 to 80% in 2002. This enabled farm families to cultivate more land per person. According to Niang (cited by Coulibaly, 1993), the amount of labour needed to cultivate 1 ha of cotton, from cleaning and ploughing up to transporting the harvested produce, is reduced from 206 man-days for a manually equipped farmer to 99 man-days for a farmer with ox-plough and donkey cart. Because most time is saved in the busiest period, June – July, farmers with ox-plough can cultivate 2.3 times more land, about 2.1 ha per active person, against 0.8 ha per active person without ox-plough. In 2002, the average number of oxen per ha cultivated land was 0.31, or 1 pair of oxen on 6.5 ha cultivated land. According to the Malian farming systems research group ESPGRN this is still below the optimum of 1 pair of oxen on 4 ha cultivated land (Sanogo, pers. comm.). This means that most farmers are not able to do all activities in time and that they have to exhaust their oxen. The expansion of cultivated area per person confirms the findings of Berckmoes et al. (1990) and later Coulibaly et al. (1993) who calculated that it was more profitable for farmers to direct their investment and efforts towards expanding the area under cultivation, rather than improving the productivity of existing fields. One other reason why farmers expanded their land as much as possible was to put a claim on scarce land and to safeguard the future of the family.

Intensification

Agriculture has also intensified more in southern Mali than in SSA between 1988 and 2002.

While in Mali the area under staple food crops, millet and sorghum, grew on average with 2.6% and 3.6% per year between 1961 and 2002, the area under cash crops cotton and maize grew on average with 9.3% and 9.7% per year over the same period. In SSA, the area under cotton grew on average with 3.6% per year. The area under maize—in many SSA countries grown as subsistence food crop—grew with only 0.9% per year.

Mineral fertiliser doses (kg $N+P_2O_5+K_2O$ per ha cultivated land) increased between 1988 and 2002 with 3.5% per year to 35.0 kg ha^{-1}, against a decrease of –1.0% to 8.3 kg ha^{-1} in SSA.

Average compost doses on the cultivated area increased on average even with 5.2% per year in southern Mali, reaching an average of 0.7 t (dry) ha^{-1} y^{-1}. Compost use is significantly higher in the high land-pressure areas. This was also found by Kanté (2001) in southern Mali: farmers under high land pressure produce more compost and fertilise a larger land area. 'Good soil fertility managers', as classified by farmers themselves, had larger farms with more cattle, were better equipped with oxen and donkey carts, collected more crop residues, especially for fodder and cattle pen bedding, and produced more compost.

Productivity

Crop yields show different trends during different periods. In the 1960s and 1970s, yields increased spectacularly; in the 1980s, yields remained stable. Yields declined between 1993 and 2002, especially for maize (-2.0% y^{-1}) and cotton (-1.2% y^{-1}). The recent cotton yield decline is most pronounced in the region of Fana, with an average decline of -2.5% y^{-1} between 1982 and 2002. We have is no explanation for this and the Malian agricultural research institute (IER) has proposed to investigate this particular yield decline in Fana (B. Traoré, pers. comm.). On the contrary, crop yields in SSA increased slightly between 1988 and 2002, especially for sorghum (+9% y^{-1}). Nevertheless, cotton yields in 2002 were higher in southern Mali (1021 kg ha^{-1}) than the average in SSA (831 kg ha^{-1}). Other crop yields were slightly higher in SSA, especially groundnut yield: 841 kg ha^{-1} against 668 kg ha^{-1} in southern Mali.

Because of the higher proportion under cotton and maize, productivity expressed in total crop value per ha increased slightly but total cereal production per ha decreased slightly between 1988 and 2002.

Expansion of the cultivated area per person compensated declining crop yields, so productivity per person increased, both in total crop value and in kg cereals. Total annual cereal production increased from 261 kg p^{-1} to 326 kg p^{-1}, which is well above the considered minimum of 200 kg cereals p^{-1} y^{-1}. Southern Mali performed much better than the average for SSA, where per capita food production declined over the last decades (Sanchez and Leakey, 1997). In SSA, cereal production per person (total cereal production / total rural population) stagnated between 1988 and 2002 (+0.2% y-1); whereas the agricultural production index (net cereal production per person, indexed at 1999-2001) decreased on average with –0.7% y^{-1} over the same period.

Sustainability

Sustainability was assessed using two methods: 1) by analysing trends in crop yields, taking into account changes in rainfall, fertilisation, land pressure and cultivation on more marginal lands; 2) by re-assessing the nutrient balance of the cultivated area.

Rainfall decreased on average with 1.8% per year between 1993 and 2002. Between 9% and 29% of the observed decline in cotton yield and about 30% of the observed decline in maize yield can be attributed to the reduction in rainfall. Jones and Thornton (2003) simulated future crop yields using the CERES growth model and the MarkSim rainfall model. In Mali, reduced rainfall would reduce maize yields from 1053 kg ha^{-1} in 2001 to 740 kg ha^{-1} in 2055.

Already in 1987, some villages were cultivating most of the available land that was suitable for agriculture and had started cultivating marginal land (Jansen and Diarra, 1992). This means that between 1988 and 2002, more marginal land has been taken into cultivation. These relatively new fields produce indeed lower cotton and maize yields. About 14% of the observed yield decline between 1993 and 2002 for cotton and maize could be attributed to the expansion on new, more marginal land.

Stoorvogel and Smaling (1990) calculated nutrient balances for the agricultural area (cultivated and fallow area) in Sub-Saharan Africa. They predicted that the negative balances calculated for 1982-1984 (-22N, -2.5P, -15K kg ha^{-1} y^{-1}) would become more negative in 2000 (-26N, -3P, -19K kg ha^{-1} y^{-1}), mainly because of the expansion of the cultivated area and the reduction of fallow land.

The negative nutrient balance calculated for southern Mali in 1988 implied a depletion of soil nutrients and soil organic matter. Without agricultural intensification, crop yields were bound to decline (van der Pol, 1992). Crop yields have indeed declined, in spite of agricultural intensification. The nutrient balance of the cultivated area (without fallow) has become less negative in 2002. In 1988, only 38% of the crop nutrient uptake (expressed in kg N+P+K) was compensated by chemical fertiliser and compost application; in 2002, this has increased to 82%. Nutrient balances are more positive in the older fields and in the high land pressure areas, which confirms the findings of Ramisch (2005) who found more positive nutrient balances in the fields nearby the homestead. Nevertheless, the nutrient balances are still negative, indicating that the agricultural system has not yet become sustainable. Considering the inevitable reduction of fallow – shorter fallow periods and reduction of fallow area – one gets the impression that the increased use of fertilizer and compost may just compensate for the reduction of fallow, but does certainly not contribute sufficiently to improve soil fertility.

Van der Pol (1992) predicted a decline of organic matter content of the soil. Berger (1990) argues that the amount of compost applied should ideally compensate for the loss of organic matter by mineralisation. He estimated for Burkina Faso, with soils containing 1% organic matter mineralising at 2% annually, that an annual application of 2 tons of dry compost (30% organic matter) would be needed. Looking at the amounts of compost applied in southern Mali, soil and climate being similar to those in Burkina Faso, the actual compost application of 0.7 t ha^{-1} y^{-1} would not be sufficient to maintain the soil organic matter content at 1%. In fact, the lacking 1.3 t ha^{-1} yr^{-1} would correspond to an annual decline of 1.3% of the soil organic matter content, representing an annual loss of about 0.13 g organic matter per kg of soil. This figure is very close to the annual loss of 0.15 g calculated for southern Mali by van der Pol (1992) on the basis of nitrogen balances.

The land degradation narrative and the intensification narrative

Based on the quantitative results of this study, where do we stand between the two opposing land degradation narratives? Our first, perhaps disappointing, conclusion is that neither nutrient balances nor trends in crop yield are conclusive indicators for land degradation. We can explain this with a simplified model of the Malian situation. Assume that crop yield is determined by nutrients from mineralised soil organic matter and from fertilisation. Assume also that soil organic matter is mineralised at a rate of 2% y^{-1} and that crop residues and manure replenish half of the mineralised soil organic matter, resulting in a net soil organic matter decline of 1% y^{-1}, from 0.70% to 0.61% over a 14-year period. Mineralised soil organic matter will provide initially about 20 and after 14 years about 17 kg N ha^{-1} y^{-1}. Over the same period, fertilisation increased from 10 to 18 kg N ha^{-1} y^{-1}, improving the negative nutrient balance for the cultivated area from –33 to –23 kg N ha^{-1} y^{-1}. Crop yields should thus increase, in spite of soil fertility decline and negative nutrient balances. This confirms Vierstra's statement (1994) that soil fertility decline is camouflaged by increased fertilisation. Taking into account the nutrient balance that is still negative, the yield decline that cannot explained by rainfall and cultivation on more marginal land only, and the increased fertilisation, we conclude that land degradation in southern Mali is continuing in 2002 but at lower rate than in 1988.

Future trend of agricultural development in southern Mali

Templeton and Scherr (1999) identified a U-shaped relation were land productivity would first decline and, after sufficient intensification, would increase. In southern Mali the trends have been different. So far two phases can be distinguished: 1) up to 1982, a phase of yield increase due to increased fertilisation and increased mechanisation, which probably resulted in accelerated mineralisation of soil organic matter; 2) from 1982 to 2002, a phase of yield stagnation and decline due to stagnated intensification, continued expansion, reduced fallowing and negative nutrient balances, all of which probably resulted in a decline in soil fertility. The next phase could be one of increasing crop yields, but this would require further intensification and a balance between soil organic matter mineralisation and replenishment.

After having analysed the general agricultural development in southern Mali over the last decades, the next chapter analyses the first step of the SWC project in southern Mali: the effect of the project approach on farmer adoption of SWC measures.

Chapter 5

How Project Approach Influences Adoption of SWC by Farmers, Examples from Southern Mali

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5 How Project Approach Influences Adoption of SWC by Farmers, Examples from Southern Mali

Abstract

Choices in project approach affect the continuation of soil and water conservation (SWC) after project withdrawal, and thus the sustainability and cost effectiveness of the project. A SWC project was carried out in southern Mali between 1986 and 1998. Its features were the promotion of simple SWC measures, a village approach without direct incentives, and incorporation in an existing extension service. By 2002, erosion control measures had been installed by 46% of the farmers and in 15% of the fields. Though external donor support has stopped, farmer adoption is steadily continuing and spreading to untargeted villages.

Key words: soil and water conservation, project phases, extension approach, sustained adoption, southern Mali, West Africa

5.1 Introduction

5.1.1 Approaches in SWC projects

The resource base of African agriculture is increasingly under pressure. Farmers and their organizations face the challenge of applying effective soil and water conservation (SWC) measures to sustain their farming activities and livelihood systems. During the 1980's in particular, governments, research and extension services and donors were strongly motivated to assist farmers to face this challenge.

A review of the approaches of five SWC projects in Mali, Burkina Faso and Niger (Kessler et al., 1995) shows that these projects vary in the choice of technical SWC measures, the extension methods and incentives used, and in how the project is institutionalised. These differences could not be attributed to differences in agro-ecological or socio-economic setting but mainly reflected the preferences of donors and project staff for short-term successes and/or long-term sustainable success. Initial farmer adoption of SWC practices can be accelerated by choosing effective but expensive erosion control measures, using direct incentives, and employing additional extension staff. However, this approach may compromise the continuation of the adopted practices and of further adoption after project closure. To assure that farmers continue to adopt the practices after project closure it may be better to choose simple and cheap erosion control measures, motivate farmers by awareness-raising and training sessions, and work through an existing extension service.

5.1.2 Farmer adoption of SWC measures

Farmers take several steps before deciding whether to adopt erosion control measures. They have to be aware of the problem (recognizing erosion symptoms and experiencing the negative effects). They have to be willing to do something about it (perceived urgency of the problem, land rights). They have to know about possible solutions (knowledge and skills to install erosion control measures, belief in benefits). Farmers may be hindered by the complexity or the social acceptability of the measures, by limited access to the necessary inputs, or they may be discouraged by the expense, the low financial returns or the high risks involved (Napier, 1991; de Graaff, 1996). Direct incentives may only temporarily bypass some of the above steps in the decision-making (Mbaga-Semgalawe and Folmer, 2000).

It is important to distinguish initial adoption from sustained adoption. Initial adoption, or the adoption decision, is mainly determined by the capacity of the farmer to install erosion control measures and by secure land rights, while sustained adoption and the adoption intensity are determined more by the costs and expected benefits (Gebremedhin and Swinton, 2003). Sustained adoption after initial adoption is an important indicator of the success of a SWC project.

Several studies have examined the dynamics of adoption within a farmer population. The adoption of innovations cannot be explained by cost-benefit analyses or household decision models alone. Diffusion of innovations depends on interactions between individual farm households, which determines the exchange of information, the possibility to see the innovations 'in the field' and, for example, the farmer-to-farmer distribution of plant materials (Berger, 2001). Farmers differ in their willingness and ability to adopt new practices. Rogers (1995) grouped farmers into innovators, early adopters, early majority, late majority and laggards. Although this classification, based on the linear Transfer of Technology extension model, has been criticized, this 'popularity hypothesis' maintains that a critical mass of adopters is needed before an innovation spreads significantly. This popularity hypothesis is complemented by the 'effective information hypothesis'. After the adoption by a few farmers, a learning period of on-farm trial and error is needed before effective information is generated that can accelerate large-scale adoption. Effective information is well approximated by the number of years the technique has been applied. The more easily farmers can experiment with new innovations, the faster adoption can take off. Unfortunately, it is more difficult to experiment with new land management practices than, for example, with a new crop variety, which is why adoption may be low and slow. The benefits are often difficult to observe and may not appear for some years. The new land management practices need to be implemented on a large scale, and for the benefits to be visible they must not be compromised by poor quality of installation or by non-adopting neighbouring farmers. High costs and high risk may discourage farmers from experimenting (Marra et al., 2003). Holt and Schoorl (1985) argue that agricultural extension should not only diffuse new messages but should be actively involved in the trial and error learning period (innovation), in assuring the quality (maintenance), and in the replacement of old techniques (obsolescence) by newer, better techniques.

5.1.3 Project sustainability

A project's sustainability is evaluated by assessing whether benefits continue after project support has stopped. World Bank (2001) and MDF (2003) suggest considering six aspects of sustainability: 1) whether the country policy will allow for continuation; 2) whether the responsible organizations will continue to function; 3) whether beneficiaries can use the technology without external support; 4) whether the benefits will outweigh the costs without external support; 5) whether positive environmental effects will continue; and 6) whether all members of the target group will continue to participate. Projecting these aspects of sustainability on the approach of a SWC project, we can relate the first and second aspects to the way the project is institutionalised, the third, fourth and fifth aspects to the choice of erosion control measures, the fourth aspect also to use of incentives, and the sixth point to the extension approach used.

Several evaluations have shown that SWC projects have had a positive effect on adoption, but some have also shown a lack of incorporation in a permanent extension service, the negative effects of the use of incentives, and an emphasis on adoption rather than on land degradation or production. In Nepal, out of 27 physical, agronomic, socio-economic, and education-related factors, 10 factors significantly affected adoption of SWC. The most influential factor was the frequency of extension visits; other significant factors were training and participation in joint land management efforts (Paudel and Thapa, 2004). In Tanzania, farmer participation in SWC promotional activities enhanced farmers' perception of erosion, knowledge of SWC and adoption of erosion control measures. However, the temporary SWC project was not incorporated into the permanent national extension service and that extension service had no effect on the perception, knowledge or adoption of SWC (Mbaga-Semgalawe and Folmer, 2000). In Ethiopia, the presence of public involvement in the construction or erosion control measures on private land discouraged adoption by farmers who did not receive public support (Gebremedhin and Swinton, 2003). In Central America, the closure of a number of SWC projects resulted in an abrupt halt of the maintenance and installation of erosion control measures (infiltration ditches and vegetation strips) promoted by direct incentives, whereas adoption of other agricultural measures not supported by direct incentives (contour farming and 'no burning') continued steadily. These projects' emphasis on adoption rather than on land degradation or productivity also risked promoting erosion control where this was not effective (Hellin and Schrader, 2003). In Burkina Faso, transport of stones by a project lorry was the major incentive for installing stone rows. However, the installation was less efficient (in terms of man-days per meter stone row) when done collectively with lorry transport and more efficient when done individually, without incentives, using donkey carts. Nevertheless, the incentives were justified because the costs were only gradually being recuperated from benefits and, furthermore, the beneficiaries include downstream populations and future generations too (Posthumus et al., 2001). It has been shown that the need for incentives depends on the labour requirements, which are much lower for vegetative barriers than for mechanical barriers (de Graaff and Spaan, 2002; Spaan et al., 2004).

From these evaluations we conclude that project approaches should be modified during the different phases of the project in order to initiate high initial adoption without compromising sustained adoption after project closure. An initial high level of project support to a critical mass of potential adopters (a group of neighbouring farmers or a whole village) during an initial learning period of several years can thus be justified.

5.1.4 Evaluating the approach of the SWC project in southern Mali

A donor-funded SWC project started in 1986 within the Malian agricultural extension service of the *Compagnie Malienne pour le Développement des Textiles* (CMDT). Its overall objective was to reduce land degradation, to intensify agriculture and to improve agricultural production (PLAE, 1986). The main aim of the project was to make the rural population responsible for natural resource management (NRM), which included the adoption of SWC measures on agricultural land, achieving equilibrium between agricultural, sylvicultural and pastoral land uses, and the management of communal natural resources by village organizations. Additional project aims were to make the rural population aware of land degradation, to increase the capacity of the CMDT extension service, and to monitor, evaluate, document and disseminate the experiences (PLAE, 1989; van Mourik et al., 1993; CMDT, 1995).

The moment the SWC approach became part of large-scale extension – the focus of this paper – other components of the broader NRM approach continued to be developed jointly by the project, the extension service, farmers in participating villages and the farming systems research group in the area. Gradually, recommendations from this action research were tested in pilot extension schemes and the results were translated into training material (Joldersma et al., 1994; Bosma et al., 1996).

The project aimed at large-scale adoption of SWC measures, which would eventually allow farmers to become independent from the temporary donor support. Therefore, it used an approach that had three specific thrusts (van Campen, 1991; Hijkoop et al., 1991): a) technical: choosing simple, low costs SWC measures; b) extension: using a participatory village approach and minimizing farmer dependence on project support and incentives; and c) institutional: phasing the project, embedding it in an existing extension service, and maximizing the size of the impact area.

The SWC project came to a halt after financial support and technical assistance were withdrawn between 1998 and 2002. Due to the reorganization of the CMDT extension service, SWC extension has been drastically reduced.

This article aims to identify how the project approach has affected the rhythm of farmer adoption, during and after project support. The following three questions receive specific attention: (i) What was the effect of the SWC project approach on the adoption in the targeted villages in the years after project intervention started? (ii) What was the effect of the SWC approach on the diffusion of SWC measures to villages that were not directly targeted? (iii) What was the effect of the SWC project approach on the continuation of adoption and on farmers' intentions after withdrawal of external financial and technical support?

Before presenting the results on farmer adoption in section 4, we will describe the SWC project approach in more detail in section 3.

5.2 Methods

Project reports were reviewed to ascertain the institutionalisation of the project, its different phases, the technical SWC measures, and the extension methods and incentives used. Data on training and adoption in southern Mali were taken from annual reports of the SWC project (which later became the SWC Unit of the CMDT) and of the M&E Unit of the CMDT. In 2001, 109 villages in Koutiala district had been surveyed for the presence and functionality of trained SWC village teams. This study also drew on the results of three field studies. The first, done by the SWC project and the M&E Unit, looked at farmer knowledge and appreciation of the SWC extension approach, in 81 villages in southern Mali in 1994 (Giraudy et al., 1996). The second, done by the SWC Unit and the M&E Unit, looked at field characteristics, erosion and crop yield, and at farmer training and adoption, in 60 villages in southern Mali in 2000 (CMDT, 2002). The third, done for Wageningen University, looked in more detail at field characteristics and at the farmer appreciation of the SWC measures, extension approach and incentives, in 6 villages in Koutiala Region in 2003.

For the ex-post evaluation with incomplete baseline data, two alternative methods were used: the ‘reconstructed interrupted time series’ and the ‘virtual time series’. For the reconstructed interrupted time series, farmers indicated *post hoc* the year of training and the year of adoption. Comparing these years gave insight into the relation between training and adoption. For the virtual time series, the adoption observed in one year (2002) was compared from different villages in which there had been training events at some time between 1986 and 2000. This presentation of adoption as function of year of training gave an indication of the adoption process after training.

5.3 The approach of the SWC project in southern Mali

5.3.1 Choice of erosion control measures

Southern Mali, with 700-1200 mm annual rainfall and cotton as cash crop, is relatively favourable for agriculture. Staple food crops benefit from the residual effect of fertiliser applied to cotton grown in rotation. The farm household typically consists of an expanded family, on average 17 persons, cultivating on average 10 ha of land (CMDT, 2003). Although southern Mali has gentle slopes, 0-3% on the cultivated area (glacis), the long slopes, poor soil structure and degraded areas above the cultivated area (plateau and escarpment) result in water runoff and sheet erosion (Hijkoop et al., 1991). On cultivated fields, the runoff coefficient is between 7 and 40 %. Sheet and rill erosion have been estimated to lead to a soil loss of 5-31 tons ha^{-1} year^{-1} (Roose, 1985; Hallam and Verbeek, 1986; Bishop and Allen, 1989; Vlot and Traoré, 1994).

The selected erosion control measures were a compromise between what was technically desirable and what was compatible with existing farming practices. An additional consideration was that the approach should not be too complicated for the CMDT extension service. Diversion terraces and protection dikes blocking the water were difficult to install, demanded specialized personnel and equipment, and were dangerous (risk of the structures collapsing). Therefore semi-permeable erosion control structures were preferred, such as stone rows, installed along the contours above the cultivated area. As fields from different families were present on the same slope, a village approach was more appropriate than an individual approach. Farmers found it too difficult to cultivate along curved contour lines and therefore erosion barriers were installed in the cultivated area along the least sloping field boundaries. These barriers were live fences, grass strips and crop residue lines. Gullies were reclaimed with stone or crop residue check dams. Erosion control measures in the fields included ploughing and sowing across the slope, box ridges and dry-season harrowing. The promotion of erosion control measures was accompanied by the promotion of organic fertilization. A flexible ‘ basket of options’ approach gave farmers a choice of measures and the possibility to pace installation over several years according to their own capacity (Hallam and van Campen, 1985; Hijkoop et al., 1991).

The species for vegetative barriers were selected on the basis of establishment success and secondary uses. *Euphorbia balsamifera* and *Jatropha curcas*, used for live fences, are not browsed by livestock and can be planted as cuttings, even before the start of the rains. Jatropha seed yields an oil used for making soap. *Andropogon gayanus,* used for grass strips, was more difficult to establish and suffered from browsing by free-roaming livestock. This grass is used for thatching.

The labour required for the erosion control measures differed. The installation of 100-metre stone rows, protection dikes or crop residue lines took about 100 man-hours. By contrast, planting 100 m of live fence took 7 man-hours, and sowing 100 m of grass strip took only 1 man-hour (Hijkoop et al., 1991). According to farmer interviews in Koutiala in 2003, it takes 14 man-days to install 100 meters of stone row. The time taken to install the same length of protective dike, crop residue line, live fence and grass strip (planting, not sowing) is respectively 11 days, 8 days, 3 days and 2 days.

5.3.2 SWC Extension

Host organization: CMDT

The CMDT covered most of the cotton growing area in southern Mali, i.e. about 125 000 km^2, and 3 million people in over 5000 villages. CMDT was owned jointly by the Malian government and the French company CFDT (renamed DAGRIS in 2001), which held respectively 60% and 40% of the shares. It had an integrated dual mission: a commercial mission to organize activities related to cotton (inputs on credit, extension, processing, export) and a public mission of rural development (e.g. literacy programs, water supply), for which the Malian government was responsible. This meant that rural development was partly financed by cotton revenues, complemented with support from the Malian government and donor agencies: a ‘public–private partnership’ *avant la lettre*. The CMDT was the most effective organization in rural southern Mali and had a dense, multi-layered network of extension workers. About 650 general extension workers covered an average of 8 villages each, and 33 district offices assisted the general extension workers and formed the link with the 6 regional offices, which were supervised by the National Directorate.

Since 1977, the CMDT had encouraged the creation of Village Associations (VA), to which it transferred tasks of credit and cotton payment administration. Different ‘village teams’ were organized to carry out different tasks. The CMDT paid a percentage of the cotton revenues to the VA, which used the money for rural development activities at the village level and to recompense the village teams (Hijkoop 1991).

Steps in the SWC extension approach

The SWC project used a village approach, built on the organization of the village association (VA), the traditional authority and the strong social coherence in the village, which was typical for southern Mali. This village approach involved a large number of farmers at the start of SWC activities and thus gave adoption a flying start. The extension approach consisted of a series of chronological steps: (1) selection of villages and awareness raising; (2) training of an SWC village team, field visits and slide shows; (3) erosion diagnosis and planning of erosion control, collective installation of erosion control measures, and evaluation; (4) additional training in soil fertility management; (5) mass media to reach farmers in all villages.

(1) General extension workers proposed villages to the SWC specialist. The first villages selected were chosen from the better-organized villages with a VA and good social cohesion. During the first awareness meeting in the village, villagers discussed past, present and future land use, using a participatory rural appraisal module. After the meeting, the village was asked how motivated it was for the SWC program. The SWC specialist selected villages based on the actual erosion risk and on their motivation.

(2) The main training activity was the installation and training of an SWC village team. The village selected a minimum of 5 active farmers for the team, at least 2 of whom were literate. The team subsequently underwent 5 days of training, based on brochures written in the local language. The main function of the SWC village team was to organize collective erosion control; they depended on working groups for this, but also assisted farmers individually. Members of the SWC village team were not paid by the project but were recompensed by the VA. A farmer-to-farmer visit was organized for the members of the newly trained SWC village team and for a limited number of responsible persons (VA board) to another village with SWC experience. After the field visit, the visitors reported to all villagers and a slide show was organized for all villagers.

(3) The village selected an area of its cultivated land for which an erosion diagnosis was performed and an erosion control scheme was developed by the SWC village team and the farmers concerned, assisted by the extension worker. During a feedback meeting in the village, the erosion control scheme was translated into a quantitative work plan for 3-5 years and a first annual work plan. Then, a start was made with the collective installation of erosion control measures: mostly stone rows along contours above the cultivated fields. Individual erosion control measures were added in the fields below the stone rows. After the first, most degraded area, had been treated, other areas were selected for erosion control. During each annual review and planning meeting, the evaluation of the previous season’s activities was linked to the planning of the next season’s activities.

(4) From 1995 onwards, interested farmers in the targeted villages received an additional 5-day training in soil fertility management.

(5) During the promotion phase (from 1989 onwards), farmers in all villages were targeted by weekly radio broadcasts, recorded music cassettes, theatre, music performances, and articles in the local language in the monthly CMDT farmer journal. During the handing over phase (from 1996 onwards), certain extension steps (awareness, slide shows) were left out, because untargeted villages had already been exposed to SWC activities in neighbouring targeted villages. Instead, emphasis was given to the training of an SWC village team, the erosion diagnosis and the planning of erosion control activities.

In the remainder of this article, villages with a trained SWC village team will be referred to as ‘targeted villages’ and villages without a SWC village team as ‘untargeted villages’, even though farmers in the latter villages may have had some extension on SWC.

Incentives

In addition to the extension activities described above, the project used a number of modest incentives as support. Each trained SWC village team received a water tube level to peg contour markers. After 2000, no more water tube levels were distributed and a small number of line levels were sold to individual farmers. Furthermore, where insufficient planting material was available, the SWC program supplied *Euphorbia balsamifera* cuttings and *Jatropha curcas* seed for live fences and *Andropogon gayanus* seed for grass strips. Initially, the seed was free; later, it was sold to farmers.

During the pilot and promotion phases an annual SWC contest was organized to financially and socially reward the most active villages. The winning villages received prizes and were visited by farmers from other participating villages. In 1995 this contest had become too strong an incentive and was replaced by ‘environment days’, with field visits but without prizes.

Under the SWC program special credit was available for the purchase of donkey carts that facilitated the production of compost (including the use of manure) and the transport of compost and stones, and for the purchase of wire netting to build improved cattle pens. Although farmers paid back the credit, the revolving funds stopped functioning in 2000 due to poor financial administration resulting from the general management crisis within CMDT.

Farmers’ appreciation of the SWC extension approach and incentives

In 2003, farmers in five targeted villages indicated the activities in which they had participated and ranked them in order of importance if new villages were to be targeted. The most important step was awareness, followed by training of an SWC village team, diagnosis of erosion problems and planning of erosion control, training in soil fertility management and distribution of plant materials (Table 5.1). Note that the credit facilities and the SWC contest (incentives) were least appreciated.

According to the farmers, the SWC village team played an important role in the first years after training, but often stopped functioning after a few years. An inventory of 109 villages in the central district of Koutiala, done in 2001, showed that 31% of the SWC village teams were still functional, 18% were only functional for part of the village and 51% were no longer functional.

Reasons for the loss of functionality were a weakened village authority, the fact that members of the SWC village team were not paid and the failure of working groups to show up for collective work. Proposed solutions were to pay the SWC village team, renew the SWC village team and install several SWC village teams, especially in larger, divided villages where collective action was problematic. In 1998, the CMDT proposed that the VAs pay SWC village team members from their cotton revenue, but most did not. During that period, many VAs had debt problems and split up into several smaller VAs. This decreased the social cohesion and complicated the functioning of the SWC village team. Although some farmers preferred individual training, the majority of farmers thought that training of an SWC village team was more effective and more efficient.

Table 5.1. Participation and appreciation of SWC extension activities by farmers in 5 targeted villages in Koutiala in 2003.

Chronological steps in SWC extension and additional support	Participation (% farmers)	Appreciation (ranking: 1 = most)
Awareness meeting	51	1
Installation and training of SWC village team	18 [a]	2
Field visit	14	6
Slide show	73	7
Erosion inventory and SWC plan	36	3
Collective erosion control	84	(not asked)
Training in soil fertility management	17	4
Distribution plant materials	27	5
Credit for donkey cart	14	8
Credit for wire netting (for improved cattle pen)	0	9
SWC village contest	(not asked)	10

[a] Interviewed farmer or family member participated in SWC village team

Note: Farmer participation and appreciation were not asked for all activities.

Collective erosion control depended on the SWC village team and social cohesion in the village and had become more difficult to organize by 2003. The majority of farmers said that both individual and collective erosion control were needed. The collective installation of erosion control measures was considered important also as a practice and training in SWC.

Euphorbia and Jatropha plant material was abundantly available in the five targeted villages, but only available in limited amounts in the untargeted villages. Farmers collected plant material for free in their own village or in neighbouring villages. Because of the poorer distribution, the lower germination rate and the higher pressure from browsing, availability of Andropogon was still limited, even in the targeted villages.

The availability of plant material for live fences and grass strips creates alternatives to stone rows (or stone barriers); the latter are more labour demanding to install, especially when stones need to be transported from far away by donkey cart. Farmers in Koutiala indicated the distance between the visited field and the nearest source of stones. On average, it was 1.7 km. The acceptable distance at which stones could still be collected was 1 km. In 52% of the fields, the distance was acceptable (average: 0.7 km); in 48% of the fields, the distance was too long (average:

3.6 km). This ‘acceptable distance’ corresponds with farmer adoption of stone rows. Farmers who had installed or planned to install stone rows reported sources of stones at 0.6 and 0.7 km respectively. This acceptable distance corresponds with the findings of Kempkes in Burkina Faso, who found that transport of stones for stone rows over distances of 2 and 4 km by lorry or donkey cart was not cost effective (de Graaff, 1996).

Some farmers insisted on the need for special credit for donkey carts and wire netting, but others thought that credit in general had resulted in too many debt problems and conflicts in villages, and did not recommend such credit.

5.3.3 Institutionalisation during different phases of the SWC project

Six different phases of the SWC project are distinguished.

Pre-project phase: 1982 – 1986. The Malian farming systems research group DRSPR (*Division de Recherche sur les Systèmes de Production Rurale*) was established in 1982 within the IER (*Institut d'Economie Rurale*), with Dutch donor support (DGIS). DRSPR had identified soil erosion as an important problem, while at the same time farmers complained to the CMDT about declining yields and water runoff. In collaboration with the CMDT, DRSPR tested SWC techniques and extension methods, and this led to the SWC project (*Projet Lutte Anti Erosive*) being set up within the CMDT in 1986 (Hijkoop et al., 1991; Schrader et al., 1998).

Pilot project phase: 1986 – 1989. The SWC project started in 1986, supported by the Dutch DGIS. The collaboration between the CMDT (extension) and DRSPR (research) assured that technical measures and extension methods were tested in a pre-extension phase. A German-funded natural resource management project (*Projet Agro Ecology*) participated in the development of the SWC approach. By the end of 1989, farmers in 36 villages, in 2 of the 5 CMDT regions, had been trained and had undertaken SWC activities.

Promotion phase: 1989 – 1996. The SWC project invested in the capacity of the CMDT extension service. The CMDT recruited additional personnel that were trained by the SWC project. They were placed in the CMDT multidisciplinary teams, initially at the district level, later also at the regional level. Each recruited district SWC specialist worked initially with one general extension worker in one village, gradually increasing the number of villages and eventually involving all general extension workers. In this way, the targeted villages were spread out over southern Mali, which was initially more costly, but assured a larger impact on the long run. In 1992, the SWC project became a CMDT division but retained project financial support (Schrader, 1997). In 1995-1996, all extension staff was trained in SWC and in soil fertility management. The number of targeted villages in which farmers had been trained and had undertaken SWC activities increased from 36 in 1990 to 1135 in 1996 (Schrader and Wennink, 1996). During the pilot phase and the first three years of the promotion phase, the Dutch donor spent on average €580,000 per year on this SWC project (IOV, 1994).

Handing-over phase: 1996 – 1998. The Dutch donor switched from project approach to program approach in 1996, as a result of which the SWC project became a component in the rural development program for which the CMDT received financial donor support. Whereas up to 1994

SWC activities were concentrated in targeted SWC villages, from 1996 onwards SWC extension became more diluted, mostly promoted by the general extension workers. The number of targeted villages increased from 1135 in 1996 to 1809 in 1998. In addition, general extension workers gave SWC advice on a more ad hoc or even individual basis, including in villages that did not receive the full SWC extension package. The CMDT received about €1,600,000 from the Dutch donor for the two-year period for several rural development programs. We estimated the annual contribution to the SWC programme to be about €457,000.

Donor withdrawal phase: 1998 – 2002. Donors gradually withdrew support to the CMDT. The Dutch stopped financial programme support halfway 1998 and technical assistance at the end of 1999 (IOB, 2000). The German NRM program stopped in the beginning of 2002. An inventory in 2000 showed that about 2562, or 51% of the 5054 villages in southern Mali, had been trained in SWC. From 2000 onwards, the CMDT faced a financial crisis and gradually allocated less budget for the SWC extension program. In the year 2000/2001, the CMDT budgeted about € 760,000 for the SWC program, from cotton revenue resources, without donor support. Only part of this was actually spent on the SWC program.

Extension withdrawal phase: 2002 onwards. Since 2002, the Malian cotton sector has been undergoing restructuring. This will probably result in the commercial activities related to cotton being consigned to several privatised companies, leaving the rural development activities to other partners: national and local government, farmer organizations and private organizations. SWC is relevant for cotton production, even from a short-term commercial point of view (CMDT, 2002). However, financial problems and political pressure to focus only on commercial activities resulted in the dismissal of the SWC specialists and a large number of general extension workers at the CMDT. Although it was contended that other players like NGOs and local authorities would take over CMDT rural development tasks, including SWC, so far this has not happened.

5.4 Farmer adoption of SWC measures

5.4.1 Adoption of SWC measures in targeted villages

Although adoption was regularly monitored, less is known about farmers' knowledge about SWC measures. The joint study by the M&E Unit and SWC Unit in 1994 investigated farmer knowledge and information sources relating to four erosion control measures and two composting techniques. The most well known were compost pits (85% of the farmers), followed by live fences (78%), stone check dams (72%), improved cattle pens (67%), crop residue check dams (51%) and grass strips (36%). More than 90% of the farmers who had heard about a SWC measure had seen the measure; 60% had learned how to install the measure. About 50% of the farmers who had heard about a SWC measure had been informed by the general extension worker or the SWC specialist. Composting techniques promoted well before the SWC program had mostly been seen for the first time in the farmer's own village. Erosion control measures introduced more recently had more often been seen for the first time in neighbouring villages (Giraudy et al., 1996). This underlines the importance of extension workers, visible examples of SWC measures, and field visits to other villages for the diffusion of information on SWC measures.

During the pilot phase, the promotion phase and the first two years of the institutionalisation phase, the number of targeted villages grew exponentially, until the Dutch donor withdrew most of the financial support to the CMDT in 1998. The intensive SWC training stopped in 2000. The adoption of erosion control measures, expressed in percentage fields, continued steadily, even during the pullout phase, when the CMDT withdrew SWC extension personnel (Figure 5.1).

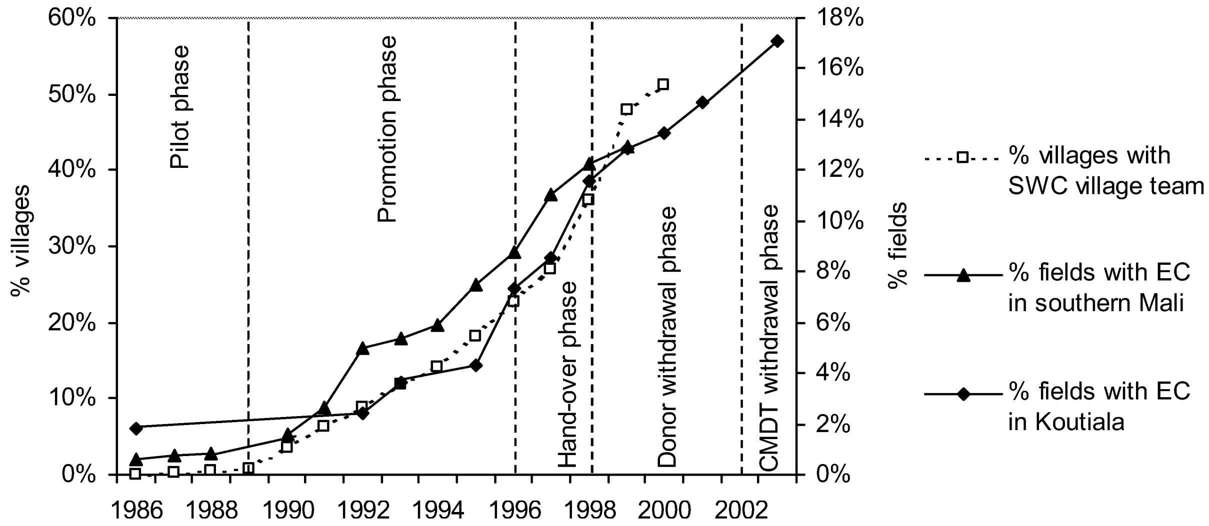

Figure 5.1. The different phases of the SWC project, the percentage of villages with a SWC village team, and the percentage of fields with erosion control (EC) measures, in southern Mali and in Koutiala region, between 1986 and 2003.

Sources: Training data from Schrader and Wennink (1996) and CMDT SWC-Unit reports; Adoption data from fieldwork 2000 (southern Mali) and 2003 (Koutiala) calibrated with M&E data 2000-2002.

There is a time lag between the training of a SWC village team and the first time a farmer installs an erosion control measure. Some farmers started the same year they received training, others started after one or several years. Using the fieldwork data from 2000, looking at villages that were trained before 1996, we reconstructed a so-called interrupted time series by comparing the year of training and the year of first installation (Figure 5.2). Notice the flying start of adoption in the year of training (year 0), which should be understood as the adoption just after the training. Most farmers started installing collective stone rows in the first two years after training, whereas the number of farmers who started installing individual live fences was more evenly spread out over the five years after training.

Another way to present the relation between adoption and training is a so-called virtual time series. The M&E data from 2002 gives us information on the adoption of erosion control measures in 2002, not on the year in which these measures were installed. Adoption in different villages can be compared with the year of SWC training in those villages (Figure 5.3). In villages that were trained a longer time ago, both the percentage of farmers and the percentage of fields with erosion control measures were higher.

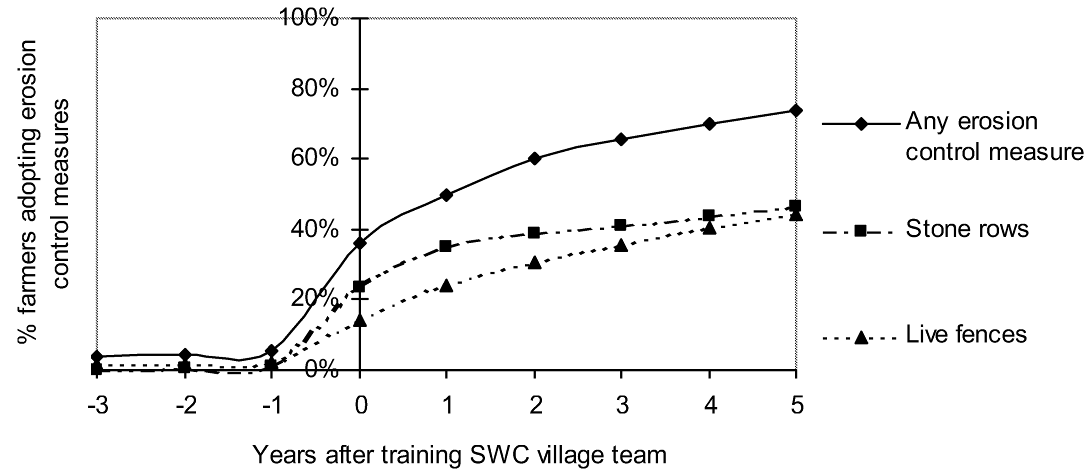

Figure 5.2. Cumulative adoption of erosion control measures in targeted villages, from 3 years before to 5 years after installation of a SWC village team, in southern Mali.
Source: Fieldwork 2000, southern Mali; 210 farmers trained before 1996.

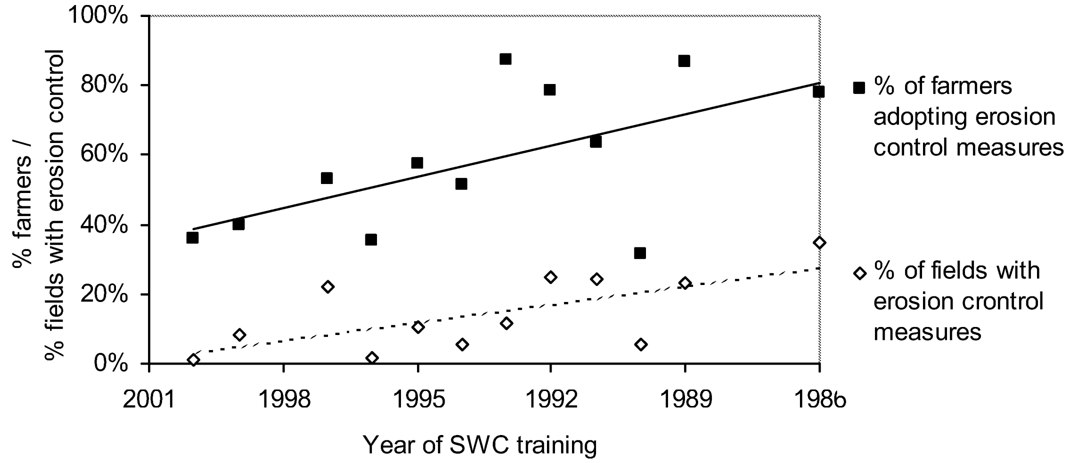

Figure 5.3. Adoption in 2002, in percentage of farmers and in percentage of fields, as function of year of SWC training.
Source: M&E data 2002. Note: It is possible that none of the sampled fields of a sampled farmer who had adopted erosion control measures had erosion control measures.

Based on the annual SWC Unit reports, we calculated that a total of about 7500 km stone rows and about 23,000 km live fences had been installed between 1986 and 2000. The annual installation of stone rows fell after 1996, while the annual installation of live fences continued steadily.

It is difficult to estimate the area protected from erosion. Farmers explain that collective stone rows above the cultivated area benefit a large area of up to several hundred meters below, but that this needs to be complemented with additional interventions below. With simple assumptions we can extrapolate the length of stone rows and live fences to the protected area. Because farmers do not install line barriers within fields, a situation that could be aimed at is one stone row above the highest field and then a live fence between all fields. If live fences are installed all around the field, only half of the live fences will be perpendicular to the slope and effective against erosion. The average field size is about 1.6 ha. Assuming square fields, the distance between the upper and lower boundaries is about 125 meters. If we assume that the line barriers would have an effect up to about 50 meters below, the cumulative length of stone rows and live fences would have an effect on about 100,000 ha, or 7% of the total cultivated area in southern Mali. We have to be careful with these figures: the effectiveness and length of live fences is overestimated because part of the fences are of poor quality or dead, while other erosion control measures are not included in this figure.

Some SWC specialists disagree that barriers as far apart as 125 meters would be sufficient to protect fields from soil erosion. Others will argue that no erosion control is needed on slopes up to 2%. From our own observations we judge that widely spaced line interventions combined with cultivation perpendicular to the slope reduce run off and soil erosion to acceptable levels on fields with slopes of 1-2 %.

According to the M&E Unit of 2002, erosion control measures had been installed in 94% of the villages, by 46% of farmers and in 15% of the fields.

The total money spent by the Dutch donor (the main donor to the SWC program) can be compared with the number of targeted villages, the number of farmers who adopted erosion control measures and the number of hectares of land ‘protected’ by erosion control measures. From 1986 to 1999, about €7,300,000 was spent on the SWC program. This corresponds with about €2,900 per village, for the 2400 villages targeted between 1986 and 1999. It also corresponds with about €74 per farm family, for the 46% of the 214,000 farm families that adopted erosion control measures in 2002. Assuming that about 100,000 ha was ‘protected’ from soil erosion in 2002, about €73 was spent by the Dutch donor per ha. These figures are only very general indications: we did not include money from other donors (e.g. the German DED), money from the CMDT from cotton revenue, or investments by farmers, nor did we take into account the adoption of other measures (composting, fodder crops, etc.).

5.4.2 Diffusion of SWC measures to untargeted villages

In 1994, adoption in the targeted villages was on average 2.5 times higher than in untargeted villages. For farmers in untargeted villages, seeing erosion control measures in targeted villages was an important information source (Table 5.2). This effect was more pronounced in Koutiala region, where the SWC program started and where targeted villages were more numerous and ‘older’. Targeted villages were not such an important information source for composting techniques (Giraudy et al., 1996). The role of targeted villages in the diffusion of SWC information will have increased since 1994, because their number increased from 711 in 1994 to 2562 in 2000.

M&E data from 1997 to 2002 show that the difference in adoption between targeted villages and untargeted villages gradually disappears (Figure 5.4). (Note: Every year, some of the sample villages changed, resulting in fluctuating figures over time.) This confirms the impact of the extension approach followed. General extension workers and neighbouring targeted villages have a positive effect on untargeted villages. Another reason for the reduced difference is that the SWC village teams in targeted villages became less active. According to the fieldwork in 2000, farmers in untargeted villages started installing erosion control measures about a year later than farmers in targeted villages in the same district.

Table 5.2. Farmers' knowledge about SWC measures in untargeted villages.

SWC measure	% Farmers who had heard about measure	% Farmers who had first seen measure in targeted village
Live fences	47%	31%
Grass strips	5%	3%
Stone barriers	34%	27%
Crop residue barriers	26%	17%
Compost pits	19%	5%
Improved cattle pens	14%	5%

Source: 41 villages southern Mali, 1994 (adapted from Giraudy et al 1996)

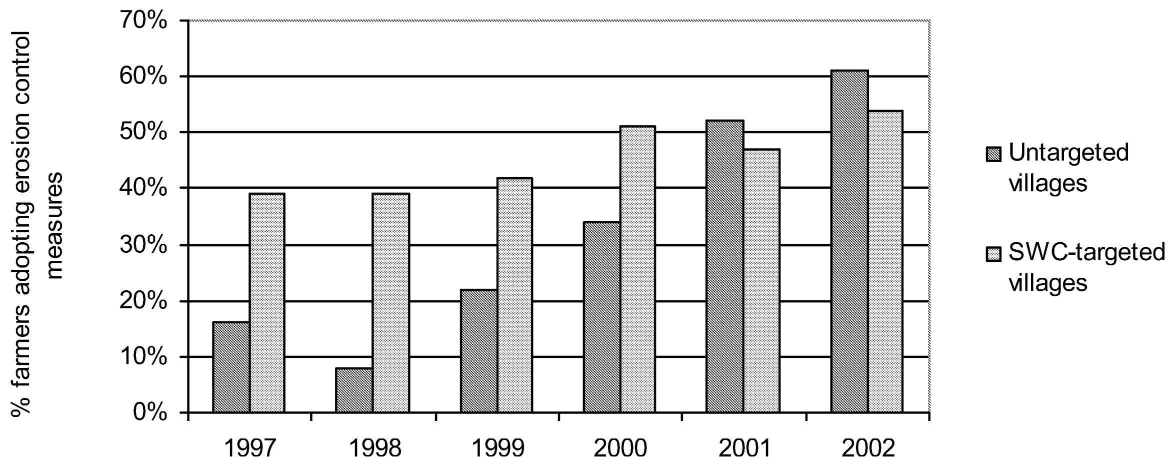

Figure 5.4. Farmer adoption of erosion control measures in SWC-targeted villages and untargeted villages, in southern Mali between 1997 and 2002.

Note: differences in adoption up to 2000 were significant; differences in 2001 and 2002 were not significant. Source: M&E data 1997-2002

Farmers who adopted erosion control measures more often made compost (M&E data 2002; Pearson 2-tailed correlation: 0.188, Sig.: 0.000). When we consider only cotton fields from farmers who produced compost and who adopted erosion control measures, we find a similar correlation at the field level: farmers preferred to apply compost on fields protected against erosion (Pearson 2-tailed correlation: 0.133, Sig.: 0.016).

5.4.3 Continuing adoption of SWC measures

The extension approach aimed at sustained adoption after the cessation of external support. However, during project planning it was not expected that the CMDT would have to pull out of rural development activities and would have to reduce its extension staff. As noted in the previous sections, adoption continued steadily until 2003. We assume that whether farmers intend to install erosion control measures is determined by the effective information about the erosion control measures, the availability of materials needed, and the perceived costs and benefits. For initial adoption (for current non-adopters to consider adoption), information and available materials would be more important, while for sustained adoption (for current adopters to consider installing more), experienced benefits and the costs / benefits ratio would be more important (Marra et al., 2003). Adoption not only influences the effective information about erosion control measures, but also the availability of materials needed for erosion control. The availability of stones, at an acceptable distance, will decrease, while the availability of planting material will increase. So, even without considering the costs, we expect a shift from the use of stones to the use of plants.

In 2000, farmers were asked about their plans to install erosion control measures, as an indication of adoption without external support. Indeed, live fences was the most adopted measure and was the measure most farmers (including those that had not yet adopted) said they planned to install (Table 5.3). The availability of Euphorbia and Jatropha planting material did not seem to be a constraint. On the other hand, only few farmers planned to install stone rows, although many farmers had installed stone rows collectively before.

Table 5.3. Current adoption and intentions to install erosion control measures (in % farmers), comparing non-adopters (i.e. farmers that had not (yet) adopted) and adopters, in southern Mali in 2000.

	Current adoption [a]	Intention to install (% Farmers)	
	(% Farmers)	Current non-adopters	Current adopters
Live fences	53	60	86
Stone rows [b]	42	18	34
Grass strips	15	23	78
Contour marker ridges	4	10	64
Stone check dams	40	22	69
Crop residue check dams	10	21	77

Source: Fieldwork 2000. In the sample of 298 farmers, SWC adopters were over-represented.
[a] Adoption includes erosion control measures present above the visited field.
[b] Includes collective stone rows above the cultivated area.

In 2003, farmers ranked the erosion control measures in order of ‘costs’ (i.e. the effort and time needed for installation) and in order of ‘benefits’ (i.e. the positive effect on crops), and indicated their plans to install erosion control measures on the visited field (Table 5.4). The farmers interviewed in 2003 showed a similar preference for erosion control measures to the farmers interviewed in 2000: live fences were planned most often, followed by crop residue barriers and grass strips.

In an ordinal regression, we related the plans of 2000 and 2003 to: 1) whether the farmer was an adopter (i.e. had already adopted that particular measure) or non-adopter (i.e. had not yet adopted that particular measure); 2) overall adoption; 3) costs; and 4) benefits. Generally, there were more adopters who intended to continue installation than there were non-adopters who intended to start installation. There was little difference between adopters and non-adopters in their preference for erosion control measures. Plans were strongly determined by actual adoption, followed by perceived costs, notably for non-adopters, but plans were not determined by perceived benefits. This was particularly the case for stone rows, which scored high in both costs and benefits but which few farmers planned to install. There was less adoption of erosion control measures made from stones or earth, because of their high labour requirements.

Table 5.4. Erosion control measures ranked in order of costs and benefits, compared with the actual adoption and planned installation (in % of fields), in Koutiala in 2003.

Costs (1: highest)		Benefits (1: most)		Adoption (% fields) [a]	Actual	Planned
1	Stone row	1	Stone rows	Live fences [b]	32%	48%
2	Drainage canal	2	Protection dike [b]	Crop residue barriers [b]	13%	11%
3	Protection dike [b]	3	Live fences [b]	Protection dike	9%	4%
4	Stone barrier	4	Grass strips	Stone row	7%	5%
5	Protection of plateau	5	Cultivation perp. slope	Drainage canal	7%	2%
6	Crop residue barrier [b]	6	Protection of plateau	Stone barrier	7%	7%
7	Live fences [b]	7	Drainage canal	Grass strip	5%	9%
8	Grass strips	8	Crop residue barriers [b]			
9	Cultivation perp. slope	9	Stone barrier			

Source: Group interviews 6 M&E villages, Fieldwork Koutiala, 2003

[a] Farmers were not asked about the planned direction (vis-à-vis slope) of cultivation;

[b] Live fences, protection dikes and crop residue barriers include line and gully interventions.

Note: actual adoption and plans are expressed in % of fields and cannot be compared with adoption and plans expressed in % of farmers in Table 5.3.

Farmers indicated how a change in the prices of cotton, fertiliser or hired labour would affect their adoption of erosion control measures and compost production. Increased cotton and fertiliser prices would strongly increase SWC adoption. A lower cotton price would discourage adoption of SWC measures. A lower fertiliser price would not really affect SWC adoption; only a few farmers would invest less effort in compost making. The effect of the price of hired labour on adoption was not clear. Most farmers do not hire labour to install SWC measures, but some ask someone with donkey cart to transport compost. In some cases this transport is paid for in cash, but in many cases it is not. When asked what would happen when unemployed young men returned from town to their village, the farmers said they expected that SWC adoption would increase because of greater availability of labour, not because of lower prices for hired labour.

Since 2000, extension has decreased and training in SWC has stopped. Planting materials, tools and special credit for SWC are no longer supplied. However, during the interviews, farmers indicated that they would continue the installation of SWC measures and there are no indications of farmer dependence on the SWC program. SWC measures have been incorporated into farm practices and are of direct economic value to rural families who depend greatly on land resources.

5.5 Conclusions

After answering the three research questions about the effect of SWC approach on adoption, we will discuss a few more general aspects about the project lifespan, sustainability and cost-effectiveness.

(1) In the villages targeted by the SWC program, farmers were most active in the year of training and steadily continued land management programs in subsequent years. The use of a village approach involving a large number of farmers gave adoption a head start. The use of simple measures and the distribution of planting materials, plus the transfer of diagnosis and planning skills to an 'SWC village team' assured the continuation of adoption in the years after SWC training. To target new villages, farmers still recommend most of the elements of the SWC extension approach. The institutionalisation of the SWC program in the Malian extension service involved 45 SWC specialists and about 650 general extension workers and made it possible to train farmers in 2500 villages, about half the villages in southern Mali, between 1986 and 2000.

(2) SWC measures gradually diffused to villages that were not directly targeted by the SWC program and, as a consequence, the difference in adoption between targeted and untargeted villages decreased over the years. The simple SWC measures were easy to copy and farmers in untargeted villages did not depend on external support and did not expect to receive incentives. Because all extension staff was involved in the SWC program, 'informal' information on SWC eventually reached all villages. The targeted villages were deliberately spread out systematically over southern Mali, to serve as examples for farmers in neighbouring untargeted villages. In terms of the overall adoption in targeted and untargeted villages, erosion control measures had been installed in 94% of the villages, by 46% of farmers and in 15% of the fields in southern Mali by 2002.

(3) Adoption continued steadily even after external donor support had gradually been withdrawn between 1998 and 2001 and the Malian extension service had ceased SWC extension activities in 2002. In 2003, farmers intended to continue the installation of erosion control measures. The choice of erosion control measures depended on the specific situation of the field and the erosion problem. Generally, farmers preferred live fences that are easy to install and for which planting materials are abundantly available. There are no signs of a farmer dependence on the SWC program or a decrease in adoption of SWC measures.

A SWC program aiming at large-scale adoption takes time. The various steps between the development of a SWC approach, training extension staff, training farmers, installation of SWC measures, positive effects of SWC measures and diffusion to untargeted villages each take up to several years. The SWC program in southern Mali received donor funding for over 14 years. The program's impact on adoption of SWC measures is due to this long-term support.

Returning to the aspects of project sustainability described in the introduction, we have observed that policies of the Malian government and donors did not allow the extension service to continue the SWC program and that other actors have not (yet) taken over the role of CMDT. The SWC village teams were not yet sufficiently strong and integrated in the village organizations to continue collective SWC activities. However, the choice of techniques, the extension methods and the limited dependence on external incentives made it possible for individual farmers to continue adopting and applying SWC measures.

The sustainability of the SWC project strongly influences the impact and cost-effectiveness of the donor support. The initial high investments (in development of SWC training modules, capacity building of extension service) bore fruits later, when with relatively modest operational costs, large numbers of farmers were assisted. This time lag makes it difficult to calculate donor costs per targeted village. Considering only the early period 1986-1992 and dividing the high investment costs among the modest number of targeted villages, we find the astronomical sum of €17,000 per village. By contrast, considering the later period 1996-1998 and dividing the modest operational costs among the high number of targeted villages, we find the modest amount of €1,350 per village. There are two more reasons, not presented in this paper, why a longer involvement of extension is desirable. The first reason is to improve the quality and effectiveness of the erosion control measures. Measures installed recently by untrained farmers are often of poor quality and this will be improved by continued SWC extension. A second and even more important reason is to broaden natural resources management (NRM) of which SWC is only a part. Between 1986 and 2002, several other NRM activities evolved from action research to pilot extension but they have not yet reached the stage of large-scale adoption. From an NRM point of view, the political decision to dismantle the extension service is a destruction of capital.

To ensure high initial farmer adoption, the design of an SWC project should include intensive project support during the pilot and extension phases, while at the same time the implementation modalities chosen should anticipate project withdrawal for sustained farmer adoption.

After this chapter, which presented the effect of project approach on farmer adoption, the following chapter will include also other factors influencing farmer adoption of SWC.

Chapter 6

Factors Influencing Adoption of Soil and Water Conservation Measures in Southern Mali

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6 Factors Influencing Adoption of Soil and Water Conservation Measures in Southern Mali

Abstract

A soil and water conservation (SWC) extension programme, promoting erosion control measures and soil fertility measures, has been going on in southern Mali since 1986. Five factors that influence farmer adoption of SWC measures were analysed: land pressure, cotton-growing area, possession of ploughing equipment, possession of a donkey cart and farmer training in SWC. Interviews were carried out with 298 farmers and two to three fields per farmer were visited, in 30 representative villages and 30 villages with high SWC adoption. Correlation, regression and factor analysis led to the following conclusions:
1. Farmers in the high land-pressure area adopt more soil fertility measures.
2. Farmers in the cotton-growing area adopt less SWC measures.
3. Farmers with more ploughing equipment adopt more SWC measures.
4. Farmers with a donkey cart adopt more soil fertility measures.
5. Trained farmers adopt more erosion control measures.

There is a strong correlation between the adoption of erosion control measures and soil fertility measures that could not be explained by these five factors only. This suggests that there are additional factors that trigger the adoption of SWC measures.

Key words: SWC adoption; erosion control; soil fertility management; agroecological area; farm equipment; SWC training; SWC village team; southern Mali

6.1 Introduction

After 20 years of soil and water conservation (SWC) activities in southern Mali, an evaluation study is currently being undertaken to assess the impact of the SWC programme on adoption, crop yields and agricultural sustainability in order to make recommendations on policies and to develop a monitoring and evaluation system for SWC programmes.

6.1.1 Research area

The SWC programme is implemented by the Compagnie Malienne pour le Développement des Textiles (CMDT), the semi-government Malian cotton and rural development organization, and covers most of the cotton-growing area in southern Mali (Figure 6.1). This is an area of about 125.000 km2, with a population of 3 million people, of which 90% is rural, forming 190.000 farm families in 5000 villages. On average a farm family has 14 members.

Three agroecological areas can be distinguished:

1. The 'old cotton area' in the centre and east with 700–1000mm rainfall, loamy-sand soils, formed on fragile sandstone, resulting in very gentle slopes (on cultivated fields 0–2%). Population density in this old cotton area is 37 persons km^{-2}. Agriculture has become permanent: for each hectare of cultivated land, less than 1 ha of fallow land is still available. The great majority (83%) of farm families has at least one plough and two oxen and 68% have a donkey cart. The cultivated area per person is on average 0.75 ha.
2. The 'non-cotton area', northeast of the old cotton zone, used to be suitable for cotton until the early 1980s when the average annual rainfall dropped below 700 mm. Soils and landscape are similar to those of the old cotton area. Population density and possession of farm equipment are lower than in the old cotton area, but land pressure is high due to low productivity. This small ex-cotton area remained assisted by the CMDT extension service.
3. The 'new cotton area' in the southwest and west, with 900–1200mm rainfall, loamy-sand soils formed on schist and granites, resulting in somewhat steeper slopes (on cultivated fields 0–5%). Due to the presence of tsetse fly in the past, which is still a problem for cattle, population density is remains low: 18 persons km^{-2}. Rotational fallowing is common: for each hectare of cultivated land, more than 2 ha of fallow land are available. About 60% of the farm families have at least one plough and two oxen and 45% have a donkey cart. The cultivated area per person is 0.41 ha (Hijkoop et al., 1991; Schrader and Wennink, 1996; CMDT, 2000a).

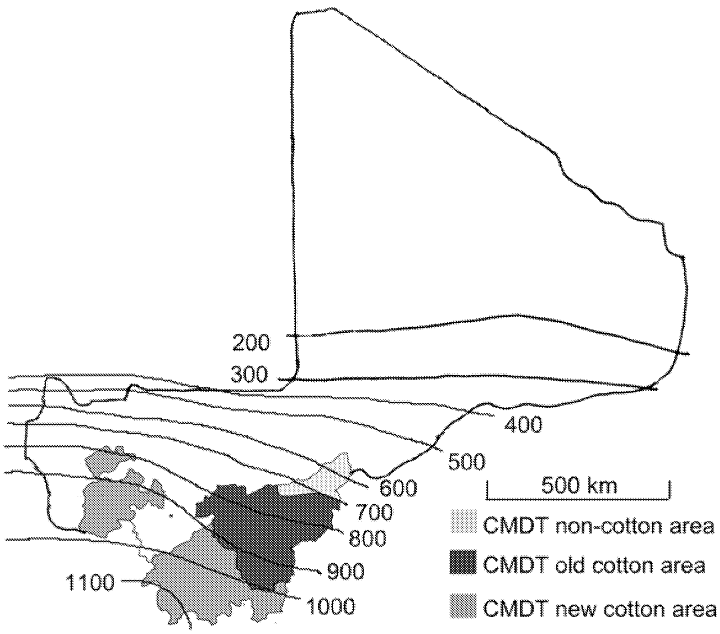

Figure 6.1. The 3 CMDT areas and rainfall isohyets (mm yr^{-1}) in southern Mali
Source: after Schrader and Wennink, 1996; CMDT Rainfall data 1991-2001.

The major crops in the cotton area are cotton (Gossypium hirsutum) (30%), sorghum (Sorghum vulgare) (27%), millet (Pennisetum glaucum) (15%), maize (Zea mays) (14%) and groundnuts (Arachis hypogea) (5%) (CMDT, 2000). Cotton, which receives fertilizers, is the main cash crop, grown in rotation with staple food crops that benefit from the residual fertilizer effects. In the non-cotton area, mainly millet, sorghum and groundnuts are grown, with very little chemical fertilizer use.

The average nutrient balances in the CMDT area have been estimated as being negative, especially for nitrogen and potassium. In the non-cotton-growing areas, crop rotations with only cereals receive less fertilizer and show more negative nutrient balances than crop rotations with cotton (Van der Pol, 1991). Recent estimates show that balances have become less negative, due to the increased area under cash crops receiving fertilizers and the increased use of compost from crop residues and manure (Doucouré and Healy, 1999; CMDT, 2002).

On cultivated fields, the run-off coefficient is between 14 and 50% depending on rainfall intensity. Sheet and rill erosion is estimated to lead to an average annual soil loss of 5–11 t ha^{-1} (Roose pers. comm. cited in van der Pol, 1991; Vlot and Traoré, 1994).

6.1.2 The SWC programme

Since 1982, the Malian farming systems research group Division de Recherche sur les Systèmes de Production Rurale (DRSPR) has tested SWC approaches. Following complaints by farmers about decreasing yields and water washing away their crops, trials were carried out in 1984 in collaboration with the CMDT. This resulted in the creation of the SWC project (Projet Lutte Anti Erosive) within the CMDT structure in 1986.

Tests in Mali and comparisons with other SWC programmes in the region made the project opt for a specific approach, with the following features:

- A village rather than an individual approach.
- Techniques increasing water infiltration rather than evacuation of excess water.
- Simple low-cost techniques.
- Incorporation in a permanent local extension system (Hijkoop et al., 1991).

The CMDT Rural Development Programme, including the SWC programme, was paid by revenues from cotton export, and contributions from the Mali government and from several donors. Farmers did not receive incentives to compensate for their labour input. However, farmers received planting materials and water-level instruments for free, and ox carts and wire fence on credit, during the start-up period (Vlaar, 1992; Schrader and Wennink, 1996).

The SWC measures can be split up into three categories: erosion control line barriers, erosion control gully barriers and soil fertility improvement measures.

(1) The erosion control line barriers (EC line) used are:

- live fences, planted on field boundaries;
- stone rows, mostly installed collectively, above the cultivated area;
- grass strips, planted within fields;
- contour marker ridges, within fields, were introduced later, from 1997;
- water evacuation dikes, above the field, were abandoned after the first project years.

(2) The erosion control gully barriers (EC gully) used are:

- stone check dams;

- crop residue check dams.

(3) The soil fertility improvement measures (SF) used are:

- compost pits;
- improved cattle pens, where crops residues are mixed in with the cow dung.

Two phases in training activities can be distinguished:

(1) First, the whole village is involved in a general EC awareness programme, after which (at least) five voluntary young farmers form a village EC team. This team receives a thorough training and helps other farmers with EC in their fields. Although the accent lies on EC, the SF aspects are being discussed as well. From 1986 to 2000, an EC village team was trained in about 50% of the villages.

(2) The second step is the additional training in SF management with an accent on improved cattle pens and compost pits. Villages are chosen where an EC village team has already been installed, but farmers are trained directly without the EC village team as intermediate contact group. About 25% of the total number of villages has received the additional SF training.

Most of the other 50% of the villages that have not received any of the two formal training sessions are indirectly informed by trained farmers from neighbouring villages. Farmers in those villages are helped less intensively by the regular extension worker, often on an individual basis (Giraudy et al., 1996; CMDT, 2002).

6.1.3 Hypotheses

About 38% of the farm families had introduced some EC measures by 2001 that were almost non-existent before the SWC programme started in 1986. About 72% of the farm families produced compost of some sort in 2001, including traditional practices such as traditional cattle pens and waste heaps that were already common before the SWC programme started (CMDT, 2001; CMDT, 2002). However, there is a large variation in adoption of such measures between areas and villages and even between farmers in the same village.

In an attempt to explain this variation in adoption rates, the following hypotheses on five factors influencing adoption were tested, grouped under the three headings.

Agroecological conditions, represented by the two factors

(1) Land pressure: farmers in the north, where agriculture is more permanent, have fewer possibilities to ‘escape’ from declining soil fertility than farmers in the south, where rotational fallowing is still common. Farmers in the more densely populated area are therefore more likely to invest in SWC measures.

(2) Cotton area: cotton-growing farmers derive more benefits from agriculture and will invest more in SWC than the non-cotton-growing farmers in the most northern villages.

Availability of farm equipment, consisting of the two elements

(1) Ploughing equipment: farm families who possess more ploughing equipment are generally larger, cultivate more land and are wealthier. They often lend out ploughing equipment to other families, often in return for money or labour (CMDT, 2000a). Therefore, these better-equipped families prepare their fields earlier and have more time and money available to invest in SWC.

(2) Donkey cart: farmers who have a donkey (or horse) cart can transport stones, plant material, crop residues and compost more easily, which facilitates SWC activities.

Exposure to SWC training sessions

(1) Farmers in villages with an EC village team adopt more SWC measures. Farmers that have attended the additional SF management training adopt even more SWC measures.

6.2 Methods

In order to test the hypotheses, use was made of two agroeconomic surveys, with a different sample size:

(1) One representative sample was taken of 82 farmers (in 30 villages), out of the regular sample used by the CMDT Monitoring and Evaluation Unit.

(2) One selective sample was taken of 216 farmers in 30 other villages with high SWC adoption. The reason for this selective sample was to have more yield data from fields with SWC measures (these yield data are not discussed in this paper). This selective sample leads to higher adoption percentages than the actual average for southern Mali.

A total of 298 farmers in 60 villages were interviewed and 841 fields were visited (two or three fields per farmer) in 2000. From each farmer, among other things, the following information was collected on the adoption:

- EC measures installed: stone rows, live fences, grass strips, crop residues strips, stone check dams, crop residue check dams, contour marker ridges and water evacuation dikes.
- Quality and maintenance of EC measures: what percentage of EC line interventions was intact and had EC structures been maintained since installation.
- SF measures installed: compost pits and improved cattle pens.
- Intentions: did farmers intend to install SWC measures in the future.

The following information was collected that could explain adoption:

- Land pressure: how many years had the fields been under cultivation since the last fallow or clearing.
- Cotton area: did the annual rainfall in most years allow the growth of cotton in the village or not.
- Ploughing equipment: did the farm family have a plough and oxen.
- Donkey cart: did the farm family have a donkey (or horse) cart.
- Training received: was there a trained EC team in the village and had the farmer participated in the additional individual training in SF management.

Various analyses were undertaken, of which the following are presented in this paper. First, different levels of adoption are described, distinguishing first installation, completion, maintenance, quality and intentions to continue in the future. Then, the effect of each factor on adoption (first installation) of all SWC measures is presented, varying one influencing factor at the time: land pressure, cotton growing, ploughing equipment, donkey cart and SWC training. Thereafter the correlations and two-way interactions between different influencing factors are assessed in order to determine what model should be used to test the effects of influencing factors. The relative importance of each factor is analysed in a linear additive model with all five factors where those that are non-significant are removed one by one from the model. The statistical significance derived from this analysis is presented in the tables for each influencing factor.

6.3 Results

6.3.1 Different levels of adoption for two EC measures and SF measures

The live fences and stone rows are taken as examples to show the different levels of adoption of EC measures: non-adoption, first installation, completion and maintenance in subsequent years. A complete live fence is at least as long as the field width. Stone rows are complete if all rows that were planned (two or three) are actually installed. The intention or plans for further installation (either to protect the same field or other fields) can be added as last level of adoption.

The different levels of adoption for live fences and stone rows are shown in Figures 6.2 and 6.3, varying from non-adoption (on the left) to complete and maintained structures (on the right). The dark, lower part of each bar represents farmers who plan to install live fences or stone rows in the future, while the clear upper part represents farmers who do not have such plans.

Only a minority of the adopters have SWC structures that are complete and maintained: 13% for live fences and 16% for stone rows.

There are a number of differences between the adoption of stone rows and live fences: Not only is the actual adoption of live fences higher than the adoption of stone rows, 54% against 43%, also many more farmers (non-adopters and adopters) intend to install (or to continue installing) more live fences than stone rows in the future: 77% against 26%. Among the adopters, live fences are less complete (19% out of 54%) than the stone rows (23% out of 43%), which means that there are many short live fences that do not cover the width of the field.

Not indicated in Figures 6.2 and 6.3, is the quality of the SWC structures, which forms another difference. Stone rows are more intact (87%) than the live fences (64%). Once installed, stone rows hardly need any maintenance while live fences do. Another reason for the lower quality of live fences is the fact that farmers not only plant live fences to control erosion but also to demarcate their fields.

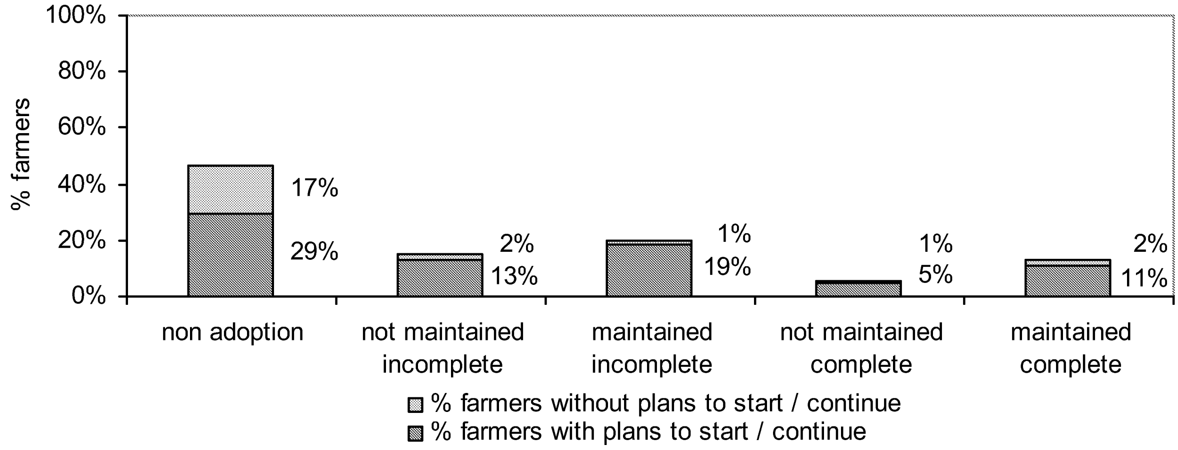

Figure 6.2. Different adoption levels of live fences in southern Mali (in percentages of farmers).

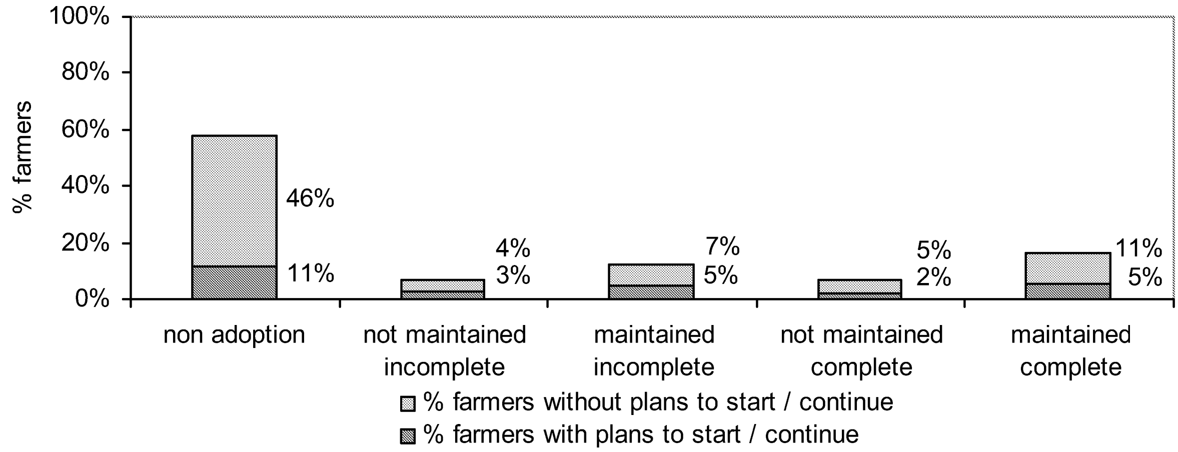

Figure 6.3. Different adoption levels of stone rows in southern Mali (in percentage of farmers).

For the SF measures, we asked adopters whether they were still using them after the initial installation. Nearly all (97%) of the adopters of compost pits and 100% of the adopters of improved cattle pens had used them in the 1999–2000 season. However, the 'quality' of the compost made in improved cattle pens is not according to the recommendations: on average only four carts of crop residues are added per cow per year while the recommended rate is 8 in the northeast and 12 in the southwest. In the results that follow, the adoption presented refers to farmers who have simply installed one measure, regardless of continuation, completion, maintenance, quality or future plans.

6.3.2 Agroecological area: land pressure and cotton area

Land pressure is determined here by the number of years the visited fields have been under continued cultivation since last clearance or fallow. For each village, the average land pressure of the visited fields was classified as follows: 'extensive' represents land under cultivation less than 10 years, ‘moderate’ under cultivation for 10–15 years, ‘intensive’ under cultivation for 15–20 years and ‘very intensive’ under cultivation for more than 20 years (Table 6.1). In areas with a high land pressure farmers adopt more SWC measures, and especially SF measures. The availability of enough fertile fallow land in the south reduces the need for SWC measures. The exception are stone check dams which are more often adopted by farmers in low land-pressure areas. This can be explained by the steeper slopes and more visible gullies and rills in areas in the southwest, where the land pressure is relatively low.

Table 6.1. Effect of land pressure on adoption of SWC measures in southern Mali

		Extensive (<10 yr)	Moderate (10-15 yr)	Intensive (15-20 yr)	Very intensive (>20 yr)	Overall	Significance
	Number of farm families	51	76	85	63	275	
EC line	% With live fences	43%	46%	60%	63%	53%	ns
	% With stone rows	22%	53%	48%	40%	42%	ns
	% With grass strips	8%	14%	9%	30%	15%	*
	% With contour marker ridges	2%	0%	2%	5%	4%	ns
	% With evacuation dikes	0%	0%	9%	2%	3%	*
EC gully	% With stone check dams	45%	51%	39%	29%	40%	*
	% With crop residue check dams	4%	17%	8%	13%	10%	ns
SF	% With compost pit	41%	76%	62%	83%	67%	*
	% With improved cattle pen	6%	34%	31%	56%	35%	**

Significance: ns non-significant; * p<0.05; ** p<0.01.

Table 6.2. Effect of cotton growing on the adoption of SWC measures in South Mali

		Non-cotton-growing area	Cotton-growing area	Overall	Significance
	Number of farm families	42	256	298	
EC line	% With live fences	69%	51%	53%	*
	% With stone rows	43%	42%	42%	ns
	% With grass strips	14%	15%	15%	ns
	% With contour marker ridges	7%	3%	4%	*
	% With evacuation dikes	0%	4%	3%	ns
EC gully	% With stone check dams	31%	41%	40%	ns
	% With crop residue check dams	17%	9%	10%	ns
SF	% With compost pit	81%	64%	67%	*
	% With improved cattle pen	31%	36%	35%	ns

Significance: ns non-significant; * p<0.05.

There does not seem to be a positive effect of cotton growing on the adoption of SWC (Table 6.2). The fact that farmers in the non-cotton-growing area are generally poorer, less well equipped and cultivate in a relatively flat and dry area, does not decrease SWC adoption. On the contrary, they adopt more live fences, contour marker ridges and compost pits.

6.3.3 Farm equipment: ox-ploughing and donkey cart

On the basis of the availability of ploughing equipment, farm families are classified in three groups: those not possessing one complete set, consisting of one plough and two oxen, those possessing one complete set and those possessing two or more complete sets.

Farm families with more ploughing equipment adopt more SWC measures, especially more stone rows, grass strips and improved cattle pens (Table 6.3). This could be due to their higher availability of time and money to invest in SWC.

Table 6.3. Effect of ploughing equipment on adoption of SWC measures in southern Mali

		No complete set	At least 1 set	At least 2 sets	Overall	Significance
	Number of farm families	31	128	131	290	
EC line	% With live fences	42%	50%	60%	53%	**
	% With stone rows	26%	36%	53%	42%	**
	% With grass strips	3%	11%	23%	15%	**
	% With contour marker ridges	0%	5%	3%	4%	ns
	% With evacuation dikes	3%	1%	6%	3%	ns
EC gully	% With stone check dams	35%	36%	47%	40%	ns
	% With crop residue check dams	10%	8%	13%	10%	ns
SF	% With compost pit	55%	63%	75%	67%	*
	% With improved cattle pen	6%	27%	50%	35%	ns

Significance: ns non-significant; * $p<0.05$; ** $p<0.01$.

Table 6.4. Effect of donkey cart on adoption of SWC measures in southern Mali

		Without cart	With cart	Overall	Significance
	Number of farm families	49	249	298	
EC line	% With live fences	47%	55%	53%	ns
	% With stone rows	33%	44%	42%	ns
	% With grass strips	2%	18%	15%	ns
	% With contour marker ridges	4%	4%	4%	ns
	% With evacuation dikes	2%	4%	3%	ns
EC gully	% With stone check dams	43%	39%	40%	ns
	% With crop residue check dams	4%	11%	10%	ns
SF	% With compost pit	37%	73%	67%	**
	% With improved cattle pen	6%	41%	35%	ns

Significance: ns non-significant; ** $p<0.01$.

Most farmers have a donkey (or horse) cart. There seems to be a minor effect on the adoption of EC measures and a major effect on the adoption of SF measures, which need transportation of crop residues, cow manure and compost (Table 6.4).

6.3.4 Training

Three levels of training are distinguished: farmers in villages without an EC village team, farmers in villages where an EC village team is installed and trained, and farmers in villages with an EC village team who have also attended the additional training on SF management.

The installation and training of an EC village team increased adoption of erosion control measure and soil fertility measures (Table 6.5). Water evacuation dikes, a traditional measure, were discouraged some years after the programme had started, thus a lower adoption is found in trained villages. The additional SF training increases adoption of both EC and SF measures, but its effect is less pronounced than the effect of the EC village team.

Table 6.5. Effect of EC training on adoption of SWC measures in southern Mali

		No training	EC team	EC team + SF	Overall	Significance
	Number of farm families	25	163	107	295	
EC line	% With live fences	44%	55%	55%	53%	ns
	% With stone rows	8%	40%	53%	42%	**
	% With grass strips	4%	13%	21%	15%	ns
	% With contour marker ridges	0%	5%	3%	4%	ns
	% With evacuation dikes	12%	2%	3%	3%	ns
EC gully	% With stone check dams	8%	38%	50%	40%	**
	% With crop residue check dams	0%	12%	10%	10%	ns
SF	% With compost pit	48%	67%	73%	67%	ns
	% With improved cattle pen	16%	34%	43%	35%	ns

Significance: ns non-significant; ** p<0.01.

6.3.5 Correlation and interaction between factors influencing adoption

Positive and negative correlations between factors influencing adoption are presented in Table 6.6.

- There are significant correlations between the five factors influencing adoption.
- Land pressure is relatively high in the non-cotton area in the northeast, especially compared with the new cotton area in the southwest. However, within the cotton-growing area, the higher the land pressure, the more ploughing equipment and donkey carts farmers have.
- In the non-cotton area, farmers have less ploughing equipment.
- Farmers with more ploughing equipment more often have a donkey cart as well.
- There is no correlation between training and any other factor except a weak positive correlation between training and the possession of donkey carts. This could be explained by the fact that during a certain phase of the SWC programme, additional credits for donkey carts were given in villages with training activities.

Table 6.6. Positive and negative correlations between factors influencing adoption in southern Mali

	Land pressure	Cotton area	Ploughing equipment	Donkey cart	Training
Land pressure		--	++	++	
Cotton area	--		++		
Equipment	++	++		++	
Donkey cart	++		++		+
Training				+	

Significance: +, - p<0.05; ++, -- p<0.01.

6.3.6 Interaction between the adoption of EC measures and SF measures

The five factors (land pressure, cotton area, ploughing equipment, donkey cart and training) explain only part of the variation in adoption of EC measures (11%) and SF measures (23%). The correlation between the number of EC measures and the number of SF measures adopted is significant (Pearson correlation: 0.325). So the number of EC measures adopted is more determined by the number of SF measures adopted, and vice versa, than by any of the five factors tested.

6.4 Discussion

Adoption of SWC measures in the non-cotton-growing area covered by the SWC programme is perhaps surprisingly high. This area has had additional assistance, to compensate for the lower farm income, in the form of longer credit refund periods for improved cattle pen materials (5 years instead of 3 years) and subsidised donkey cart credit facilities. However, to the north, outside of the CMDT area, the area is much less developed and the adoption of SWC measures is very low.

There is a tendency to overemphasize the effect of ploughing equipment on adoption because the better equipped farm families are larger and cultivate more land: families with at least two sets of ploughing equipment consist of 26 persons and cultivate 17 ha on average; families without one complete ploughing set consist of only 9 persons and cultivate 4 ha on average (CMDT, 2000a).

The effect of SWC training, when simply comparing ‘formally trained’ and ‘formally untrained’ farmers, is underestimated because of ‘informal training’ of untrained farmers. Untrained farmers get information and assistance from other farmers from neighbouring villages and by the local extension worker.

The effect of SF training, when compared with the actual adoption by trained and untrained farmers, was not significant. However, when analysing relations in time between the year of training and the year of adoption the effect of training becomes more evident: adoption by trained farmers very often takes place in the same year or in the year following the SF training, indicating the effect of training.

An interesting aspect is the combined adoption of both EC and SF measures by the same farmers, which could not be explained sufficiently by the five factors considered in this study. It is possible that there is either a farmer characteristic triggering both adoption of EC and adoption of SF measures, such as being innovative, intelligent or SWC aware, or that the adoption of one measure triggers the adoption of the other. Another reason could be the dedication of extension staff that goes beyond the training sessions considered in this study: the initial awareness meetings, regular follow up visits, and planning and evaluation meetings.

6.5 Conclusions

High land pressure in the north-eastern area decreases the possibility of including rotational fallow in order to restore the soil organic matter content. Farmers have responded to this problem by adopting improved cattle pens and compost pits as measures to increase soil fertility.

The traditional water evacuation dikes and grass strips are found more often in high land-pressure areas, where SWC awareness is generally greater. However, stone check dams are found less often in this relatively flat area with fewer gullies and rills than in the south-eastern low land-pressure area.

Farmers in the most northern non-cotton-growing area adopt more live fences, contour marker ridges and compost pits. The lower income of these farmers caused by the absence of cotton does not discourage adoption of SWC measures. These farmers are in a difficult situation: rainfall limits crop yields so they need to maximize rainfall infiltration using SWC measures; they do not receive fertilizers on credit as cotton growers do and they cannot clear new fertile land, so they have to recycle the maximum amount of cow manure and crop residues.

Trying to explain SWC adoption by means of cost benefit analysis, it could be argued that by lack of alternatives their opportunity costs are lower than in the southern cotton-growing area.

Farm families with more ploughing equipment, at least two sets of ploughs with four oxen, adopt more stone rows, live fences, grass strips and improved cattle pens than families with less ploughing equipment. However, not too many conclusions should be drawn from the effect of this ploughing equipment because it correlates with family size and cultivated area.

Families possessing a donkey cart adopt more compost pits. The effect on the adoption of improved cattle pens is not significant. Because compost pits are adopted by all types of farmers, while improved cattle pens are mostly adopted by farmers with more ploughing equipment, the effect of donkey carts on improved cattle pen adoption is partly ‘captured’ by the strongly correlated possession of ploughing equipment.

Training, especially the installation and training of a village SWC team, increases adoption of EC measures. When looking at the situation in 1999–2000, the effect on SF measures was not significant.

Many other factors that may influence adoption have not been discussed in this paper. During the introduction phase of a new technology, the awareness, technical knowledge and availability of, for example, planting materials play an important role. After this introduction phase, farmers will undertake a form of cost benefit analysis and weigh the investments (mainly labour) for installation, maintenance and annual work against the improved crop yields and other possible benefits of the SWC measures.

Chapters 5 and 6 presented the effect of project approach and other factors on adoption of SWC. Chapter 7 looks suitable erosion indicators, needed to evaluate erosion control in Chapter 8.

Chapter 7

Soil Crusts and Deposits as Sheet Erosion Indicators in Southern Mali

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Soil Use and Management, in press

7 Soil Crusts and Deposits as Sheet Erosion Indicators in Southern Mali

Abstract

Rills are indicators of erosion, easily recognised by farmers and extension workers. However, they are rare on fields in Mali with slopes of 0 – 3%, even though runoff and sheet erosion may be a problem. The suitability as erosion indicators of three other soil surface features was therefore investigated: (1) structural crusts formed by rainfall impact without lateral soil movement; (2) *in situ* depositional crusts, formed by sedimentation leaving the finest particles on top; and (3) runoff deposits of fine and coarse sand, formed after the removal of finer particles. Feature 1) occurred on the elevated parts and ridges, whereas (2) and (3) occurred in lower parts and in furrows. Soil cover with a runoff deposit of coarse sand proved to be a suitable indicator and this was well explained by erosion risk: a 2% increase in slope related to a 9% increase in deposit cover. The extent of this deposit also related well to cotton yield from the previous season: a 30% increase in deposit cover was reflected in a 23% decrease in cotton yield. Only a few farmers confirmed that the deposits were produced by erosion. It is recommended that soil and water conservation programmes pay more attention to the presence of crusts and deposits.

Keywords: soil crusts, soil deposits, erosion, soil conservation, Mali

7.1 Introduction

Field manuals for assessment of land degradation and erosion damage often emphasise observations on gullies and rills (Herweg, 1996), although other indicators may be included (Stocking and Murnaghan, 2000). In areas where erosion rills and gullies are rare, runoff and sheet erosion may still be a serious problem but will be underestimated if no sheet erosion indicators are used. Additional erosion indicators are needed that can be related to erosion risk and crop yield. Such soil surface features could serve as useful indicators for runoff and erosion assessment in soil and conservation extension programmes.

Crusts have been classified in detail on micromorphological characteristics and on the lateral movement of soil particles (Casenave and Valentin, 1989; Valentin and Bresson, 1992). A structural crust quickly forms on a soil disturbed by tillage by the impact of rainfall with minimal lateral movement of soil particles. Once runoff starts transporting soil, deposits of sand are formed where runoff is slow enough for coarse particles to settle and fast enough to dislodge finer particles. Laminated deposits of sand alternating with seals of finer particles may form ‘runoff depositional crusts’. *In situ* depositional crusts, also called still depositional crusts (Valentin and Bresson, 1992), form in areas where water infiltrates and suspended finer particles settle. If loose particles are removed from such a structural crust, an erosion crust may result (Le Bissonnais et al., 1998).

The objective of the study described in this paper was to test indicators of sheet erosion, suitable for areas where rills are scarce or absent. Our hypotheses were that the sheet erosion indicators would correlate with erosion risk indicators (slope, rainfall and soil characteristics), crop yields, and also with the occurrence of erosion rills. The indicators developed had to be simple for extension workers and farmers to use when prioritising areas for erosion control and, ultimately, when evaluating the effectiveness of erosion control.

7.2 Materials and methods

The data on soil crusts, deposits and erosion rills presented in this study come from fieldwork done in 6 villages in the Koutiala region of southern Mali in 2003. Additional data on erosion rills were derived from fieldwork in 60 villages in southern Mali in 2000.

7.2.1 Southern Mali and Koutiala region

The study area in southern Mali is the part covered by the semi-government Malian cotton and rural development organisation (*Compagnie Malienne pour le Développement des Textiles, CMDT*) (Figure 7.1). In the area, annual rainfall varies from 1300 mm in the southwest to 700 mm in the northeast. The rainy season lasts from May until October. Altitude varies from 280 to 400 m above sea level. The dominant soil parent materials are sandstone in the central and eastern parts, and schist and granite in the southern and western parts. Crops are grown mostly on the glacis, situated between the plateau and valley bottom, which is relatively flat in the north and east (0 – 2%) and slightly steeper in the south and west (0 – 5%). The main crops are cotton (29%), sorghum (22%), millet (20%), maize (16%) and groundnuts (7%). Tillage is mostly by oxen and consists of ploughing only (60%) or harrowing followed by ploughing (12%). In other cases, the crop (often millet or sorghum) is directly sown on the old ridges (CMDT, 2003). On cultivated fields, the runoff coefficient is estimated at 20 - 40% resulting in an annual soil loss of 10 – 26 t ha^{-1} (Roose, 1985). Bishop and Allen (1989) measured an average soil loss of 10 t ha^{-1} yr^{-1} on cultivated fields, going up to 31 t ha^{-1} yr^{-1} in the most southern, steeper part of southern Mali.

Koutiala region is the old cotton zone in the east of southern Mali (Figure 1). Annual rainfall was about 650 mm in 2002 and 870 mm in 2003. The dominant parent material is sandstone. The glacis has a light-textured topsoil (48 – 77% sand, 17 – 45% silt, 6 – 8% clay) over a heavier-textured subsoil (20 –28% clay). Soils are mainly Lixisols and Luvisols according to the FAO classification (Keita, 2000). The topsoil has a low organic matter content (0.3 – 0.5% carbon) (Hijkoop et al., 1991; Keita et al., 1994; Bitchibaly et al., 1995). From field observations and interviews (unpublished) we established that in most fields (65%) the sowing direction was perpendicular to the ploughing direction and that most fields (65%) were sown in the same direction every year. Only farmers who are conscious of the erosion problem reduce the slope of tillage and sowing direction by ploughing and sowing every year across the slope, i.e. in straight lines parallel to the least sloping field boundary and not exactly following curved contour lines. Most crops are weeded at least twice, 3 – 4 weeks and 6 – 7 weeks after sowing. There may be a third weeding, but more often the fields are ridged about 8 – 9 weeks after sowing (CMDT, 2003). In cultivated 5m runoff plots, runoff coefficients of 7 – 14% and annual soil losses of 5 – 7 t ha^{-1} were found (Vlot and Traoré, 1994).

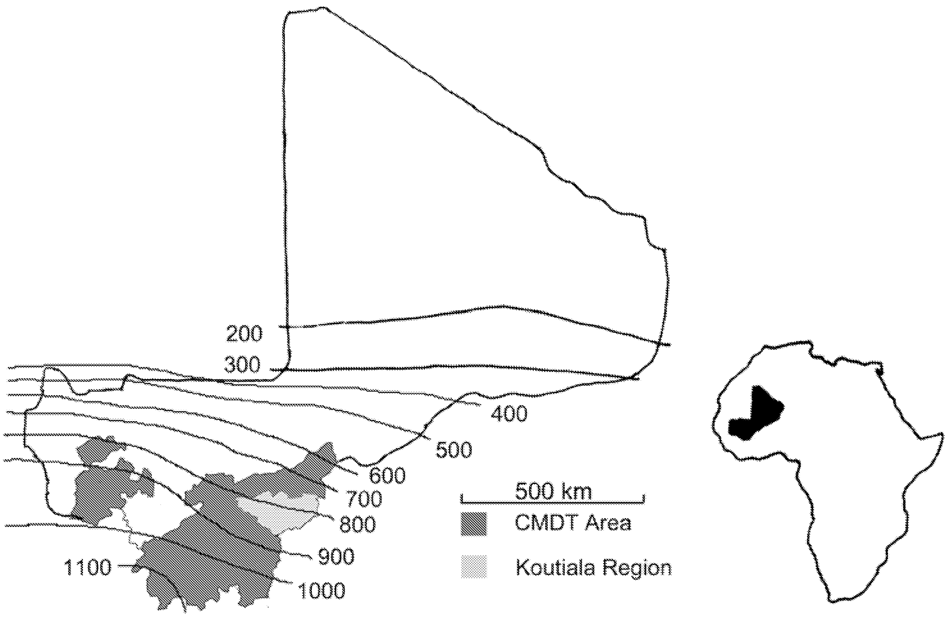

Figure 7.1. The CMDT area in southern Mali, Koutiala region, and rainfall isohyets (mm annual rainfall, average 1991-2001; CMDT data). On the right: Mali's location in Africa.

7.2.2 Fieldwork in 2000

In April 2000 (the dry season) the soil and water conservation unit and the monitoring and evaluation unit of the CMDT interviewed 298 farmers and visited 841 fields in 60 villages in southern Mali. Only 584 fields that provided sufficient and consistent data on slope and presence of erosion rills were included in the analyses. Erosion indicators were limited to observations on rills that were formed in the 1999 rainy season (Table 7.1). Farmers were asked about their crop yields in 1999. The yield data from cotton had been recorded and were more accurate than yield data from other crops.

7.2.3 Fieldwork in 2003

The survey, which was done in August and September 2003 (the rainy season), focused on 56 fields in 6 villages in Koutiala region. All these fields had been under cotton in 2002. In that year the monitoring and evaluation unit of the CMDT had monitored all agricultural practices and cotton yield in these fields. Erosion indicators included observations on rills, soil crusts and soil deposits.

With the 0.8 m spacing between sowing lines as reference, we estimated % soil cover for structural crusts, runoff deposits of fine and coarse sand, and *in situ* depositional crusts (Table 7.1). Soil resistance at 0.05, 0.10, 0.15, 0.20 and 0.25 m depth was measured using a penetrometer, giving an indication of soil compaction or the presence of a plough pan. Aggregate stability was estimated by submersing a small clod of topsoil in a glass of water and assessing the % intact after one minute.

The first set of observations was made halfway through the rainy season, from 30 July, about 7 weeks after crops were sown, until 15 September. At the start of the observations, the farmers were still weeding or ridging, as this is usually done up to about 8 weeks after sowing. The observations were done on two transects perpendicular to the slope, at two locations per transect. A second set of observations was made towards the end of the rainy season when crops were fully-grown, from 6 until 20 September, this time on one transect per field. The aim of the second set was to observe all 56 fields in a shorter period. Therefore, six fields visited at the end of the first set were not revisited in the second set. During individual and group discussions with farmers, the effects of runoff and erosion were ranked according to how frequently these were found. We did not measure actual runoff (%) or soil loss (t ha^{-1}), either in 2000 or 2003.

Table 7.1. Indicators of erosion risk and erosion used in the fieldwork of 2000 and 2003.

		Fieldwork 2000	Fieldwork 2003
Erosion risk	Rainfall	Annual rainfall (mm)	Annual rainfall (mm)
			Rainfall days >30mm
	Position	Slope (%)	Slope (%)
		Distance from plateau (m)	Distance from plateau (m)
		Vegetative cover plateau [a]	Land use upslope [b]
	Soil	Texture [c]	Texture [c]
		Gravel (yes/no)	Gravel (yes/no)
			Aggregate stability [d]
			Soil resistance (kN m^{-2}) [e]
	Field	Size (ha)	Size (ha)
	Land pressure	Years since fallow [f]	Years since fallow [f]
Erosion	Rills	Number (per 100 m transect)	
		Cross-section (m^2 per 100m)	Cross-section (m^2 per 100m)
	Crusts / deposit cover		Structural crust (%)
			In situ depositional crust (%)
			Runoff deposit of coarse sand (%)
			Runoff deposit of fine sand (%)

[a] Vegetative cover plateau classes: 0-30%, 30-60% and 60-100%.

[b] Land use upslope classes: bare, agricultural land, uncultivated plateau.

[c] Texture classes 1: sand; 2: loamy sand; 3: silt loam; 4: loam; 5: clay loam; 6: light clay; 7: heavy clay; assessed by rolling moist soil (Herweg, 1996);

[d] Aggregate stability of one soil clod of about 10 cm^3 after 1 minute immersion in a glass of water: from 0 = disintegrated to 10 = intact.

[e] Soil resistance at depths of 0.05, 0.10, 0.15, 0.20 and 0.25 m, using a penetrometer.

[f] Land pressure, expressed as the number of years fields have been cultivated since last fallow, averaged per village

7.2.4 Description of soil crusts and deposits

We used Valentin and Bresson's (1992) classification of crusts including runoff depositional crusts. However, the sand sediment we found in the furrows did not qualify as crust and we will therefore refer to it as 'runoff deposit.' Four soil surface features were distinguished. The soil surface colours described below refer to moist soil.

1. Structural crust. A crust of finer particles on the soil surface, sealed by the impact of raindrops and with the soil aggregates still visible. These crusts are found on the higher parts of the fields and on ridges.
2. *In situ* depositional crust. A thin, smooth, often dark top layer of silt and clay, coating the concave floor of the furrow, and formed by water containing fine sediment that has infiltrated slowly (Figure 7.2a).
3. Runoff deposit of fine sand. A flat-topped furrow infill of darker fine sand, often with coarse sand on the edges, formed by slow runoff (Figure 7.2b).
4. Runoff deposit of coarse sand. A flat-topped furrow infill of pale coarse sand, formed by fast runoff (Figure 7.2c).

7.2.5 Analyses

The relationships between erosion risk indicators (slope, etc.), erosion indicators (rills, deposits, etc.) and cotton yield were investigated by correlation and regression analyses, the latter by backward regression.

The number of rills per 100 m transect was not normally distributed. Many fields had no rills; in fields with rills, the number of rills showed a Poisson distribution. Therefore the analysis was split into two steps. In the first, the response variable was the presence/absence of rills and use was made of binary logistic regression (Jongman et al., 1995). In the second, in which only fields with rills were considered, the response variable was the natural logarithm of the number-of-rills-plus-one (in 1999) or the natural logarithm of the rill-volume-plus-one (in 2003), both of which were normally distributed and therefore could be subjected to linear regression analysis.

Cotton yield of the previous year (2002) was the selected indicator for crop yield, corrected for differences in fertilisation, sowing and weeding dates, and the availability of plough-oxen, which together explained about 32% of the yield data. The cotton yield was analysed using linear regression for these factors, and the un-standardised residuals were saved and used as the dependent variable (residual yield) for subsequent analyses.

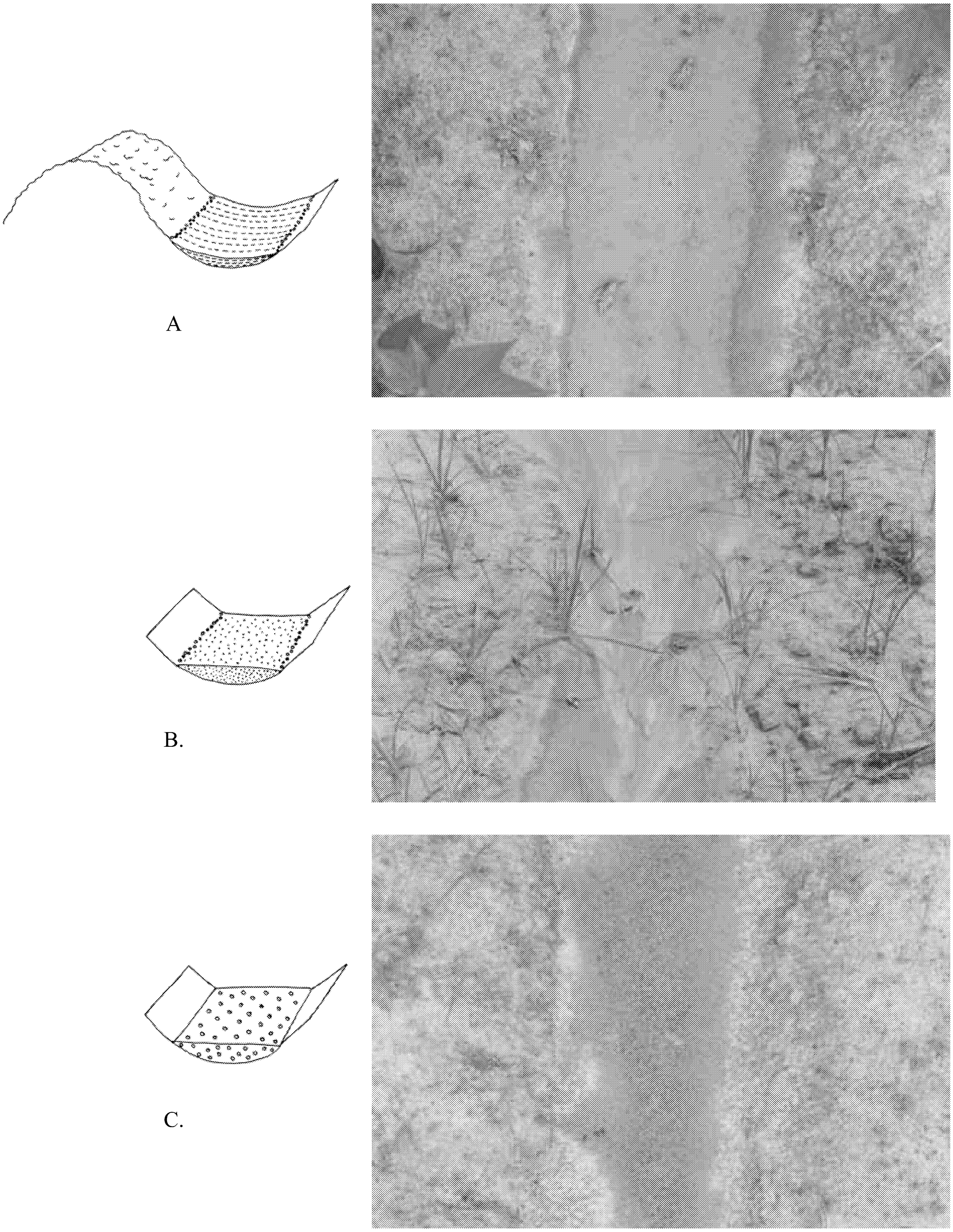

Figure 7.2. Soil crusts and deposits: (A) *In situ* depositional crust in the furrow; (B) Runoff deposit of fine sand in the furrow; (C) Runoff deposit of coarse sand in the furrow. Structural crusts on all ridges. Distance between ridges: 0.80 m. Average furrow width: 0.25m. Cultivated fields in Koutiala Region, southern Mali, 2003.

7.3 Results

7.3.1 Development of soil crusts and deposits during the rainy season

Pearson correlations between the observation date and the soil surface features showed that during the observation period there was a decrease in the cover of structural crust and of the runoff deposit of coarse sand. During the same period, the cover of fine sand from surface runoff and *in situ* depositional crust, and the soil aggregate stability increased.

7.3.2 Rills, soil crusts and deposits explained by erosion risk

The presence or absence of rills was only poorly explained (R^2: 0.090-0.128) by erosion risk indicators (Table 7.2: Step 1). Rills were more frequent in areas with high rainfall, on steeper slopes, at some distance from the plateau that is poorly vegetated, on light textured soils and on large fields. For fields with erosion rills, the severity of erosion (number of rills in 1999; rill volume in 2003) was somewhat better explained (R^2: 0.320-0.368) by erosion risk (Table 7.2: Step 2). More severe erosion was found in areas with heavy rainstorms (number of rain days > 30mm), on sloping fields below a sparsely vegetated plateau, on light-textured soils with good aggregate stability (surprisingly) and low soil resistance.

Table 7.2. Presence and severity of rill erosion explained by erosion risk indicators, analysed in two steps: binary logistic (all fields) and linear regression (only fields with rills), in southern Mali (1999) and Koutiala region (2003).

	Step 1. Presence (yes/no)		Step 2. Severity (number; volume)	
	1999	2003	1999	2003
Rainfall (mm)	++			-
Number of rain days >30mm				+++
Slope (%)	+++		+++	
Distance from plateau (km)	++			
Vegetative cover plateau	---		-	
Soil texture	---			--
Aggregate stability				+++
Soil resistance at 5cm depth				--
Land pressure			---	
Field size	+	+	---	
Number of fields	429	56	157	20
$R^{2\,a}$	0.128	0.090	0.320	0.368

[a] R^2 in Step 1: binary logistic regression, Nagelkerke method; Step 2: linear regression, adjusted R^2.
The sign of beta coefficients is indicated with + or –. The level of significance is indicated by the number of signs: +++ or – – – P<0.01; ++ or – – P<0.05; + or – P<0.10.

The different types of soil crusts and deposits were fairly well explained (R^2: 0.307-0.517) by erosion risk (Table 7.3). Structural crust occurred more frequently in fields with more rainstorms, in fields without gravel, with good aggregate stability and soil resistance, in smaller fields, and in intensively used areas (fields regularly cultivated). The incidence of structural crusts was not related to slope. *In situ* depositional crust was found more in fields with fewer rainstorms, in flat fields below farmed hill slopes, on heavier textured soils with low aggregate stability. These crusts occurred more frequently in areas used less intensively (fields recently under fallow). From the β coefficient it was found that for every 1% increase in slope there was a 3.9% decline in crust cover. In summary, *in situ* depositional crust was found in areas with low erosion risk. In terms of the relationship with erosion risk, the runoff deposit of fine sand seemed to be intermediate between the *in situ* depositional crust and the runoff deposit of coarse sand. It was not related to slope. The runoff deposit of coarse sand occurred more frequently in areas with more rainstorms (number of rain days >30mm), on sloping fields, close to the plateau, on light soils and on soils with low resistance. It was typically found more in fields where *in situ* depositional crusts were less common. From the β coefficient it was found that for every 1% increase in slope there was a 4.6% increase in deposit cover. The key finding was that runoff deposits of coarse sand occurred in areas with high erosion risk.

Table 7.3. Soil cover with structural crust, *in situ* depositional crust, runoff deposit of fine sand, and runoff deposit of coarse sand, explained in linear regression analyses by erosion risk factors and observation date, mid-rainy season (obs1) and end-rainy season (obs2), in Koutiala region in 2003.

	Structural crust		*In situ* depositional crust		Runoff deposit of fine sand		Runoff deposit of coarse sand	
	Obs1	Obs2	Obs1	Obs2	Obs1	Obs2	Obs1	Obs2
Rainfall (mm)		---	+++	+	+++	+	---	-
Rain days >30mm	++	+++	---	---	---	--	++	+++
Slope			-				+	
Distance plateau						+++	-	---
Land use upslope			-	---	++	+++		
Soil texture			+++		++		--	--
Gravel	---				++	+		
Aggregate stability		+++	--					
Soil compact. 5cm	+++						--	---
Field size (ha)	-							
Land pressure		++	--					
Observation date	--							
Number of fields	54	56	54	56	54	56	54	56
Adjusted R^2	0.357	0.378	0.505	0.320	0.326	0.307	0.403	0.517

The sign of beta coefficients is indicated with + or –. The level of significance is indicated by the number of signs: +++ or – – – P<0.01; ++ or – – P<0.05; + or – P<0.10.

7.3.3 Cotton yield explained by erosion

The 2002 cotton yield was found to be related to the observed crusts, deposits and rills in 2003 (Table 7.4). The only two erosion indicators that correlated significantly with yield were structural crusts (positive correlation) and runoff deposits of coarse sand (negative correlation), observed during the mid-rainy season. Note that only one-third of the 56 fields showed erosion rills whereas most fields showed structural crusts and runoff deposits of coarse sand. During the mid-season observations, rills were found more on fields with less structural crust and with more runoff deposits of fine sand. During the end-season observations fewer rills were found in fields with more *in situ* depositional crusts.

By combining the rill and cotton yield data from 1999 with the crust, deposit and cotton yield data from 2002/2003, it was possible to estimate the contribution of the different erosion indicators to cotton yield (Table 7.5). It was found that both the number of rills and the rill volume were negatively related (p<0.01) to cotton yield in 1999. Rills could explain about 3% of all variation in cotton yield. About 18% of the 1999 cotton yield could be explained by rainfall, fertilisation and farm equipment. A comparison of fields at the bottom and top ends of the erosion range (5 and 95 percentiles) revealed that an increase from 0 to 2.6 rills per 100m transect, or from 0 to 80 m^3 rill volume per ha, related to a yield reduction of 18%, about 200 kg ha^{-1}.

Table 7.4. Correlations between cotton yield, crust and deposit cover [1] and rill erosion mid-rainy season (Obs1) and end rainy season (Obs2) in Koutiala region in 2003.

			Cotton yield	First observations						Second observations					
				Soil cover (%)				Rills		Soil cover (%)				Rills	
			($kg\ ha^{-1}$)	Struc.	*In situ*	Run.F	Run.C	Yes/no	Volume	Struc.	*In situ*	Run.F	Run.C	Yes/no	Volume
Cotton yield				++			--								
Obs 1	Crust	Struc.	++		---	---	---	--	-	++					
		In situ		---			---			---	+++		---		
		Run.F		---				+	++			+++	-		
		Run.C	--	---	---						---		+++		
	Rills	yes/no		--		+			+++					+++	+++
		Volume		-		++		+++		++				+++	+++
Obs 2	Crust	Struc.		++	---				++		---	---			
		In situ			+++		---			---		---	---	--	
		Run.F				+++				---	---				
		Run.C			---	-	+++				---				+
	Rills	Yes/no						+++	+++		--				+++
		Volume						+++	+++				+	+++	
% Fields with symptoms				100	59	54	94	33	33	100	91	55	91	29	29

[1] Crust and deposit covers: Struc: Structural crust; *In situ: In situ* depositional crust; Run.F: Runoff deposit of fine sand; Run.C: Runoff deposit of coarse sand.

The sign of beta coefficients is indicated with + or –. The level of significance is indicated by the number of signs: +++ or – – – P<0.01; ++ or – – P<0.05; + or – P<0.10.

The presence of structural crusts and runoff deposits of coarse sand, observed mid-rainy season, related positively to cotton yield ($p<0.05$). Runoff deposits of fine sand and *in situ* depositional crust did not relate to cotton yield. Runoff deposits of coarse sand could explain about 7% of all variation in cotton yield. About 32% of the 2002 cotton yield could be explained by rainfall, fertilisation, sowing date and farm equipment. An increase in runoff deposit of coarse sand from 0% to 28% related to a decrease in cotton yield of 23%, about 250 kg ha^{-1}. The soil crusts observed in the second round at the end of the rainy season did not relate to cotton yield.

Table 7.5. Presence of erosion indicators and linear regression of erosion indicators on cotton yield: rills in 1999, and crust and deposit cover observed mid-rainy season in 2003.

		Presence of erosion indicators			Regression on cotton yield			
			90% Range					Yield effect
		Mean	Bottom 5%	Top 95%	Sign.	$R^{2\,a}$	β^{b})	(kg ha^{-1}) ^{c}
Rills	Number / 100m	0.6	0.0	2.6	0.006	0.031	-75	-194
	Vol. (m^3 / ha) ^{d}	13.8	0.0	97.5	0.007	0.029	-2.2	-210
Cover	Structural crust	74%	55%	92%	0.015	0.091	8.6	318
	In situ dep. crust	90%	0%	30%	n.s.			
	Runoff dep. fine	50%	0%	19%	n.s.			
	Runoff dep. coarse	13%	0%	28%	0.026	0.074	-8.8	-246

[a] Adjusted R^2: cotton yield variation explained by erosion.

[b] β coefficient in cotton yield (kg ha^{-1}) per erosion unit: number of rills per 100m transect, m^3 rill volume per ha, crust cover or deposit cover.

[c] Effect of erosion on crop yield: 90% range in erosion presence (high - low) multiplied by β.

[d] Rill volume m^{3}ha^{-1} extrapolated from rill cross-section per 100 m transect (1m^2$\rightarrow$100m^3).

We attempted to establish whether one combined indicator, 'total runoff deposit of (coarse and fine) sand', would give better results as an erosion indicator. It was found that total runoff deposit of sand correlated better with erosion rills (significance p=0.011) and accounted for more variation in cotton yield (R^2: 0.098) compared with runoff deposits of coarse sand. However, the total runoff deposit of sand was poorly explained by erosion risk (slope, etc.), which made this indicator unsuitable as an erosion indicator.

7.3.4 Farmers' perception of runoff and erosion effects

According to the farmers, the most frequently noticed effects of runoff and erosion were gullies and rills, followed by damaged plants, soil loss, compost and manure loss, fertiliser loss, and sand deposits, with soil crusts being placed last because they were the least frequently noticed. The farmers in the village with most experience of soil and water conservation mentioned that fertiliser loss was the most frequent effect, because this occurred even with minor runoff and before soil loss occurred.

7.4 Discussion

Our study confirmed that crust cover varies during the rainy season. The first few observations were affected by weeding and ridging by farmers. It was expected that the second set of observations would show clearer relationships between crusts, deposits, rills, erosion risk and cotton yield for two reasons, because of our increased experience in making observations, and because the observation period was shorter. However, the second set of observations did not show clear relationships. In other studies in Koutiala, southern Mali, Vlot and Troare (1994) evaluated runoff and erosion in runoff plots and found that although runoff in August was similar to runoff in July, there was much less soil loss in August than in July. This decline in soil loss is not unexpected, given that as the rainy season progresses the crop grows, its roots retain the soil and its canopy protects the soil from the impact of rain. The runoff deposit of fine sand and *in situ* depositional crust which we found partly covered runoff deposits of coarse sand observed during our first observations, not only obscured the signs of erosion, but also indicated that runoff velocity was slower later in the rainy season. From this it can be concluded that observations on crusts early in the rainy season are more useful when assessing erosion than observations later in the rainy season.

Our unexpected finding that aggregate stability increased during the rainy season does have a precedent. An increase in aggregate stability after soil disturbance by the impact of rain has been reported in Canada (Bryan et al., 1989; Kuhn and Bryan, 2004).

Our comparison between the soil crusts observed in 2003 and the cotton yield results obtained in 2002 was based on the assumption that between-field differences in erosion symptoms in 2003 reflected between-field erosion differences in 2002. However, 2002 was a dry year, with, according to the farmers, very few erosion problems. By contrast, 2003 was a wet year with many erosion problems. It is nevertheless likely that the fields showing evidence of sheet erosion in 2003 were the fields with poor soil water retention in 2002. This would account for the inverse correlation between erosion symptoms and crop yield.

It will be recalled that in our study two types of runoff deposits were distinguished: one of fine sand and one of coarse sand. The deposit of coarse sand correlated with slope and cotton yield, and gradually decreased during the rainy season. The deposit of fine sand correlated with erosion rills, and gradually increased during the rainy season.

Although soil crusts and deposits seemed obvious erosion indicators, only a few farmers confirmed that a runoff deposit of sand indicates soil fertility loss and that an *in situ* depositional crust indicates enhancement of soil fertility (i.e. retention of soil nutrients and organic material).

7.5 Conclusion

This study has investigated the extent to which soil crusts and associated deposits reflect soil erosion. It was expected that soil crusts and deposits would correlate with slope angle, crop yield and occurrence of rills. It was found that structural crust cover did not correlate with slope, but correlated positively with crop yield, and negatively with erosion rills. *In situ* depositional crust cover correlated negatively with slope, but did not correlate with crop yield or the incidence of erosion rills. Runoff deposit of fine sand did not correlate with slope or crop yield, but correlated positively with erosion rills. Runoff deposits of coarse sand correlated positively with slope and negatively with crop yield, but did not correlate with rills.

Of the four crust types, the most suitable erosion indicator proved to be runoff deposits of coarse sand. A 2% increase in slope related to a 9% increase in extent of deposits. A 30% increase in deposit cover was related to a decrease in cotton yield of 23%, about 250 kg ha^{-1}. Although erosion rills occurred in only one third of the surveyed fields, runoff deposits of coarse sand were found in almost all fields (94%). The best observation period was found to be between 2 and 6 weeks after the last soil disturbance (weeding or ridging).

This study has demonstrated the value of making observations of soil crusts and deposits to use as runoff and erosion indicators to aid soil and water conservation programmes. From our findings it can be concluded that to prevent erosion rills from forming, soil and water conservation programmes should pay more attention to monitoring fields and this should not be delayed until erosion has been initiated. Programmes monitoring rills and gullies as erosion indicators are likely to emphasise curative gully interventions, whereas programmes that also monitor sheet erosion indicators are likely to emphasise preventive contour cultivation and area interventions such as mulching.

Chapter 8

Ex-Post Evaluation of Erosion Control Measures in Southern Mali

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8 Ex-Post Evaluation of Erosion Control Measures in Southern Mali

Abstract

As part of an impact study of a soil and water conservation (SWC) project in southern Mali, the effect of erosion control measures on soil erosion was evaluated. In one village, a baseline situation from 1988 was compared with the situation in 2003, after farmers had installed stone rows, live fences and grass strips, and had started cultivating across to the slope. This comparison showed a spectacular decrease in gully volume in cultivated fields of 87%, from 58 m^3 ha^{-1} to 8 m^3 ha^{-1}. Estimated annual soil loss decreased with 77% from 42 t ha^{-1} y^{-1} to 10 t ha^{-1} y^{-1}. However, baseline data on erosion gullies were not available for other villages. In the absence of baseline data, a simple 'with – without' comparison does not allow a correct evaluation because farmers install erosion control measures especially in fields with more erosion. Two alternative methods were used: a reconstructed baseline and a virtual time series. Using the reconstructed baseline, looking not only at active gullies but also at (partly) reclaimed gullies, we conclude that line interventions, gully interventions, and a combination of both, reduced the proportion of active gullies by 48%, 47% and 70% respectively. Using a virtual time series, comparing erosion in fields with erosion control measures installed in different years, we conclude that erosion gradually decreased by 50% during the three years after installation of erosion control measures. In a separate study, a positive effect was found of gully interventions and sowing across the slope in reducing sheet erosion. A reduction of the slope of the sowing direction by 1% reduced the cover of runoff deposit of coarse sand with 8%. Although a documented baseline is preferred, both a reconstructed baseline and a virtual time series are useful tools and make ex-post evaluations more relevant than a simple with-without comparison.

Key words: ex-post evaluation, erosion control, reconstructed baseline, virtual time series, southern Mali

8.1 Introduction

8.1.1 Evaluating erosion control as one step in the evaluation of impact

When evaluating the impact of a project, the evaluator tries to attribute change at the global objective level to project activities (van Leeuwen et al., 2000; Guijt and Woodhill, 2002). For the soil and water conservation (SWC) project discussed here, the global objectives were to reduce land degradation, intensify agriculture and improve productivity (PLAE, 1986). The main project activity was training farmers in SWC. There is a long cause-effect chain between project activity and impact and to prove a causal relation it is best to split this chain into several subsequent and parallel steps. One of these steps is the effect of erosion control measures on water runoff and soil erosion.

Besides splitting the cause-effect chain into smaller steps, the evaluator wants to attribute the observed change to the project. One method is a ‘with-without’ comparison: soil erosion in fields with and without erosion control measures. However, because erosion control measures are especially installed in fields with severe erosion problems, this simple comparison would not be correct. Therefore, the evaluator needs to include a ‘before-after’ comparison: soil erosion before and after erosion control measures were installed. For a correct ex-post evaluation, the evaluator thus depends on baseline information monitored in the past.

The main purpose of the SWC programme was to achieve adoption of SWC measures by as many farmers in as many villages as possible. Therefore, the monitoring and evaluation system focused on extension activities and on adoption of SWC measures. There was no regular monitoring of land degradation. Here we are confronted with a problem: how to evaluate the effectiveness of erosion control measures in the absence of baseline data on erosion?

The main objective of this study is to evaluate the effect of erosion control measures in reducing erosion in southern Mali. A second objective is to test evaluation methods that can be used in the absence of baseline data.

Before evaluating erosion control measures, a general description of the soil types and land uses in southern Mali is presented, water runoff and soil erosion problems are reviewed, and an overview of the SWC project is given.

8.1.2. Soil types and land uses in southern Mali

The study area is the part of southern Mali where the semi-government Malian cotton and rural development organisation (*Compagnie Malienne pour le Développement des Textiles, CMDT*) operates (Figure 8.1). Annual rainfall varies from 1200 mm in the southeast to 600 mm in the northeast. The dominant parent material to soils is sandstone in the central and eastern part, and schist and granite in the southern and western part of southern Mali. Differences in soil type and land use can be explained by the position on the so-called ‘toposequence’: plateau, escarpment, glacis, embankment and valley bottom. Most area under arable rain fed crops is located on the glacis, but more and more land on the plateau is cleared for cultivation as well (Hijkoop et al., 1991).

Soil analysis of the glacis in Koutiala showed that light textured topsoil (8% clay) covers heavy textured subsoil (20-28% clay). Topsoil is low in nutrients and carbon (average 0.03% total N, 4ppm available P, 0.3ppm exchangeable K, and 0.4% carbon) (Kanté and Defoer, 1994; Keita et al., 1994; Bitchibaly et al., 1995).

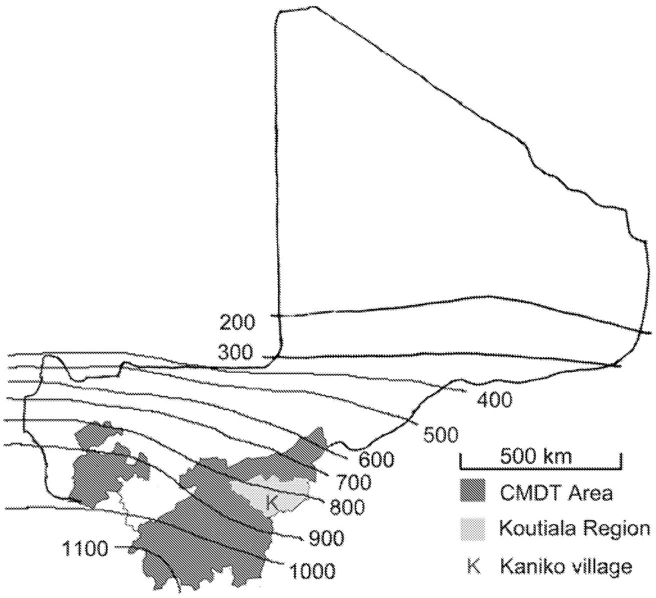


Figure 8.1. The CMDT area in southern Mali (light and dark grey), Koutiala region, Kaniko village, and rainfall isohyets (CMDT rainfall data 1991-2001).

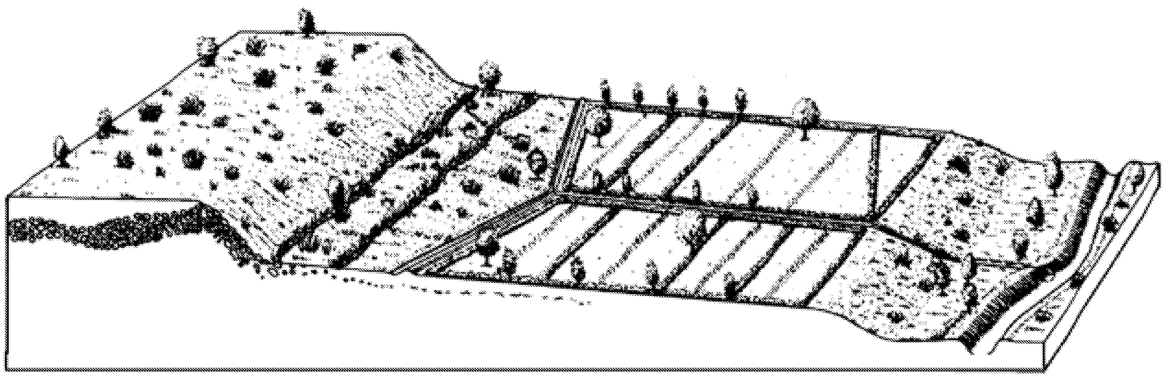
8.1.3. Water runoff, soil loss and the effect on agricultural production

Although slopes are gentle (0-5%), there is substantial water runoff and soil erosion caused by high rain erosivity, long slopes, poorly covered soils, and fragile soil structure. Water runoff was estimated at 20 – 40% of annual rainfall and up to 70% of individual rainstorms (Roose, 1985). Because of the light textured topsoil and heavier textured subsoil, erosion gullies may become wide but are seldom deep. Soil loss was estimated (using the Universal Soil Loss Equation) at 26 t ha^{-1} y^{-1} for a cultivated field with a 2% slope in southern Mali (Roose, 1985). Bishop and Allen (1989) measured an average soil loss of 10 t ha^{-1} y^{-1} on cultivated fields, going up to 31 t ha^{-1} y^{-1} in the most southern, steeper part of southern Mali. Vlot and Traoré (1994) measured 7 – 14% runoff and 5 – 6 t ha^{-1} soil loss per year in cultivated 5-meter long runoff plots with a 1.4 - 1.7% slope in Koutiala region. However, they noticed that runoff and soil erosion inside the runoff plots were lower than outside the runoff plots, so extrapolation to the field level is difficult.

There is little information about long-term trends in soil erosion. Jansen and Diarra (1992) assessed land degradation by examining grass, shrub and tree cover, and visual symptoms of runoff, sheet and gully erosion. Using aerial photographs, they compared the situation of 1952 with the situation in 1987 for different land uses. Land degradation had increased in all categories of land use; it was most pronounced in the non-cultivated areas and less pronounced in the cultivated areas. Various researchers have estimated the effect of soil erosion on crop yield. Veldkamp (1994) estimated that one ton soil loss reduces cotton yield with 40 kg ha^{-1}, considering the nitrogen content of the eroded material and the crop response to nitrogen. Hallam and Verbeek (1986) relate a soil erosion of 15 t ha^{-1} y^{-1} to a yield reduction of 2.6 – 5.4% per year, based on research done in Ibadan by Lal (Lal, 1976, cited by Hallam and Verbeek, 1986). The cotton yield decline by soil erosion is camouflaged – thus underestimated – by the increase of chemical and organic fertiliser doses (Vierstra, 1994). Bishop and Allen (1989) estimated that erosion reduced farm net revenue with 2-10% per year in Burkina Faso, and that erosion accounted for a loss of 1-2% of the agricultural GDP per year in Mali.

8.1.4. The SWC project and the proposed erosion control measures

Since 1982, the Malian farming systems research group (*Division de Recherche sur les Systèmes de Production Rurale*) has tested SWC approaches, including both technical and extension aspects. Following complaints by farmers about decreasing yields and water washing away their crops, trials were carried out in 1984 in collaboration with the CMDT. This resulted in the creation of the SWC project (*Projet Lutte Anti Erosive*) within the CMDT structure in 1986.



Unit:	Plateau	Escarpment	Glacis	Embankment	Valley
Slope:	0-2%	5-7%	0-2%	0-5%	0-1%
Soil:	Gravel	Stone	Loamy sand	Sandy clay	Clay
Land use:	Pasture, wood	(none)	Annual crops	(none)	Rice, veget.
SWC:	Regulated use	Protection; Stone rows	Protection dike and drainage canal; Live fences, grass strips, crop residue and stone check dams	Protection	

Figure 8.2. Land units in a typical toposequence in Koutiala region and the erosion control measures as applied in Kaniko village.
Source: Hijkoop et al.

The SWC approach takes the different land units of the toposequence into account (Figure 8.2). On the one hand, protective measures are taken above the cultivated glacis. On the escarpment and in some cases on the plateau, the natural vegetation is protected or its exploitation is regulated. Collective measures are taken to improve water infiltration or, if necessary, to drain the excess of water. Individual line and gully interventions are taken on the cultivated glacis, mostly on field boundaries.

The selected erosion control measures are a compromise between what was technically desirable and what was compatible with the existing farming practice. Protection dikes blocking the water turned out to be difficult to install and dangerous in case the structure collapsed. Therefore water-spreading semi-permeable erosion control structures were preferred such as stone rows, installed on contour lines, above the cultivated area. Farmers found cropping on contour lines too difficult and preferred installing the erosion barriers - those in the cultivated area - following the least sloping field boundaries: live fences, grass strips and crop residue lines. Water drainage canals would be less necessary if water was dispersed and infiltration was improved. Gullies were reclaimed with stone or crop residue check dams. Erosion control measures in the fields included ploughing and sowing across to the slope (Hijkoop et al., 1991).

The dense network of the CMDT extension service, with about 650 general extension agents, complemented by about 45 SWC specialists at various levels, has reached a large number of villages and farmers. Between 1986 and 2000, about 2,500 villages, half of the villages in southern Mali, received the package of SWC training (Bodnár and de Graaff, 2003). Farmers in other villages received at least some general information on SWC. In 2002, erosion control measures were installed in 94% of the villages, on 46% of the farms and in 15% of the fields (CMDT, 2003). The most common measure was live fences (6% of the fields), followed by stone rows (3%), gully interventions (3%), grass strips (2%) and other measures (2%). These figures do not include the protection from erosion control measures installed some distance above the observed field; the total percentage fields protected will thus be higher. The popularity of live fences is explained by the low labour requirements (Spaan et al., 2004)

8.2 Material and methods

The data on erosion and erosion control measures came from three studies. In the first, a case study in Kaniko village, the situation in 2003 was compared with a real baseline situation in 1988. In the second study, undertaken in 60 villages in 2000, the relation between erosion control and erosion gullies was analysed. In the remainder of this paper, ‘gullies’ refer also to smaller rills. In the third study, done in 6 villages in 2003, the effect of erosion control on gullies and sheet erosion symptoms (crusts and sediment) was analysed.

To evaluate the effect of erosion control in the absence of baseline data, two alternative methods were applied using the data of 2000: a reconstructed baseline and a virtual time series. Because the number of gullies follows a non-normal distribution, analyses had to be adapted.

8.2.1 Case study in Kaniko village

In 1988, a series of maps was made of Kaniko, a village in Koutiala region (Figure 1). Aerial photographs and field observations were used. Among other things, field boundaries and the location of gullies were indicated. Gullies were classified according to depth: 0 – 0.25 m, 0.25 – 0.50 m, 0.50 – 0.75 m, and > 0.75 m (Baltissen and Coulibaly, 1988). However, gullies that were visible in the aerial photographs more likely had a depth of at least 0.10 m (Baltissen, pers. comm.).

Tests on erosion control had already started in 1984, and a number of stone rows had already been installed above the cultivated area when the map was made in 1988. Since 1988 more erosion control measures have been installed, live fences and grass strips have grown into effective erosion barriers and cultivation was done more often across to the slope.

In 2003 part of this village area was revisited towards the end of the rainy season. An area of about 2 x 2 km was chosen, based on the abundance of gullies in 1988 and on the actual presence of erosion control measures. The position and dimensions (depth and width) of gullies were measured, using a GPS and measuring rod, on two transects across to the slope. The erosion control measures were indicated on one transect parallel to the slope. The number and the dimensions of gullies in 2003 were compared with those in 1988.

8.2.2 Field observations in 2000

In 2000, a study to evaluate the SWC programme was carried out by the SWC Unit and the M&E Unit of the CMDT. Two samples were used:

1. One representative sample was taken of 82 farmers (in 30 villages), from the regular sample used by the CMDT M&E Unit.
2. One selective sample was taken of 216 farmers in 30 other villages with high SWC adoption. The reason for this selective sample was to have more data from fields with SWC measures.

A total of 298 farmers in 60 villages were interviewed and 841 fields were visited (two or three fields per farmer). Out of these, 713 fields provided sufficient information for yield analyses and 584 fields provided also sufficient and consistent data on slope and presence of erosion gullies. Field observations and interviews considered general field characteristics and erosion risk, erosion control, actual erosion, and crop yield.

Farmers indicated the ‘field age’: how many years a field had been under cultivation since last fallow. From this two indicators were derived: ‘land pressure’, by averaging field ages per village, and ‘relative field age’, by comparing the field age with the village-average. Observations on erosion risk further included slope; slope length, expressed in meters between observed field and non-cultivated area above; soil texture, assessed by using the ‘rolling of wet soil’ method (Herweg, 1996); and soil organic matter content, assessed by looking at soil colour.

Observations on erosion control included the presence of erosion control measures in the field, on field boundaries, and above the field. Erosion control measures were grouped into line interventions (stone rows, live fences and grass strips) and gully interventions (stone check dams and crop residue check dams). About 20% of the fields had both line and gully interventions, 9% had only gully interventions, 38% had only line interventions, and 33% did not have any erosion control interventions. For line interventions, 'protection' was expressed in percentage of field-width covered, and 'quality' was expressed in percentage intact (i.e. no gaps).

Observations on erosion symptoms were done on one field transect, in the middle of the field, across to the slope. These included: the number of active gullies (including small rills) and their depth and width; the number of partly reclaimed gullies, still visible but slowly filling up; and the number of fully reclaimed gullies, sometimes still visible, sometimes identified by interviewed farmer, all per 100 m transect.

8.2.3 Field observations in 2003

More detailed observations were made in 6 villages in Koutiala region, chosen from the regular CMDT M&E sample. In a first observation round halfway the rainy season, 56 farmers were visited, one field per farmer. At the end of the rainy season, 50 fields were revisited.

Besides similar observations as made in 2000, the following additional observations were made. As erosion risk indicator, soil resistance was measured at 0.05, 0.10, 0.15, 0.20 and 0.25 m depth, using a penetrometer. As erosion control indicators, the sowing direction was compared with the slope direction. As sheet erosion indicator, crust and deposit cover was measured, considering four soil features that could be easily distinguished (Valentin and Bresson, 1992) (Chapter 7):

1. Structural crust. A crust of finer particles on the soil surface, sealed by the impact of raindrops and with the soil aggregates still visible. These crusts are found on the higher parts of the fields and on ridges (Figure 8.3a).
2. *In situ* depositional crust. A thin, smooth, often dark and shiny top layer of loam and clay, coating the concave floor of the furrow, and formed by water run-on containing fine sediment that has infiltrated slowly (Figure 8.3b).
3. Runoff deposit of fine sand. A flat-topped furrow infill of darker fine sand, often with coarse sand on the edges, formed by slow runoff (Figure 8.3c).
4. Runoff deposit of coarse sand. A flat-topped furrow infill of pale coarse sand, formed by fast runoff (Figure 8.3d).

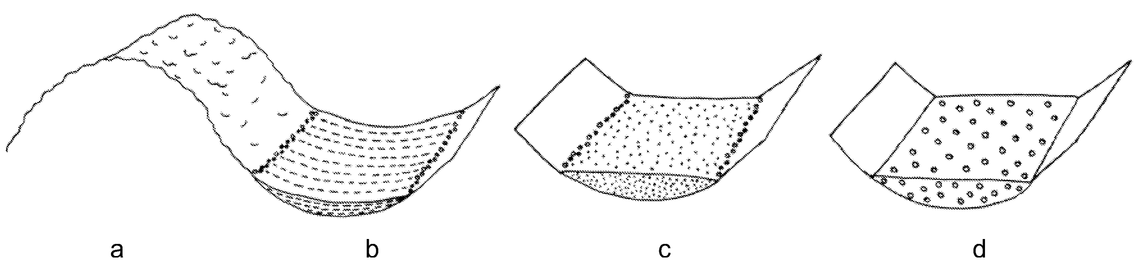


Figure 8.3. Structural crust on the ridge (a); *in situ* depositional crusts in the furrow (b); runoff deposit of fine sand (c); runoff deposit of coarse sand (d). Distance between ridges: 0.80m; average furrow with: 0.25m.

8.2.4 Analyses of gullies observed in 2000

In order to compare the erosion observed in 2000 with erosion in the past, two methods were used: a reconstructed baseline situation and a virtual time series. A baseline situation of erosion in the past was reconstructed by adding up the observed 'active' erosion rills to the partly reclaimed rills and the fully reclaimed rills. This total number of erosion rills is an indication of erosion in the past and was used as covariate in the analysis of effectiveness of erosion control measures. A virtual time series of erosion was constructed by comparing erosion, observed in 2000, of fields with erosion control measures of different ages. This method assumes a cumulative or increasing effect of erosion control during the years after installation.

The number of gullies (including shallow rills) per 100 m transect had a non-normal distribution that needed care in statistical analyses. About two-thirds of the fields had no gullies at all, while in the fields with gullies, the number of gullies showed a Poisson distribution. The analysis was therefore split in two steps. In the first step, the response variable is the 'erosion presence' whether or not there were gullies, and use was made of (backward) binary logistic regression. In the second step, in which only fields with gullies are considered, the response variable was 'the erosion severity', the natural logarithm of the number-of-gullies-plus-one, which showed a normal distribution to validate the use of (backward) linear regression analysis. Note that presented B coefficients in binary logistic regression are different from the β coefficients in linear regression, but in both cases positive and negative values indicate a positive and negative relation respectively. The number of fields used in each analysis depended on what field data were required for each analysis.

8.3 Results

8.3.1 Comparing erosion in 1988 with erosion in 2003 in Kaniko

On one transect parallel to the slope, starting on the plateau going down through the cultivated area towards the village, 16 erosion control line interventions were found over a distance of 2,160m. Just under the plateau but above the cultivated area, there were three stone rows and one drainage canal, on average about 25m apart. In the cultivated area, there were 11 live fences, one of which was combined with a grass strip, and one stone row, all installed on field boundaries across the slope. Measures in cultivated fields were on average about 200m apart. In all visited fields, farmers had ploughed and sown across to the slope.

Two parallel transects were followed with a total length of 3530m: 550m in uncultivated land, just below the plateau and towards the stream embankment, and 2980m in cultivated fields. Gullies in the uncultivated area were distinguished from, gullies on field boundaries (including footpaths and drainage ditches), and from gullies in cultivated fields. Gullies in the uncultivated area and on field boundaries were deeper and represented a larger volume than gullies in the fields. For farmers however, gullies in the fields are a bigger problem.

From the 34 gullies present in 1988, 6 had disappeared, 28 were still found in 2003, and an additional 21 new gullies had appeared. From the old gullies that were still present, the majority had become shallower, the remaining had maintained more or less the same depth, and only one old gully, in the uncultivated area, had become deeper. The majority of new gullies were shallower than 0.10 m. When gullies shallower than 0.10 m in 2003 are considered, the total number of gullies increased between 1988 and 2003; if these shallow gullies are not considered, the total number decreased (Figure 8.4).

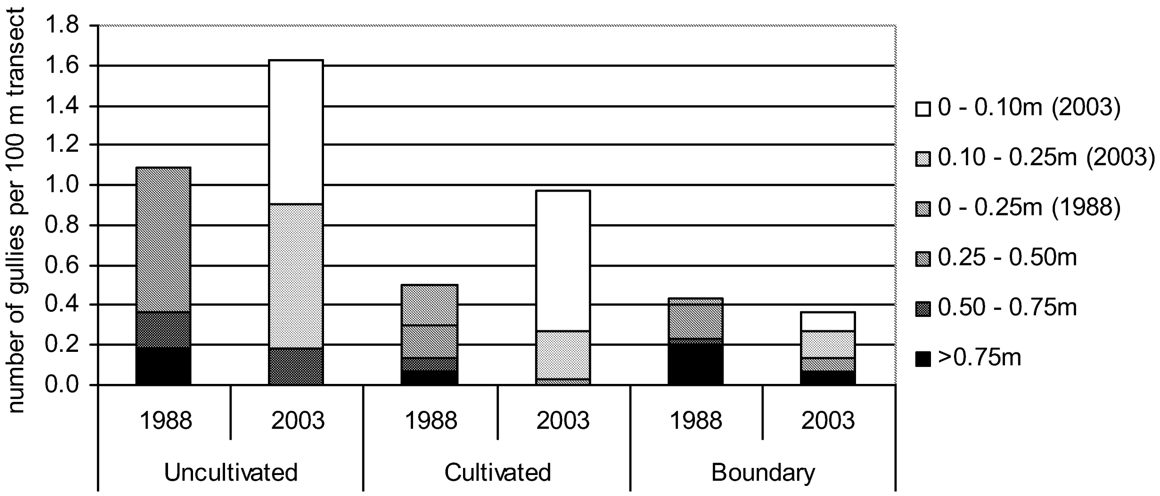


Figure 8.4. Comparison of the number of gullies by depth-class in 1988 and 2003 in Kaniko village, southern Mali. (Rills < 0.10 m were probably not observed in 1988, but they were in 2003.)

Changes in gully volume are larger than changes in number of gullies. Focussing on the situation in cultivated fields, most relevant for farmers, we see that gully volume has spectacularly decreased from 58 m^3 ha^{-1} in 1988 to 8 m^3 ha^{-1} in 2003 (including rills < 0.10 m) (Figure 8.5).

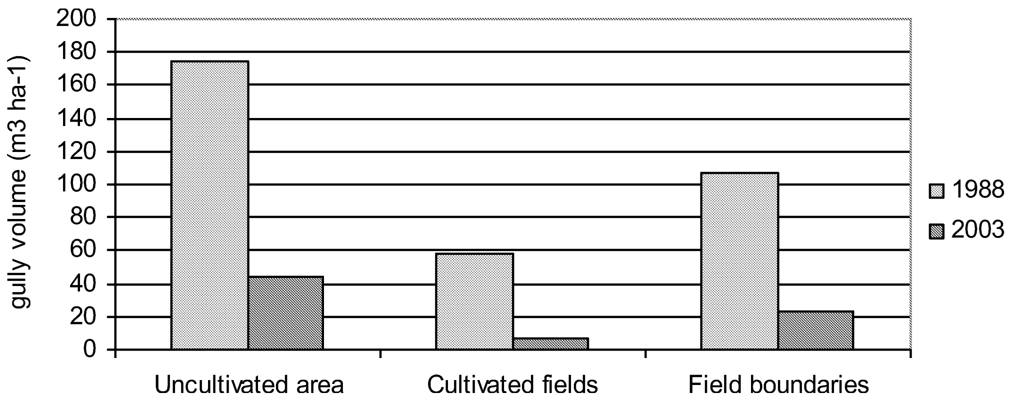


Figure 8.5. Gully volume in 1988 and 2003, distinguishing the uncultivated area, cultivated fields and field boundaries in Kaniko village, southern Mali. (Rills < 0.10 m were probably not observed in 1988, but they were in 2003.)

It is likely that shallow rills in cultivated fields arise within a year and correspond with annual soil loss, but deeper gullies arise over a longer period of time. Therefore, gully volume cannot simply be converted into annual soil loss. In an attempt to estimate changes in annual soil loss, we assume here that all rills shallower than 0.15 m had formed in one year, and that from rills and gullies deeper than 0.15 m only the upper 0.15 m was lost in one year. Erosion in cultivated fields would have decreased from 23 t ha^{-1} y^{-1} in 1988 to 10 t ha^{-1} y^{-1} in 2003. However, soil loss in 2003 consisted for 45% of rills shallower than 0.10 m, which were not monitored in 1988. If the same proportion of soil loss from shallow gullies is added to the 1988 estimate, annual soil loss would have decreased with 77% from 42 t ha^{-1} y^{-1} in 1988 to 10 t ha^{-1} y^{-1} in 2003.

8.3.2 Erosion gullies affected by erosion control line and gully interventions

From the 584 fields visited in southern Mali in 2000, active gullies were found in 33% of the fields, partly or fully reclaimed gullies in 21% of the fields, and no gullies in 46% of the fields. On 100 m transect, on average 0.54 active gully, 0.38 partly reclaimed gully and 0.26 fully reclaimed gully were found. Gullies are shallow, on average 0.17 m, but wide, on average 1.47 m. The extrapolated average gully volume was 14 m^3 per ha.

The comparison of erosion with and without erosion control measures, with erosion risk indicators as covariates, gave unsatisfactory results. The erosion presence (step 1. gullies: yes / no) is lower in fields with line interventions, but higher in fields with gully interventions. The erosion severity (step 2. number of gullies), considering only fields with erosion, is lower in fields with gully interventions. In spite of including erosion risk indicators, we still find a 'negative effect' (or positive correlation) of gully interventions on erosion. This raises the question of baseline information about erosion in the past.

Reconstructed baseline

A first alternative method is reconstructing a baseline situation. To give an indication of erosion before erosion control measures were installed, we also present the number of partly reclaimed gullies—gullies that were no longer active, gradually filled up but still clearly visible—and the number of fully reclaimed gullies—gullies that were completely filled up, often hardly visible, indicated by farmers (Figure 8.6). Not only the number of active gullies but also the number of reclaimed gullies was higher in fields with gully interventions than in fields without gully interventions. The proportion of total gullies that was no longer active represents the effectiveness of erosion control. Line interventions, gully interventions, and a combination of both, reduced the proportion of active gullies by 48%, 47% and 70% respectively.

Using the reconstructed baseline (total number of gullies) and erosion risk indicators as covariates, we find that line interventions reduced the number of fields with erosion (step 1) and gully interventions reduced the number of gullies in fields with erosion (step 2) (Table 8.1). Generally, we find more erosion on sloping fields under a longer slope length. In larger and high-positioned fields, more often gullies are found (step 1). However, considering only fields with erosion, one finds that the number of gullies is smaller in larger and high-positioned fields with erosion (step 2).

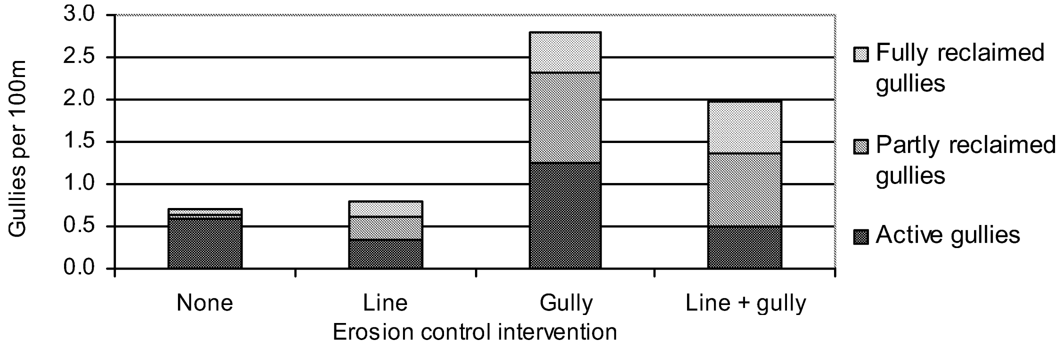


Figure 8.6. The reconstructed baseline: active, partly reclaimed and fully reclaimed gullies on fields with and without erosion control interventions, in southern Mali (565 fields) in 2000.

Table 8.1. Erosion as function of erosion control, erosion risk, and a reconstructed baseline of 'total gullies', in southern Mali in 2000.

		Step 1. Presence (gullies: yes / no)	Step 2. Severity (number of gullies)
Erosion control	Line interventions	---	
	Gully interventions		---
Erosion risk	Slope (%)		+++
	Slope length (km)	++	
	Toposequence (low / high)	+	-
	Field size (ha)	+++	---
Reconstr. baseline	Total gullies / 100m	+++	+++
	Number of fields	416	150
	R^2 (1: Nagelkerke; 2: adjusted)	0.501	0.709

Significance: +-p<0.10; ++--p<0.05; +++---p<0.01

Virtual time series

A second alternative method is presenting a virtual time series. Over the period since 1986, when the SWC project started, a significant trend can be seen: less erosion is found in fields where erosion control interventions had been installed longer ago (Figure 8.7). Roughly, the number of active gullies is 50% lower in fields with 3-year old measures than in fields with 1-year old measures. In Figure 8.7, the horizontal reference line represents erosion in fields without erosion control. Note that erosion in fields with recently installed erosion control measures was higher than in fields without erosion control measures.

The trend of the virtual time series can also be analysed in a regression analysis. Erosion is explained in two steps by the year of installation of erosion control measures and erosion risk indicators (Table 8.2). In fields with older erosion control measures, less fields showed erosion (step 1) and erosion was less severe (step 2). The overall effect of the age of erosion control measures is composed of several aspects. Firstly, when looking at live fences as an example, we find that older live fences have a lower plant density but are more intact and protect a larger part of the field-width, which result in a lower number of gullies. Secondly, farmers gradually install more erosion control measures protecting the same field.

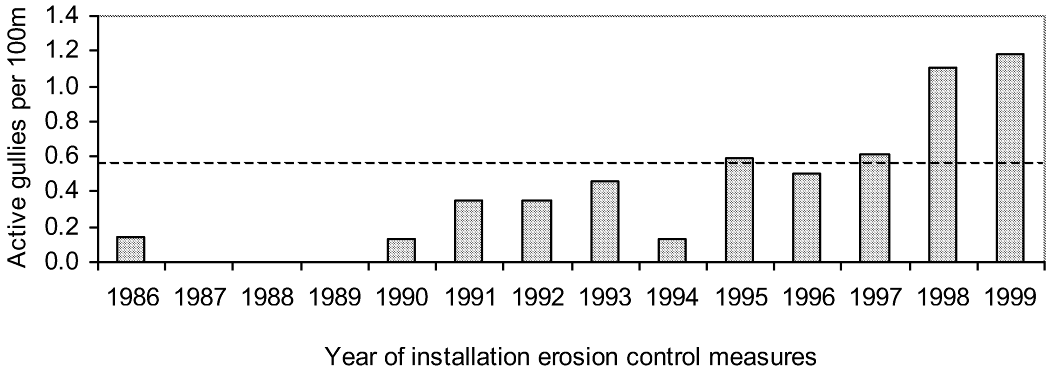


Figure 8.7. Virtual time series: erosion observed in 2000 in fields with erosion control measures installed between 1986 and 1999, compared with erosion in fields without erosion control (horizontal reference line y=0.58) in southern Mali (571 fields).

Table 8.2. Virtual time series: erosion observed in 2000 as function of the year of installation of erosion control measures and erosion risk indicators, in southern Mali.

	Step 1. Presence (gullies: yes / no)	Step 2. Severity (number of gullies)
Year of installation erosion control	++	++
Rainfall (mm)	+	
Slope (%)	+++	+++
Vegetative cover plateau [1]	--	--
Texture [2]	---	
Relative field age 3	++	
Field size (ha)	+	---
Number of fields	291	103
R^2 (1: Nagelkerke; 2: adjusted)	0.165	0.334

[1] Vegetative cover classes: 1=0-30%; 3=60-100%.

[2] Soil texture classes: 1=sand; 7=clay

[3] Relative field age: number of years that field has been under cultivation since last fallow, compared with village-average.

Significance: +-p<0.10; ++--p<0.05; +++---p<0.01

8.3.3 Sheet erosion affected by erosion control interventions

A more subtle form than rill and gully erosion is sheet erosion, for which soils crusts and deposits are good indicators. The advantage of soil crusts and deposits is that they are found in most fields, unlike gullies, and that they correlate well with both erosion risk and with crop yield (Chapter 7). During observations halfway the rainy season, structural crusts were found in all fields, *in situ* depositional crusts in 59% of the fields, and runoff deposit of fine and coarse sand in 54% and 95% of the fields respectively.

The effect of line interventions, gully interventions and the slope of the sowing direction on the cover of four crust types was evaluated, taking into account erosion risk and soil characteristics (Table 8.3). The effect of line interventions on soil crusts was not significant. In fields with gully interventions, less structural crust and more runoff deposit of coarse sand were found. Most significant is the effect of the slope of the sowing direction. In steep furrows, more runoff deposit of coarse sand, less *in situ* depositional crust and less structural crust were found. The effects of other factors - erosion risk and soil and field characteristics - on soil crusts and deposits are discussed in the previous chapter (Chapter 7).

Table 8.3. Crust and deposit cover as function of erosion control and other field characteristics, analysed in linear regression analyses, in Koutiala region in 2003.

	Structural crust	*In situ* depositional crust	Runoff deposit of fine sand	Runoff deposit of coarse sand
Line interventions				
Gully interventions	-			+
Sowing slope (%)	---	--		+++
Rainfall (mm)	-	+++	+++	---
Rain days >30mm	+++	---	---	+++
Distance plateau (km)				--
Land use up [1]			++	
Texture [2]	--	+++	++	
Gravel (yes / no)			++	
Aggregate stability		---		
Soil resistance (kP m^{-2})	++			--
Field size (ha)	--			
Land pressure [3]	++	--		
Number of fields	54	54	54	54
Adjusted R^2	0.406	0.520	0.326	0.469

[1] Land use above the field, classes: 1=agricultural land; 2=grass or plateau.

[2] Texture classes: 1=sand; 7=clay.

3 Land pressure: number of years that fields have been under cultivation since last fallow, averaged per village.

Significance: +-p<0.10; ++--p<0.05; +++---p<0.01

8.4 Discussion

8.4.1 The effectiveness of erosion control measures in southern Mali

The case study in Kaniko village showed that erosion was spectacularly reduced between 1988 and 2003. Although the number of gullies did not change that much, total gully volume decreased with 80% and estimated annual soil loss in cultivated fields decreased with 77%. Given the large interval of about 200 m between the live fences, these results are encouraging and comparable to the reduction in soil loss by grass strips on-farm measured in Ethiopia and Eritrea (55-84%) (Herweg and Ludi, 1999) and approaching the reduction by grass strips in experimental plots measured in Burkina Faso (82%) (Zougmore et al., 2003). In interviews, farmers in Kaniko village confirmed that land degradation had reversed. Fields that were too degraded to grow cotton or maize in 1988 had become productive again, with above-average cotton and maize yields in 2002. Although both initial erosion and adoption of erosion control were relatively high in Kaniko village, this case study shows the potential of erosion control.

The evaluation using a reconstructed baseline for 60 villages confirms the effect of erosion control. The gully dimensions were not measured with sufficient accuracy to calculate gully volume or to estimate annual soil loss. However, the proportion of active gullies out of the number of total gullies (active and reclaimed) was a good indicator to distinguish erosion in fields with and without erosion control. Line interventions, gully interventions, and a combination of both reduced the proportion of active gullies with 48%, 47% and 70% respectively.

The evaluation using a virtual time series showed that the number of gullies in fields with recently installed erosion control measures was about twice as high than the average number of gullies in fields without erosion control measures. It also showed that the number of gullies in fields with 6 to 10-year old erosion control measures was about half the number found in fields without erosion control. Firstly, this confirms that farmers install erosion control measures especially in fields with more erosion. Secondly, this shows that erosion is gradually reduced during the years after installation of erosion control measures.

In addition to rills and gullies, which were used as erosion indicators in the evaluations above, soil crusts and deposits prove useful sheet erosion indicators. The soil cover of runoff deposit of coarse sand, found in the furrows, turned out a good indicator for sheet erosion, sensitive to the slope of the sowing direction. However, only observations done halfway the rainy season are useful as erosion indicators. Towards the end of the rainy season, runoff deposit of coarse sand is gradually covered with runoff deposit of fine sand and *in situ* depositional crusts (Chapter 7).

If one wants to extrapolate the field-level effect of erosion control (reducing erosion by about 50%) to the impact on erosion in southern Mali, one will have to take into account that erosion control measures were installed on only 15% of the fields, and that the initial erosion (reconstructed baseline) in fields with erosion control was about 2.6 times more severe that in fields without erosion control. This implies that erosion in southern Mali as a whole would have been reduced by about 16%, due to erosion control measures.

8.4.2 Methods for evaluations in the absence of baseline data

In the absence of baseline data, the reconstructed baseline and the virtual time series proved useful in evaluating the effect of erosion control on erosion. However, some of the assumptions and risks of these methods need to be discussed.

The reconstructed baseline assumes that the total number of gullies (active, partly reclaimed and fully reclaimed gullies) gives an indication of erosion before erosion control measures were installed. Three scenarios may affect the conclusions.

1. Some active gullies may have appeared after the installation of erosion control measures. This would not really affect the conclusions.
2. Some reclaimed gullies may no longer be visible. In fields with ‘older’ erosion control measures, less active gullies were found—as we would expect—but not more reclaimed gullies were found. It is unlikely that fields with older erosion control measures initially suffered less from erosion. We thus probably underestimate the number of reclaimed gullies because some are no longer visible. In this case, the effect of erosion control measures is underestimated.
3. It is possible that enumerators made more effort to ‘find’ reclaimed gullies in fields with gully interventions. In that case, the effect of erosion control measures would be overestimated.

The risk to overestimate the effects can be reduced by a more objective definition of what should be considered a reclaimed gully. It may be better to consider only partly reclaimed gullies that are still visible and not to consider fully reclaimed gullies that are not always visible. Recalculations with the reconstructed baseline, excluding fully reclaimed gullies, gave similar results to those presented in this paper.

The interpretation of a virtual time series depends on the assumption that erosion before the installation of erosion control measures was the same in fields with older erosion control measures as in fields with recently installed erosion control measures. Two scenarios may affect the conclusions.

1. If erosion were initially higher in fields with older erosion control measures, the trend of decreasing erosion would be underestimated.
2. If on the contrary, erosion were initially higher in fields with recently installed erosion control measures, the trend of decreasing erosion would be overestimated.

At the time of installation, the fields chosen for erosion control were those suffering most from erosion. Gully volume Kaniko village in 1988 was higher (58 m^3) than the average gully volume found in other villages in 2000 (14 m^3), which reassures the assumption that erosion was initially higher in fields with older erosion control measures than in fields with recently installed erosion control measures.

8.5 Conclusions

The erosion control measures installed by farmers at large intervals (>100m) on gentle slopes (1-2%) in southern Mali reduced soil erosion by about 75%. Different evaluation methods come to similar conclusions. The case study in Kaniko village showed that a combination of line interventions and cultivation across to the slope decreased gully volume and soil loss between 1988 and 2003. In 60 villages without documented baseline, the evaluation using a reconstructed baseline of total (active and reclaimed) gullies showed that line and gully interventions decreased the proportion of active gullies. In the same 60 villages, a virtual time series, comparing erosion in fields with erosion control measures installed in different years, showed a trend of decreasing erosion after installation of erosion control measures.

Ex-post evaluations are often handicapped by missing baseline data. An evaluation that uses a reconstructed baseline or a virtual time series is not as convincing as a correct evaluation with real baseline data, but both methods tell us much more than a simple 'with-without' comparison that does not consider the situation in the past.

After this chapter, which evaluated the effect of erosion control on soil erosion, the following chapter will evaluate the effect of erosion control on crop yield.

Chapter 9

Impact of Erosion Control on Crop Yield in Southern Mali

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Submitted to: CATENA

9 Impact of Erosion Control on Crop Yield in Southern Mali

Abstract

In the absence of baseline data, a simple 'with-without' comparison does not allow a correct impact evaluation because farmers install erosion control measures especially in fields with more erosion and farmers adopting erosion control measures generally cultivate more intensively. Two alternative methods are used: 1) expanding the 'with-without' comparison with several farm and field characteristics as covariates in linear regression analyses; 2) constructing a virtual time series, comparing fields with erosion control measures installed in different years, and comparing villages targeted by the SWC programme in different years. Results from linear regression analyses show a positive interaction between stone rows installed above the cultivated area and rainfall in their effect on crop yield, whereas the effect of vegetative barriers seems not to depend on rainfall. The average cotton yield increase, comparing fields with and without erosion control, is estimated at 4.8%. Results from virtual time series show that stone rows have an immediate effect on crop yield whereas the effect of vegetative barriers gradually increases over the years after installation. The average cotton yield increase, comparing old SWC villages with new SWC villages, is estimated at 12.5%. We strongly recommend that SWC projects monitor baseline data for later impact evaluations.

Key words: impact evaluation, erosion control, crop yield, southern Mali

9.1 Introduction

9.1.1 One step in the evaluation of impact

When evaluating the impact of a project, we try to attribute change at the global objective level to project activities (van Leeuwen et al., 2000; Guijt and Woodhill, 2002). For the soil and water conservation (SWC) project discussed here, the global objectives were to reduce land degradation, intensify agriculture and improve productivity (PLAE, 1986). The main project activity was training farmers in SWC. There is a long cause-effect chain between project activities and impact and to prove a causal relation it is best to split this chain into several subsequent and parallel steps. One of these steps is the effect of erosion control on crop yield and will be the topic of this paper.

Besides splitting the cause-effect chain into smaller steps, we also want to attribute the observed change to the project. Therefore, we need a 'with-without' comparison of crop yields in fields with and without erosion control measures. However, erosion control measures are not installed at random in farmers' fields but are installed especially in fields with severe erosion problems, so we cannot simply compare fields with and without erosion control measures. Ideally, we would include a 'before-after' comparison of crop yields before and after erosion control measures were installed. For a correct ex-post evaluation, we thus depend on baseline information monitored in the past.

The main focus of the SWC programme in southern Mali was large-scale extension, eventually reaching as many farmers in as many villages as possible, to ensure large-scale adoption of SWC measures. Therefore, the monitoring and evaluation system was geared mainly to extension activities and adoption of SWC measures by farmers and there was no regular monitoring of crop yields by the SWC programme. Here we are confronted with a problem: how to evaluate (ex-post) the effectiveness of erosion control measures in the absence of baseline data?

9.1.2 Attribution of crop yield to erosion control

It is often difficult to separate the effect of erosion control and the effect of other yield-affecting factors. Reij and Thiombiano (2003) have done an impact study on the Central Plateau of Burkina Faso (annual rainfall 600 – 700 mm). The study is interesting because of the large scale, the wide view on impact and the long period over which changes were followed. Trends in average crop yields were explained by SWC projects, rainfall and population pressure. Although the study concludes that the situation has improved over the last decades, separation of causes and effects and attribution of impact to the SWC project remains vague. A comparison of sorghum and millet yield in fields with and without erosion control measures showed an increase by erosion control varying from +2% to +22%.

The comparison of crop yields with and without erosion control is complicated first of all because erosion control measures are installed especially in fields with erosion problems, which generally yield lower than fields without erosion problems. Farmers in southern Mali explained that before SWC measures were taken in certain degraded fields they could only grow sorghum and millet, whereas now they grow also the more demanding crops cotton and maize. Some farmers on the Central Plateau in Burkina Faso indicated even that they would have abandoned the field if no SWC measures had been taken. (Ouedraogo et al., 2001).

The comparison of crop yields with and without erosion control is also complicated because farmers adopting erosion control measures cultivate more intensively: they produce more compost, are often better equipped which enables them to do farm operations more timely and more frequently. Haima (1996) compared sorghum and millet yield in fields with and without stone rows in two sites in Burkina Faso in 1994. Although a simple comparison showed 14% higher yields in fields with stone rows, a more complete regression analyses showed that this was the effect of higher fertilisation and labour input, not the effect of stone rows.

9.1.3 Attribution of erosion control to crop yield

Erosion can result in reparable productivity loss – fertility loss that can be restored by fertiliser – and residual productivity loss – reduced infiltration, diminished rooting zone and weakened soil structure (de Graaff, 1996). We consider three effects of erosion control that may increase crop yield: water conservation, fertiliser conservation and soil conservation.

Water conservation

Where water is limiting, erosion control will usually reduce runoff, allow water more time to infiltrate and increase water availability to the crop. This effect will be more pronounced in dry years, and with drought sensitive crops.

Schorlemer (2000) evaluated the effect of stone rows, zai, compost and mulching in the PASP project in Niger during three years (annual rainfall 280 – 499 mm). Although the set up did not allow a good separation of the effect of erosion control from the effect of fertilisation, it appeared that stone rows alone increased crop yields in the dry year (+52%) and in the average year (+19%), whereas in the wettest year, stone rows increased crop yields only in combination with organic fertilisation or mulch (+60%).

In an experimental set up, the effect of stone rows on sorghum yields was tested in a dry area of Burkina Faso (Kirsi village, annual rainfall in 1992 and 1993 of 470 and 664 mm). At inter-stone row distances of 50, 33 and 25 m, sorghum yields increased with 58%, 109% and 343% respectively (Zougmore et al., 2000).

Better effects under sub-optimal water availability conditions were found also by Hengsdijk et al. (2005) in Ethiopia. However, better effects in wet years were found by Sharma et al.(1999) in India.

Fertiliser conservation

Erosion control will reduce losses of organic and chemical fertiliser. This effect will be more pronounced in average and wet years, and with fertilised crops.

In an experiment in a more humid area of Burkina Faso (Saria research station, annual rainfall in 2000 – 2003 of 713 – 796 mm), stone rows or grass strips increased sorghum yield only if combined with organic fertilisation (+142%) or inorganic fertilisation (+65%) (Zougmore et al., 2003).

The relation with fertiliser is not always clear. PATECORE, a large SWC project in Burkina Faso, evaluated the effect of stone rows and earth bunds in combination with inorganic and organic fertilisation on sorghum and millet yields (PATECORE, 2000). Rains in 1999 started late but total rainfall was above average (765 mm). Overall, fields with erosion control measures yielded 20% more (+130 kg ha^{-1}) than the control. Effects of erosion control measures were positive if no fertiliser or mineral fertiliser was applied, but negative if compost was applied, an observation for which no explanation was given.

Soil conservation

Where runoff, sheet and gully erosion are excessive, erosion control will reduce losses of topsoil and soil organic matter and reduce the degradation of soil chemical and physical properties. This effect will be strongest in wet years, and with crops supporting erosion less well.

Soil erosion, considered separately from water and fertiliser losses, is a slow and cumulative process. The effect of soil erosion on crop yields has been estimated as a percentage of yield reduction per year. Hallam and Verbeek (1986) relate a soil erosion of 15 tons ha^{-1} y^{-1}, or 1.2 mm of soil y^{-1}, to a yield reduction of 2.6 – 5.4% y^{-1}, based on research done in Ibadan by Lal (Lal, 1976, cited by Hallam and Verbeek, 1986). Bishop and Allen (1989) estimated that erosion reduced farm net revenue with 2-10% per year in Burkina Faso, and that erosion accounted for a loss of 1-2% of the agricultural GDP per year in Mali.

In southern Mali, about 33% of the fields showed erosion gullies (including smaller gullies) which are shallow, on average 0.17m, but wide, on average 1.47m. In a regression analysis of cotton yield on erosion, in which rainfall, fertilisation, crop management and field characteristics were taken into account, a significant negative effect of gullies was found of -75 kg ha^{-1} $gully^{-1}$ (Chapter 7). With an average of 0.6 gullies per 100 m transect, this would correspond with an overall cotton yield reduction of 45 kg ha^{-1}, or about 4,5% of the average cotton yield. In the same study, erosion control proved effective in reducing the number of active erosion gullies compared to the total number of gullies (active, partly reclaimed and fully reclaimed gullies).

Although soil conservation may significantly reduce runoff and soil loss, this does not automatically increase crop yield (Herweg and Ludi, 1999).

9.1.4 Yield trends after installation of erosion control measures

Yield trends could support the evaluation of erosion control measures, based on the following hypotheses.

1. In ‘new SWC villages’, yields before SWC activities start will be lower than in ‘non-SWC villages’, because of bigger erosion and land degradation problems. After SWC activities have started, crop yields will gradually increase over several years. In ‘old SWC villages’, where the SWC programme has run for several years, crop yields will be higher than in new SWC villages.
2. The time lag between installation of erosion control measures and yield benefits is short (one year) if benefits are related to conservation of water or fertiliser, but longer (several years) if benefits are related to soil conservation.
3. Stone rows and check dams are immediately effective in reducing runoff and erosion, whereas vegetative barriers – especially live fences from woody shrubs – need several years to grow into effective barriers.
4. The difference in crop yields between fields with and without erosion control will gradually increase in the years after installation.

To our knowledge there has been no SWC programme that systematically monitored crop yields under farmer conditions from before erosion control measures were installed up to several years after installation.

9.1.5 Objectives and research questions

The objective of this study is to evaluate the effect of erosion control measures on crop yield under farmer conditions. To meet this objective, the following technical and methodological questions are formulated:

1. What are the interactions between erosion control and rainfall and between erosion control and fertilisation in their effect on crop yield?
2. To what extent can an ex-post evaluation, in the absence of baseline data, estimate the 'net effect' of erosion control measures by including other yield affecting variables in the analyses?
3. To what extent can yield trends, both real time series (with crop yields of different years) and virtual time series (with crop yields of one year from fields with erosion control measures of different age) help evaluate the effect of erosion control?

9.2 Material and methods

9.2.1 Description of research area and SWC project

The study area is the part of southern Mali covered by the semi-government Malian cotton and rural development organisation (*Compagnie Malienne pour le Développement des Textiles, CMDT*). Annual rainfall varies from 1300 mm at the southern border with Guinea to 600 mm in the northeast, just north of the cotton-cultivation limit (700 mm). The area covers 125 000 km^2 and hosts over 5000 villages. Based on different sources and assuming a population growth of 2.2%, we estimate the rural population in southern Mali at 3.1 million in 2002 (CMDT, 1996; Schrader and Wennink, 1996; MaliArp, 1999). An average farm family is composed of 17 persons and cultivates 10 ha of land, or about 0.6 ha per person. 77% of the farm families have at least 1 plough and 2 oxen. Cotton is the main cash crop, grown by 81% of the farm families, in a 2 or 3-year crop rotation with cereals. About 29% of the land area is under cotton, 22% under sorghum, 20% under millet, 16% under maize, 7% under groundnuts, 4% under rice and 2% under other crops and crop associations (CMDT, 2003).

Although slopes are gentle, there is substantial water runoff and soil erosion caused by high rain erosivity, long slopes, poorly covered soils, and fragile soil structure. Roose (1985) estimated water runoff at 20 – 40% and soil loss at 26 t ha^{-1} y^{-1} for a typical 2% cultivated slope. Bishop and Allen (1989) measured an average soil loss of 10 t ha^{-1} y^{-1} on cultivated fields, going up to 31 t ha^{-1} y^{-1} in the most southern, steeper part of southern Mali. Vlot and Traoré (1994) measured in 5-meter cultivated runoff plots, on a 1.4 – 1.7% slope, runoff coefficients of 7-14%, and annual soil loss rates of 5-6 t ha^{-1} , but they remarked that runoff and erosion outside the small runoff plots were higher.

Since 1982, the Malian farming systems research group (*Division de Recherche sur les Systèmes de Production Rurale*) has tested SWC approaches, including both technical and extension aspects. Following complaints by farmers about decreasing yields and water washing away their crops, trials were carried out in 1984 in collaboration with the CMDT. This resulted in the creation of the SWC project (*Projet Lutte Anti Erosive*) within the CMDT structure in 1986 (Hijkoop et al., 1991).

The dense network of the CMDT extension service has reached a large number of villages and farmers. Between 1986 and 2000, about 2500 villages, half of the villages in southern Mali, received the package of SWC training (Bodnár and de Graaff, 2003). Farmers in other villages received at least some general information on SWC. In 2002, erosion control measures were installed in 94% of the villages, on 46% of the farms and in 15% of the fields. The most found erosion control measures were vegetative barriers (7% of the fields), which include live fences (6%) and grass strips (2%) installed on field boundaries, followed by stone rows (3%) installed on contour above the cultivated area, gully interventions (3%) where stone or crop residue check dams are installed, and other measures (3%) including dikes, drainage canals and contour marker ridges (CMDT M&E data 2002).

9.2.2 Field observations in 2000

In 2000, a study to evaluate the SWC programme was carried out by about 30 soil conservation specialists from the SWC Unit and 30 enumerators from the Monitoring and Evaluation (M&E) Unit of the CMDT. Two different samples were used:

1. One representative sample was taken of 82 farmers (in 30 villages), from the regular sample used by the CMDT M&E Unit.
2. One selective sample was taken of 216 farmers in 30 other villages with high SWC adoption. The reason for this selective sample was to have more data from fields with SWC measures.

So, a total of 298 farmers in 60 villages were interviewed and 841 fields were visited (two or three fields per farmer). Out of these, 713 fields provided sufficient information for yield analyses, and only 584 fields provided also sufficient and consistent data on slope and presence of erosion gullies.

Field observations and interviews considered 1) annual rainfall, general field characteristics and erosion risk, 2) erosion control, 3) actual erosion, 4) fertilisation, and 5) crop yields obtained in 1999.

Observations on field characteristics and erosion risk included number of years the field had been under cultivation since last fallow, which serves as indication of land pressure (average value per village) and as indication of field age (compared with village-average); slope %; slope length, expressed in meters between observed field and non-cultivated area above; soil texture, using the 'rolling of wet soil' method (Herweg, 1996).

Observations on erosion control measures included the presence of each type erosion control measure; the protection by line interventions expressed in percentage of field width protected; the quality of line intervention expressed in percentage intact; and year of installation. Measures in the field (including on field boundaries and stone rows within 50m distance) were distinguished from measures above the field (in neighbouring fields and stone rows at more than 50m distance).

Observations on erosion were done on a field transect, in the middle of the field perpendicular to the slope, and included number of active gullies (including smaller rills), partly reclaimed gullies (visible, slowly filling up) and fully reclaimed gullies (visible or identified by farmer) per 100 m transect. Depth and width of active gullies were measured.

Crop yield and fertilisation data were asked in interviews. Yield data of cotton are registered at the village level and are more accurate than of other crops. Other crops considered in this study were maize, sorghum and millet.

9.2.3 Data from monitoring and evaluation

The M&E Unit of the CMDT collects data from a sample of 41 - 55 villages, representative for the different agro ecological zones of southern Mali. Enumerators interview over 4000 farm families and measure field sizes and yields in a sub-sample of over 800 farm families annually.

Monitored farm characteristics include farm size and area under different crops, family size and household composition, and available farm equipment and animals. Monitored field characteristics include years since last fallow and crop rotation history. Monitored crop management characteristics include type and date of tillage, sowing, weeding, fertiliser application and doses, compost use and insecticide treatment. Farmers were asked about crop yields of the whole field; yield is measured in two sample yield plots per field. Plant density and crop damage causes are monitored as well. Up to 1999, adoption of erosion control was only known at the farm level, not at the field level. From 2000 onwards, erosion control was also known at the field level.

In this study, only the sub-sample of 800 'measured' farms was used, and therefore results differ slightly from other published CMDT M&E reports referring to 4000 farmers. Numbers of yield data per year and per crop, distinguishing fields with and without erosion control measures are presented in Table 9.1.

Table 9.1. Number of yield data from fieldwork (1999) and from the M&E Unit (1999-2002), distinguishing crops and erosion control measures.

		Fieldwork	M&E Database			
		1999	1999 [a]	2000	2001	2002
Cotton	Without erosion control	83	332	259	564	566
	Vegetative barrier	74	128	57	100	85
	Stone row	34	64	13	37	35
	Check dams	68	37	10	24	25
Maize	Without erosion control	69	304	387	465	528
	Vegetative barrier	56	119	61	59	61
	Stone row	24	62	10	19	18
	Check dams	39	39	9	11	15
Sorghum	Without erosion control	63	318	566	499	581
Millet	Without erosion control	65	217	373	369	391
	Vegetative barrier	107	211	118	80	82
	Stone row	35	91	35	30	43
	Check dams	68	73	14	12	45

[a] M&E data in 1999 included adoption of erosion control at farm level, not at field level.

9.2.4 Linear regression analyses including other yield-affecting variables

By including other yield-affecting factors as covariates in a regression analyses, we move from a 'first sight' correlation, a simple comparison of fields with and without erosion control, to a more plausible 'cause-effect' relation between erosion control and crop yield. The following variables were added: rainfall and interaction with erosion control; fertilisation and interactions with erosion control and rainfall; crop management; and field characteristics. Four rainfall indicators were used: annual rainfall, in a linear and quadratic term (assuming a rainfall optimum); and the difference between annual rainfall and the 10-year average rainfall, in a linear and quadratic term (assuming an additional effect of relatively dry and wet years). By adding more variables, we explain more crop yield variation and discriminate better the 'net' effects of the erosion control. On the other hand, by including too many factors, often partly interdependent, we may trouble the attribution of yield effect to underlying causes, especially if the data set is small. For each analysis, all available variables were entered and non-significant variables were one by one removed (backward linear regression). The total effect of each erosion control measure is calculated by adding up the main effect and the interactions with rainfall and fertilisation, using the average rainfall and fertilisation values from fields with that erosion control measure.

Because of its simplicity, linear regression and least squares analyses were preferred over more advanced analyses (non linear model with maximum likelihood estimates).

9.2.5 Crop yield trends after installation

No baseline crop yields were collected from before erosion control measures were installed. However, M&E yield data from 1997 to 2002 can be separated into yields from 'old SWC villages' where the SWC project had started activities at least 4 years ago, 'new SWC villages' where the SWC project had started more recently, and 'non-SWC villages' where the SWC project had not started and where only limited SWC information was given by the general extension workers. A comparison of these three groups of villages gives an indication of yield trends after SWC training.

Another method, applied to the fieldwork data, is to create a virtual time series by comparing crop yields in 1999 from fields with erosion control measures installed in different years. The presentation of crop yield as function of year of installation gives an indication of the yield trend after installation.

9.3 Yield difference between fields with and without erosion control

9.3.1 Simple comparison with and without erosion control

When we simply compare crop yields from fields with and without erosion control measures we would draw different conclusions for different erosion control measures, for different crops and in different years (Table 9.2). Firstly, positive effects of erosion control, especially the effect of stone rows, are more pronounced in the wet year. Erosion control hardly seems to have an effect in the dry year. Secondly, effects on cotton and maize are positive, whereas effects on sorghum and millet yield are sometimes negative.

Besides the effect of erosion control measures in the field there is also an effect of erosion control measures installed above the observed field. According to the fieldwork data from 1999, cotton yield is 207 kg ha^{-1} higher under stone rows more than 50 m away. This means that the distance between the field and the stone row does not matter for its effect. On the contrary, sorghum and millet yields are 211 kg ha^{-1} lower under fields in which check dams are installed. In other words, fields with check dams yield higher, but fields underneath other fields with check dams yield lower, even in combination with check dams in the field. We assume that fields below check dams have serious erosion problems and that check dams are not sufficient to control erosion.

Table 9.2. Crop yield and the effect of erosion control measures on different crops, in a wet year (1999), average years (2000 and 2001) and in a dry year (2002) in southern Mali, not taking into account other yield-affecting factors.

		Wet year 1999		Average years	Dry year
		Field work	M&E	2000-2001	2002
Rainfall (mm)		1025	957	832	682
Cotton	Without EC	1092	1002	1018	936
	Vegetative barrier			+169***	
	Stone row	+207***	+133**		
	Check dams				
Maize	Without EC	1691	1571	1217	1161
	Vegetative barrier		+170**	+122 *	
	Stone row		+237**		
	Check dams				
Sorghum	Without EC	938	963	794	750
Millet	Without EC	874	793	754	656
	Vegetative barrier		+168***	+105***	
	Stone row		-96**		
	Check dams	+104 *	-82 *		+170***

Significance: *** p<0.01; ** p<0.05; * p<0.10

9.3.2 Effect of rainfall and interactions with erosion control

The presence of erosion control measures correlates with rainfall. Vegetative barriers are found more in the dryer regions Koutiala (12% of the fields) and San (19%) than in the wetter regions Sikasso (6%) and Bougouni (5%). On the contrary, stone rows and check dams are found more in the wetter regions (5%) than in the dryer regions (2%) (M&E data 2002).

We find a consistent positive interaction between stone rows and rainfall on cotton yield (Table 9.3). In other words: the effect of stone rows is more positive with more rainfall. For the other erosion control measures and for other crops, interactions are not as clear.

Table 9.3. Interactions between rainfall and vegetative barriers, stone rows and check dams in their effect on crop yield.

		Wet year (1999)		Average year	Dry year
		FW	M&E	2000-2001	2002
Cotton	Rain x Veg. barrier		+0.4**		-0.8***
	Rain x Stone row	+1.3***	+2.2***	+0.7*	+1.0*
	Rain x Check dam		+0.5***		
Maize	Rain x Veg. barrier				
	Rain x Stone row				
	Rain x Check dam		+2.7**		+3.0***
Sorghum	Rain x Veg. barrier				
Millet	Rain x Stone row	+0.2***			+0.9*
	Rain x Check dam		-0.1**	+0.5 *	+0.3***

Significance: *** $p<0.01$; ** $p<0.05$; * $p<0.10$

The positive interaction between rainfall and stone rows explains the positive effect of stone rows in the wet year 1999. Interactions become clearer when cotton yield is plotted against the rainfall expressed as difference from the 10-year average rainfall (Figure 9.1). For clarity, the 2019 yield points are not plotted. Regression coefficients of trend lines are significant ($p<0.10$). Stone rows increase cotton yield especially when there is excess of water, but reduce cotton yield if rainfall is less than 170 mm below average. Vegetative barriers generally increase cotton yield and more so in average rainfall years. Check dams seem to have a positive effect in wet years but a negative effect in wet years (sorghum and millet in Table 9.2; cotton in Figure 9.1).

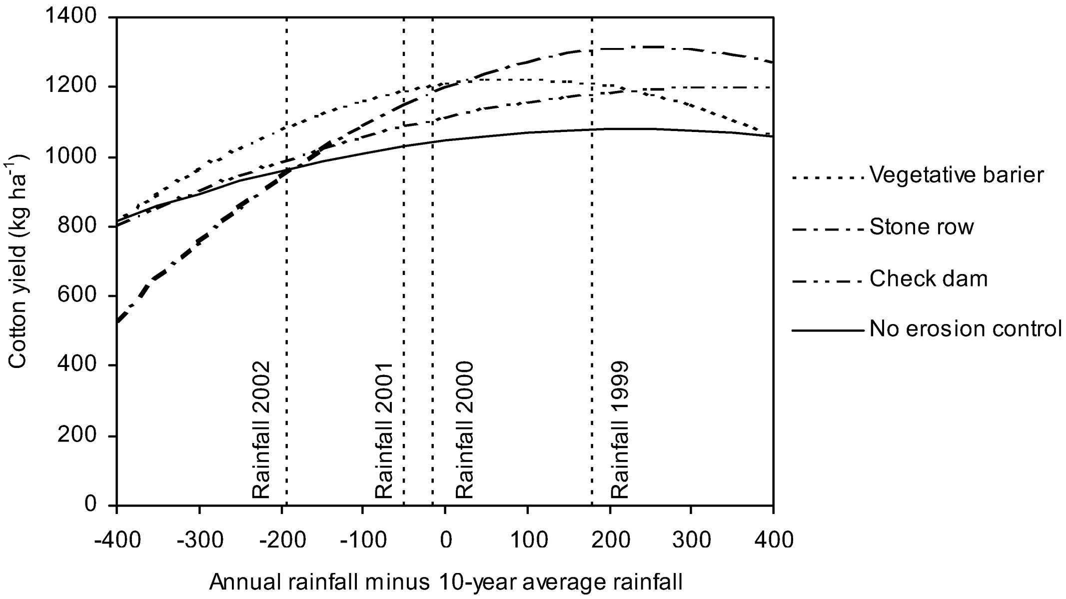

Figure 9.1. Interactions between erosion control measures and relative rainfall, expressed in difference with the 10-year average rainfall, in their effect on cotton yield.
Source: M&E data 1999-2002, southern Mali.

9.3.3 Effect of fertilisation and interactions with erosion control

The effect of mineral fertiliser is most pronounced in the wet year 1999. However, the negative interaction between rainfall and mineral fertiliser on cotton yield indicates a decreasing effect of mineral fertiliser with increasing rainfall. With the average rainfall in 1999 of 957 mm, 1 kg of mineral fertiliser (complex fertiliser and urea) would have given 1.3 kg cotton. This low response compared to that of maize (2.2) and that of sorghum and millet (5.4) is due to the higher doses applied to cotton, closer to the optimum dose. In the dry year 2002, only maize seemed to respond to mineral fertiliser and its effect increased with increasing rain.

The interpretation of crop yields with and without compost is complicated by the farmers' 'compensation strategy'. Compost, mainly reserved for cotton and maize, is applied to those fields (or parts of fields) that are most impoverished. Farmers apply cotton in a rotation, aiming to eventually fertilise all fields. Maize grown after well-fertilised cotton receives compost less often (34%) than maize grown after sorghum or millet (50%). This compensation strategy camouflages the positive effect of compost. Nevertheless, from the analyses it seems that the effect of compost is positive with average and slightly above average rainfall, but decreases with both excessive rainfall and with low rainfall (Table 9.4).

Farmers who adopt erosion control measures, especially farmers with vegetative barriers, produce more often compost and have more often compost pits or improved cattle pens, two composting techniques that were promoted by the SWC project (Table 9.5).

Table 9.4. Effect of mineral fertiliser[a] and compost[b] and the interactions[c] with rainfall on crop yield.

		Wet year (1999)		Avg. year	Dry year (02)
		Fieldwork	M&E	2000-2001	2002
Cotton	Mineral fertiliser		+6.4**	+1.2***	
	Min. fert. x Rain		-0.005 *		
	Compost				
	Compost x Rain			+0.087**	
	Compost x Min. fert.				
Maize	Mineral fertiliser		+2.2***		
	Min. fert. x Rain			+0.001***	+0.001*
	Compost		+1794***		
	Compost x Rain		-1.519***		
	Compost x Min. fert.				
Sorghum	Mineral fertiliser		+5.4***	+3.6**	
Millet	Min. fert. x Rain		-0.004**	-0.004*	
	Compost	+316***	+69**	+81**	-96**
	Compost x Rain	-0.465***			
	Compost x Min. fert.	+0.791***			

[a] Effect in kg crop yield per kg fertiliser.
[b] Effect in kg crop yield per ton compost (fieldwork 1999) or per 3 tons compost (other data).
[c] Interaction effect in kg crop yield per mm rainfall per unit fertilisiser (kg mineral fertiliser, ton compost in fieldwork 1999, or 3 tons compost in other data).
Significance: *** $p<0.01$; ** $p<0.05$; * $p<0.10$

Table 9.5. Adoption (in % of farmers) of compost production, compost pit and improved cattle pen by farmers without erosion control, and additional adoption by farmers with vegetative barriers, stone rows and check dams.

	No erosion control	Vegetative barrier	Stone row	Check dam
Compost production	70	+21		+12
Compost pit	15	+37	+11	
Improved cattle pen / stable	7	+8	+9	

For adopters of erosion control, only significant differences ($p<0.10$) are shown.
Source: M&E 2002.

Farmers fertilise fields with erosion control measures more than fields without erosion control measures. This is more pronounced in cotton fields (more fields with compost) and in fields with vegetative barriers (more mineral fertiliser) (Table 9.6).

In the average rainfall years (2000-2001), there were no significant interactions between fertilisation and erosion control in their effect on crop yields. Only in the wet year (1999) and the dry year (2002), a few significant interaction effects showed up (Table 9.7).

Table 9.6. Fertilisation on fields without erosion control (No EC), and additional fertilisation on fields with vegetative barriers (VB), stone rows (SR) and check dams (CD).

	Mineral fertiliser (kg ha^{-1})				Compost (% fields)			
	No EC	VB	SR	CD	No EC	VB	SR	CD
Cotton	166	+12			36	+21	+14	+11
Maize	104	+25	+27		39	+13		
Sorghum / Millet	5	+6	-4		11			+7

For adopters of erosion control, only significant differences (p<0.10) are shown.
Source: M&E 2000-2002.

Table 9.7. Interactions [a] between fertilisation and erosion control (vegetative barriers [VB], stone rows [SR] and check dams [CD]) in their effect on crop yield.

		Wet year (1999)				Dry year (2002)	
		Fieldwork		M&E		M&E	
		Min.fert.	Compost	Min.fert.	Compost	Min.fert.	Compost
Cotton	Fert. x VB		+28 *				
	Fert. x SR	-6.6 ***					+243 **
	Fert. x CD			-2.6 **			
Maize	Fert. x VB						
	Fert. x SR	+5.5 ***					
	Fert. x CD		+112 ***	-4.6 ***		-2.3 *	
Sorghum	Fert. x VB		+48 ***	+2.0 ***			
Millet	Fert. x SR		-39 *	-1.9 **		6.4 *	
	Fert. x CD		+60 ***				

[a] Interactive effect, if erosion control is present: in kg crop yield per unit fertiliser (kg mineral fertiliser, ton compost in fieldwork 1999, or 3 tons compost in other data.
Significance: *** p<0.01; ** p<0.05; * p<0.10

In the wet year 1999, interactions between mineral fertiliser and erosion control are more often negative than positive whereas interactions between compost and erosion control are more often positive than negative.

9.3.4 Effect of crop management

Crop management (tillage, sowing, weeding, plant density) is an important source of crop yield variability and is partly explained by farm characteristics (farm size, family size, farm equipment and plough-oxen).

Crop management and farm characteristics are different in fields with erosion control measures. Both correlations between these indicators (farm characteristics and crop management) and their effect on cotton yield in a linear regression analysis are presented in Table 9.8. (Crop management indicators that contributed to cotton yield but that did not correlate to adoption of erosion control are not presented.) Generally, those farm characteristics, crop management practices and crop stand indicators correlating with erosion control, have a positive effect on cotton yield.

Table 9.8. Left: Correlation between adoption of erosion control (vegetative barriers [VB], stone rows [SR] and check dams [CD]), and farmer characteristics and crop management, expressed in difference with farmers and fields without erosion control (No EC); Right: Effect of farm characteristic and crop management on cotton yield.

	Correlation with erosion control				Effect on cotton yield in linear regression		
Farm characteristics	No EC	VB	SR	CD	Wet year	Avg. years	Dry year
Family size (p)	14.8	+6.6	+5.1				
Literates	1.7	+1.4	+0.7				
Farm size (ha)	9.0	+2.7	+4.6				+
Cultivated ha / person	0.7		+0.2				
Farmer type (ABCD) [a]	18%	+15%	+18%	+22%		+++	
Ploughs	1.1	+0.6	+0.4	+0.4			
Oxen	2.5	+1.6	+0.9	+1.0			
Oxen / ha	0.3	+0.1		+0.1			
Other cattle	4.7	+7.2	+4.0	+5.7			
Carts	0.6	+0.3	+0.2	+0.2			
% Land under cotton	23%	+3%	+6%	+4%			
% Land under maize	14%	-4%	+3%				
Crop management (cotton)							
Direct sown	6%	-5%	-5%		---	--	
Manual tillage	4%	-4%			--		
Ridging before sowing	11%	-9%	-7%	-9%	-	---	
Ploughing	63%	+13%	+18%		---	--	
Harrow and plough	7%	+6%		+12%		--	
Sowing date farmer [b]	-8	-3			---	---	---
Mechanic sowing	59%	+9%		+11%	+++		
Thinning	83%	+6%					-
Times weeding	2.0	+0.2	-0.2			--	--
Mechanic weeding	71%	+10%	+11%	+14%		++	-
1st weed date (d.a.s.)	24	-1					
Ridging after weeding	74%	+15%					
Herbicide use	26%	-7%	+12%	+10%			
Times insect treatm.	4.4	+0.2	+0.7		++	+++	+++
1st treatm. date (d.a.s.)	49	-3				---	---
Plant density	44690			+3241	++	+++	+++
Damage by cattle	0.4%		+2.7%	+1.6%			

[a] Farmer type: A=at least two ploughing sets (plough and 2 oxen); B=at least one set; C=one incomplete set; D= manual farmer. For correlations: in each adoption column, the percentage of farmers type A are given. For regression: farmer type is used as continuous variable.

[b] Sowing date farmer expressed in days difference with village average.

Significance correlations: for adopters of erosion control, only significant differences ($p<0.10$) are shown. Significance regression: +++, --- $p<0.01$; ++, -- $p<0.05$; +,- $p<0.10$.

Source: Farmer characteristics: M&E 2002. Crop mgt.: M&E 2000-2002.

Farmers who adopt erosion control measures often have larger families, cultivate more land, and have more equipment (ploughs, oxen, carts), which allows them to cultivate more ha per person. Even the number of oxen per ha cultivated land is slightly higher, which allows farmers to do mechanical operations more intensively (ploughing), more often and more timely (weeding). They have a larger portion of their land under cotton. Crop damage from livestock is higher in fields with stone rows and check dams, which are closer to the communal grazing areas on the plateau.

9.3.5 Effect of field characteristics and interactions with erosion control

Two groups of field characteristics are distinguished: 1) detailed observations on erosion and erosion risk from the fieldwork, and 2) crop rotation and fallow history, monitored both during fieldwork and by the M&E Unit. Correlations between field characteristics are presented in Table 9.9.

Table 9.9. Correlations between field characteristics only observed during the fieldwork (left) and field characteristics also monitored by the M&E Unit (right).

	Total gullies	Slope	Veget. plateau	Texture	Gravel	Position	Land press.	Field age	Cotton rotation	Maize rotation
Total gullies [a]		+++	---	---		(+)	---	++	(+)	
Slope	+++		(+)			+++	---		+++	+
Veg. cover plateau [b]	---	(+)		+		--			++	+++
Texture [c]	---		+		---	---			(+)	+++
Gravel				---		+++	--		(+)	
Position: low / high	(+)	+++	--	---	+++			--		---
Land pressure [d]	---	---			--					
Field age [e]	++					--			(+)	++
Cotton in rotation	(+)	+++	++	(+)	(+)			(+)		
Maize in rotation		+	+++	+++		---		++		

[a] Total gullies includes active and reclaimed gullies, per 100 m transect across the slope.
[b] Vegetative cover plateau, estimated in classes (0-30%, 30-60%, 60-100%)
[c] Soil texture classes from sand to clay.
[d] Land pressure, expressed in number of years fields have been cultivated since last fallow, averaged per village
[e] Field age, expressed in number of years the field has been cultivated since last fallow, compared with village-average.
Significance: +++ --- p<0.01; ++ -- p<0.05; + - p<0.10; (+) (-) p<0.20.

Most erosion (total gullies) is found in sloping fields, under a plateau with poor vegetative cover, with light textured soils, often higher positioned on the toposequence (between valley and plateau). These fields are mostly found in villages in low land-pressure areas, which happen to be located more in the south and west, where slopes are generally steeper. Within the villages, most erosion is found in older fields, that have been under cultivation for a longer time, and where cotton is cultivated more often. Older cotton fields are situated lower on the toposequence.
Field characteristics vary between fields with and without erosion control measures (Table 9.10). Vegetative barriers are installed more often in fields that are positioned lower on the toposequence,

where soils contain less gravel, underneath a plateau with a higher vegetative cover. On the contrary, stone rows and check dams are installed more often on steep slopes, positioned high on the toposequence, in older fields in which more often cotton is grown. Stone rows are installed more often above fields with a heavier soil texture. This seems contradictory with the higher position on the toposequence, but these correlating differences in soil texture are differences between villages, not within villages. Stone rows are installed more often in high land pressure areas (the old cotton zone) and above fields where maize is grown more often. Check dams are installed especially on fields with more erosion risk (total gullies, as one would expect, and slope) and more erosion (active gullies).

Table 9.10. Correlations between field characteristics and presence of erosion control measures, gullies and crop yield.

	Vegetative barrier	Stone row	Check dam	Total gullies [a]	Active gullies [a]	Crop yield [b]	Cotton yield [b]
Total gullies	(+)	(+)	+++		+++		(-)
Active gullies	(-)		++	+++			--
Slope		+++	+++	+++	+++		
Field position (low-high)	---	+++	+++				(+)
Texture [c]		+++		---	---		
Gravel	---						
Vegetative cover plateau	+			---	---	+++	++
Land pressure [d]		++	(-)	---	---	++	++
Field age [e]		++	++	(+)		(+)	
Cotton in rotation		++	+++	+		+	+
Maize in rotation		+				(+)	++
Distance field-home		-		---	---		

Significance: +++ --- $p<0.01$; ++ -- $p<0.05$; + - $p<0.10$; (+) (-) $p<0.20$.

[a] Total gullies include active gullies and (partly) reclaimed gullies

[b] Crop yield in 1999, taking into account crop, rainfall and fertilisation

[c] Soil texture classes from sand (1) to clay (7)

[d] Land pressure, expressed in number of years fields have been cultivated since last fallow, averaged per village

[e] Field age, expressed in number of years the field has been cultivated since last fallow, compared with village average.

Source: Fieldwork 2000 southern Mali

Crop yield will thus be affected not only by the presence of erosion control measures, but also by the correlating field characteristics of which some are favourable (e.g. vegetative cover and land pressure) and others unfavourable (erosion gullies).

Two erosion risk indicators – slope and total gullies – were tested for their effect on crop yields, distinguishing main effects and interactions with erosion control measures. The only significant effects ($p<0.10$) that came out were a negative effect of total gullies on maize yield (-45 kg ha^{-1} $rill^{-1}$) and a positive interaction between slope (S in %) and vegetative barrier (VB yes/no) on maize yield (+258 kg ha^{-1} S^{-1} VB^{-1}).

9.3.6 From simple comparison to complete regression analysis

By gradually including more yield-affecting factors in the analyses, the 'net effects' of erosion control measures come out more clearly. As an example, we follow the effects of erosion control measures on cotton yield (in average rainfall years 2000-2001) during the sequence of five analyses (Table 9.11). First of all, the explained variance (adjusted R^2) in cotton yield increases from 0.031 in the simple analysis to 0.327 in the complete analysis, which makes conclusions based on the latter more reliable. Secondly, the apparent effect of vegetative barriers in the simple comparison is for more than half attributed to more favourable rainfall, fertilisation, crop management and field characteristics. Stone rows come out negative in the complete analysis, although only significant at the $p<0.10$ level.

Table 9.11. Effect of erosion control measures[a] on cotton yield (kg ha^{-1}) in an average rainfall year, in five analyses from simple comparison, gradually including other factors, to a complete linear regression analysis.

	Simple	+Rainfall	+Fertilisation	+Crop mgt.	+Field type
Vegetative barrier	+169***	+147***	+136***	+84**	+74**
Stone row			+28*	-49*	-51*
R^2adj.	0.031	0.049	0.095	0.288	0.327

[a] Check dams had no significant effect on cotton yield in 2000-2001

Note: the effects of the other independent variables that were taken into account are not presented.

Significance: *** $p<0.01$; ** $p<0.05$; * $p<0.10$

Table 9.12. Crop yield and the 'net' effect of erosion control measures (kg ha^{-1}), in a wet year (1999), average years (2000 and 2001) and in a dry year (2002) in southern Mali, eliminating the effects of rainfall, fertilisation, crop management and field characteristics.

		Wet year 1999		Average years	Dry year
		Field work	M&E	2000-2001	2002
Rainfall (mm)		1179	957	832	682
Cotton	Without EC	1092	1002	1018	936
	Vegetative barrier	+67 *	+22 **	+74 **	+107 ***
	Stone row	+187 ***	+163 ***	-51 *	-60 *
	Check dams		+46 **		
Maize	Without EC	1691	1571	1217	1161
	Vegetative barrier	+341 ***	+147 *		
	Stone row	-72 ***			
	Check dams	+257 ***	-204 *		-46 *
Sorghum	Without EC	938	963	794	750
Millet	Without EC	874	793	754	656
	Vegetative barrier	+77 ***	+41 ***	+66 *	
	Stone row	+108 *	-49 **		-35 *
	Check dams	+110 ***	-109 **	-96 *	+179 ***

Significance: *** $p<0.01$; ** $p<0.05$; * $p<0.10$

The 'net' effects of erosion control measures on crop yields, as analysed in the most complete analyses, distinguishing wet, average and dry years, are presented in Table 9.12. A comparison between Table 9.2 (simple comparison) and Table 9.12 (complete analyses) shows that more effects come out significantly. Vegetative barriers show positive effects more often than stone rows or check dams. Cotton yields are improved more often than yields from other crops. In a wet year, the effect of erosion control, especially the effect of stone rows, is more positive than in average or dry years.

The effect of erosion control measures on cotton yield, presented in Table 9.12, is averaged for 1999-2002: vegetative barriers, stone rows and check dams increase crop yield with 75, 3 and 6 kg ha^{-1} respectively. The adoption rates, presented in Table 9.1, can be averaged for 2000-2002: vegetative barriers, stone rows and check dams are present in 14, 5 and 3% of the cotton fields. Combining the yield effects with the adoption rates gives an overall yield effect of erosion control measures of 49 kg ha^{-1} or 4.8%. This figure is small but it should be recalled that it is calculated using significant results from statistical analyses and that it is the 'net effect', without the influence of rainfall, fertilisation, crop management or field type.

Extrapolation of this field-level effect, taking into account that erosion control measures are installed in 22% of the cotton fields, shows that the erosion control measures have contributed to a 1.1% increase of the total cotton production in southern Mali.

9.4 Yield trends after installation of erosion control measures

9.4.1 Comparing 'old' SWC villages, 'new' SWC villages, and non-SWC villages

When we simply compare 'SWC – villages' (villages targeted by the SWC programme and having installed an SWC village team) with 'non – SWC villages', we find no difference in crop yields.

On the one hand, villages were selected for the SWC programme on the basis of erosion problems, where crop yields are expected to be lower. On the other hand, the combined effect of erosion control and increased compost use should increase crop yields.

We compared 'new SWC villages', where the SWC programme has run for less than 4 years (on average 2 years), with 'old SWC villages', where the SWC programme has run at least 4 years (on average 8 years), and 'non SWC villages', where no SWC project activities had been undertaken yet (Figure 9.2). Averaged for 1997 to 2002, cotton yield in new SWC villages was lower than in non-SWC villages (-8.8%). Cotton yield in SWC villages gradually increased overtime (+12.5%), resulting in slightly above average cotton yields (+2.7%) in old SWC villages. Both in the very wet year 1999 and in the very dry year 2002, differences were not significant.

Considering all SWC villages, the average period that had elapsed since SWC training happened to be 6 years. Assuming a gradual linear yield improvement since the start of SWC training, we would conclude that in the SWC villages, crop yields are now 12.5% higher than they were during the SWC training. Extrapolating this village-level effect, taking into account that 51%

of the villages had received SWC support, we conclude that the SWC training has increased the total cotton production with 6.4% in southern Mali.

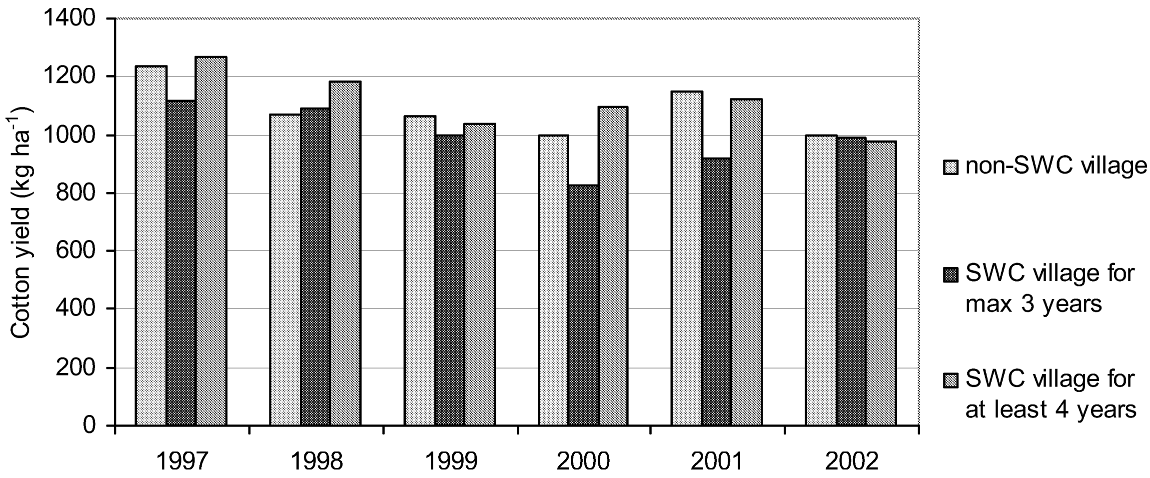

Figure 9.2. Cotton yield in non-SWC villages, new SWC villages, and old SWC villages, in southern Mali between 1997 and 2002.

Note: No statistical tests were done for 1997 and 1998; differences were significant in 2000 and 2001 [$p<0.10$], but not in 1999 and 2002.

9.4.2 Effect of age of erosion control measure on crop yield

One way to evaluate the effect of the age of erosion control measure on cotton yield is to construct a virtual time series: comparing crop yields obtained in 1999 (fieldwork data) from fields with erosion control measures installed in different years (Figure 9.3). Only the virtual yield trend of fields with vegetative barriers was significant ($p<0.10$): fields where live fences had been installed recently yielded about average, whereas fields where live fences have been installed a longer time ago yielded above average. Virtual yields trends in fields with stone rows or check dams were not significant.

The M&E data do not include the year that erosion control measures were installed, but include the year of SWC training. Assuming a relation between year of training and year of installation, we can thus construct a virtual time series comparing cotton yield in 2000 – 2002 from fields in villages trained in different years (Figure 9.4). For clarity, the yield points are not plotted. Indeed, a similar picture is found as with the fieldwork data: a significant virtual yield trend in fields with vegetative barriers. However, even the virtual yield trend in fields without erosion control (in SWC villages) was significant ($p<0.10$): crop yields in 'older SWC villages' are higher, even in fields without erosion control measures. This effect may be due to erosion control in neighbouring fields up stream and increased use of compost. Virtual yield trends in fields with stone rows and check dams were not significant.

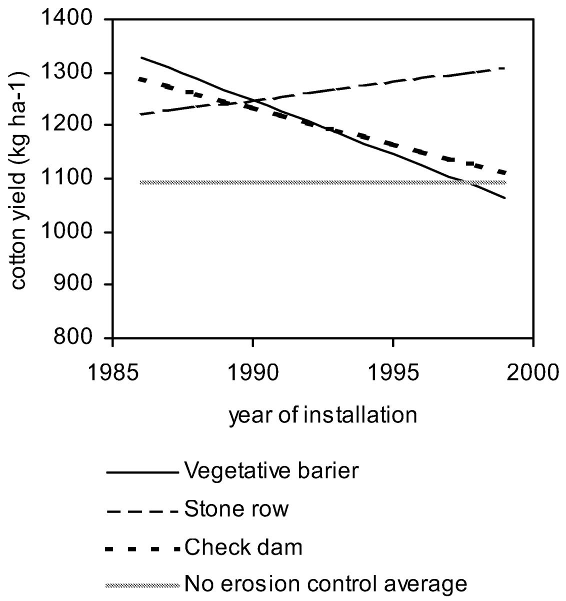

Figure 9.3. Virtual time series of cotton yield in 1999 as function of year of installation.

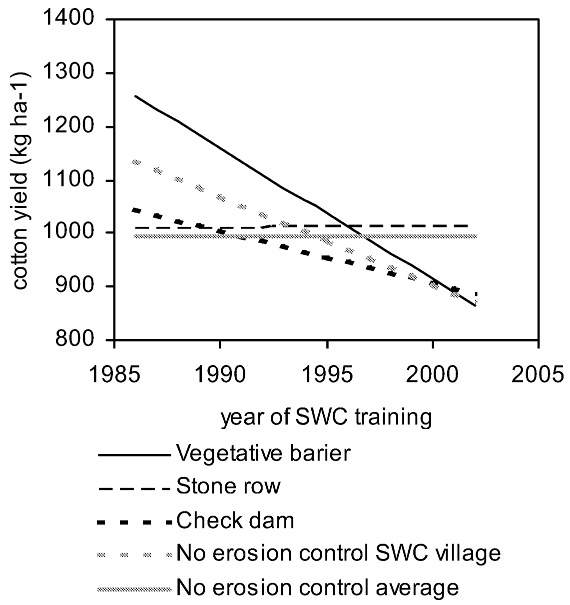

Figure 9.4. Virtual time series of cotton yield (2000-2002) as function of year of SWC training.

9.5 Discussion

The positive interaction between stone rows and rainfall found in southern Mali is not found in Burkina Faso. Haima (1996) found no effect of stone rows in Burkina Faso in 1994, which was an extremely wet year. He described that the area above the stone rows, which is expected to benefit, suffered from water logging. The reason for these different results is that stone rows in southern Mali are installed above the cultivated area and are expected to increase crop yield below the stone rows. In Burkina Faso, stone rows are installed in between fields and are expected to increase crop yields especially above the stone rows. A yield study by PATECORE (2000) in Burkina Faso showed highest crop yields 10 – 20 m above the erosion control measures. In wet years, stone rows will increase water logging just above the stone rows, but reduce runoff and erosion damage below the stone rows. On the contrary, in dry years stone rows will increase water conservation above the stone rows but reduce water harvesting from run-on below the stone rows. These different practices are adapted to the higher rainfall in southern Mali and the lower rainfall in Burkina Faso.

In southern Mali, very few interactions between erosion control and fertilisation were found, which were sometimes negative and sometimes positive. In Burkina Faso however, these interactions are important, especially in wet years. Zougmore found positive effects of stone rows in a dry area (470 – 664 mm) even without fertilisation, whereas positive effects of stone rows and grass strips in a more humid area (713 – 796 mm) only became significant in combination with fertilisation (Zougmore et al., 2000; Zougmore et al., 2003).

Why would interactions between erosion control and fertilisation be more positive in Burkina Faso than in southern Mali? This can only partly be explained by the higher fertiliser doses, closer to the optimum dose, in cotton growing southern Mali. Both fertiliser response and interaction with erosion control will therefore be lower than in Burkina Faso.

Adoption of erosion control is correlated with other agricultural intensification activities, which include increased fertilisation, more intensive tillage and crop management, which all positively affect crop yields. By excluding these factors we overestimate the effect of erosion control; by including them one approaches the 'net effect' of erosion control.

Adoption of erosion control measures, especially stone rows and check dams, is also correlated with field characteristics that represent erosion (gullies) and erosion risk (slope, position on the toposequence). However, we are not convinced that the inclusion of these field characteristics in the regression analyses helped us to further approach the net effect of erosion control. The explained yield variation (adjusted R^2) increased indeed, but we found no systematic increase of the net effect of stone rows or check dams. In many cases, the presence of stone rows and check dams was still correlated with lower crop yields. Does this mean that stone rows and check dams really have a negative net effect (under average rainfall conditions) or that we still have insufficient information about the specific field characteristics in which stone rows and check dams were installed?

Yields in southern Mali show a declining trend between 1993 and 2002, which can only partly be explained by declining rainfall and expansion of cultivation on more marginal fields (Chapter 4). When we compare the yield trend in SWC villages with the yield trend in non-SWC villages, we don't find no diverging yield trends between 1997 and 2002. On the contrary, the yield difference has disappeared in 2002. This is disappointing because we expect to see a more positive (or less negative) yield trend in SWC villages. There are a few possible explanations. Firstly, land was probably more degrading in the SWC villages at the time SWC activities started and farmers install erosion control measures especially on fields suffering from erosion. Secondly, adoption of SWC measures in non-SWC villages had reached levels similar to adoption in SWC villages, in 2001 and 2002 (Chapter 5). Thirdly, in the dry year 2002, the effect of stone rows on crop yield will have been small or even negative.

Based on a closer look at time series, we can distinguish two time lags: between training and installation of erosion control measures and between installation and improved crop yield. In villages where the installation of erosion control measures was followed for six years, it appeared that 80% of the stone rows and 57% of the vegetative barriers were installed in the first two years after SWC training (Chapter 5). After the installation of vegetative barriers, crop yields increased gradually over the years. During interviews, farmers indicated that it takes 2 – 3 years before live fences are grown into effective erosion barriers. This is consistent with the lower erosion found in fields with older live fences (Chapter 8). After the installation of stone rows, crop yields are immediately higher and remain constant over the years, which indicates that the immediate effect of reducing water runoff and fertiliser losses is more important than the gradual and cumulative effect of reducing soil loss. A few farmers indicated that the effect of stone rows diminishes over time, because of the sedimentation above the stone rows resulting in a rapid overflow of runoff water. On the other hand, this increased sedimentation on a bare plateau is often accompanied by a regeneration of the vegetation, which increases infiltration.

One problem with constructing virtual time series is that we assume that the situation at the start, just before installing erosion control measures, in fields where measures were installed recently is similar to the situation in fields where measures were installed a longer time ago. Because especially villages and fields with erosion problems were targeted, we have reason to believe that the situation in fields with older erosion control measures was worse than the situation in fields with recently installed erosion control measures. In that case, the virtual yield trend would underestimate the real yield trend after installation of erosion control measures.

9.6 Conclusions

Erosion control measures increase crop yields in southern Mali. Positive effects are found more with cotton than with other crops, more with vegetative barriers than with stone rows or check dams, and more in wet years than in average or dry years.

There is a clear interaction between the effect of stone rows and rainfall. Especially in wet years, crop yields are higher in fields protected from water runon and sheet erosion by stone rows installed above the cultivated area. The effect of vegetative barriers or check dams does not depend much on rainfall.

There was no clear interaction between erosion control and fertilisation.

A simple comparison of fields with and without erosion control measures overestimates the effects of erosion control because adoption of erosion control correlates with other agricultural intensification practices: fields are better fertilised and crops are more intensively managed.

On the other hand, a simple comparison of villages targeted by the SWC programme with villages not targeted by the SWC programme underestimates the effect of the SWC programme because villages with more severe erosion problems were targeted first. Crop yields in SWC villages are initially lower than crop yields in non-SWC village but gradually increase over time. This effect is explained by the time lag between SWC training and the installation of erosion control measures, and by the time lag between the installation of vegetative barriers and the improvement of crop yields.

Both the inclusion of other yield affecting factors in regression analyses and the use of virtual time series helped to evaluate ex-post the ‘net’ effect of erosion control measures in the absence of baseline data. When using regression analyses and neglecting some of the less favourable conditions of fields at the start of erosion control, we find only 4.8% higher cotton yields in fields with erosion control measures (on average 6 years old). When using virtual times series, comparing old SWC villages (on average 8 years since training) with new SWC villages (on average 2 years since training), we find an average cotton yield increase of 12.5%. However, we strongly recommended that SWC projects monitor and document good baseline data for an adequate impact evaluation later on.

After this chapter, which presented the effect of erosion control on crop yield, the next chapter will present how monitoring is linked to evaluation at the various levels between project activity and impact.

Chapter 10

Linking Monitoring to Evaluation in a Soil and Water Conservation Project in Southern Mali

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10 Linking Monitoring to Evaluation in a Soil and Water Conservation Project in Southern Mali

Abstract

In recent discussions it is argued that a more timely evaluation of impact is needed to steer projects to more effective and efficient approaches. With the soil and water conservation (SWC) project in southern Mali as case study, we assessed to what extent the monitoring system allowed the evaluation of effectiveness, impact and efficiency. Two weaknesses were found: effectiveness could not be compared with long-term targets at the purpose level (adoption of erosion control), and the evaluation of impact was hindered by insufficient monitoring at the goal level (especially land degradation). Two strengths were found: internal monitoring was complemented by external monitoring, and situations with and without project interventions were monitored, which allowed attributing impact (agricultural production) to project activities. This, in turn, allowed the evaluation of efficiency, comparing input costs (project) with impact benefits (farmer benefits of improved cotton yields). We recommend future SWC projects to use a logical framework when developing a monitoring system with indicators and baseline data up to the goal level and long-term targets up to the purpose level. More emphasis on outcome and impact allows more flexibility in activities and outputs. We also recommend SWC projects to collaborate with external monitoring organisations, and to include comparisons with and without project interventions.

Key words: monitoring and evaluation; logical framework; soil and water conservation; attribution gap; project impact

10.1 The need for more timely evaluations

Evaluations and the logical framework

Project evaluations serve three main purposes: to give timely feedback for improvements, to account for the expenses made and to draw lessons for future projects. Evaluations refer to a project strategy and project plan, which can be visualised in a logical framework, or logframe. The logframe was first developed in the late 1960s for USAID to facilitate monitoring and evaluation, but is later also much used and adapted by other organisations as a project-planning tool (USAID, 1980; GTZ, 1988; Crawford and Bryce, 2003).

We make use of a typical logframe, with 4 columns x 4 rows, for the soil and water conservation (SWC) project that will be used as case study in this paper (for a presentation, see Chapter 2, Table 2.1). Vertically from the bottom row upwards, the logframe presents the project strategy of how project activities (training sessions) contribute to project outputs (farmers prepared for erosion control), to project purposes (farmer adoption of erosion control), which will then contribute to the wider goal (reduce degradation, improve production). Other logframe examples have an additional fifth row at the bottom with (financial) inputs, or combine the inputs and activities in one level. Going from the left column to the right, each narrative summary in the first column is accompanied by objectively verifiable indicators in the second column, which should include baseline data describing the situation at the start of the project and long-term targets describing the desired situation. However, targets at the goal level, which are affected also by other factors, are often not quantified. The third column describes the means of verification: how and by whom is progress monitored and reported. The last column gives the assumptions and risks: conditions, outside project control, that need to be fulfilled for the project to succeed.

In addition to the long-term targets in the logframe, annual targets may be specified in annual work plans, giving details at the input, activity and output level. Annual targets are often based on the capacity of the project (budget and personnel) and on the participation of beneficiaries.

Monitoring and evaluation

We will use the following definitions to distinguish monitoring and evaluation:

- Monitoring is the on-going data collection and comparison of achievements with targets within each horizontal level in the logframe.
- Evaluation is the analyses of the contribution of project achievements at one level in the logframe to a higher-level.

In this paper, we consider the aggregation of annual achievements to cumulative achievements and the comparison of cumulative achievements with long-term targets as part of monitoring.

Five aspects of evaluation

Complete project evaluations, after project closure, typically look at the following five aspects (OECD, 2002):

- Effectiveness in the fulfilment of project objectives.
- Impact, where intended and unintended, positive and negative effects of the project are considered.
- Efficiency, comparing the project achievements with their costs.
- Relevance, comparing project achievements with the needs and priorities of the beneficiaries, with the country policy and with the donor policy.
- Sustainability, assessing whether benefits will continue after project closure.

Changes in M&E approach

Traditionally, monitoring and evaluation were well distinct activities. Monitoring was an ongoing internal comparison of achievements with plans, e.g. on an annual basis. One step further in the analysis was to aggregate annual achievements to cumulative achievements over a longer period that can be compared with long-term targets. Evaluation was often an external, more in-depth analysis of how project outputs contributed to project outcome (achievement of purposes) and project impact (achievement of goal), validating the vertical logic in the project strategy. Typically, an evaluation was done at project appraisal, halfway the project, and after project closure (Casley and Kumar, 1987; van de Putte, 1995).

In current discussions however, the need is felt for more timely internal feedback during project implementation. This feedback should emphasize less the comparison of achievements with plans at the activity and project output level, but emphasize more the comparison of project outcome and impact with project purpose and goal. This means that the project strategy itself, including the assumptions, should be regularly validated and adjusted (Cameron, 1993). Early impact assessment is not only valuable to improve the project strategy but also facilitates capacity building through learning-by-doing (Hauge and Mackay, 2004) and serves as a convincing extension tool (Nill, 2000). Different terms are used for this internal impact assessment: ongoing evaluation, impact monitoring (Vahlhaus and Kuby, 2001), impact monitoring and assessment (Herweg and Steiner, 2002) and performance measurement (Binnendijk, 2001). The need for a more timely and regular assessment of project outcome and, as far as possible, project impact, requires at the one hand more in-depth analyses and on the other hand relatively simple methods that can be done on a more regular basis during project implementation.

The problem: the attribution gap

Vahlhaus and Kuby (2001) and Herweg and Steiner (2002) argued that one should not expect from individual projects to evaluate the impact they have on the achievements of the higher-level development goal. They suggest, in what they call the GTZ model, two evaluation pathways: one internal evaluation from project activity upward, and one external evaluation from higher development goal downward.

On the one hand, project evaluations should be limited to the highest level of outcomes that can unambiguously be attributed to the project: the direct benefits experienced by beneficiaries who use the project outputs. These direct benefits are also called farm-level effects (van de Fliert and Braun, 2002). In the example of a SWC project, the project would thus evaluate, for example in case studies, whether adopters of SWC experience a reduction in erosion or an improvement of crop yields, without assessing land degradation or agricultural production at the district or province level. Douthwaite et al. (2003) argue that the evaluation of direct benefits requires more detailed cause-effect steps than usually presented in the logframe and propose an ‘impact pathway evaluation’.

On the other hand, impact at the higher goal level should be assessed in larger project-independent evaluations (e.g. regional surveys on agricultural production) without attributing impact to individual projects. The gap between these bottom-up and the top-down evaluations, in respect to the cause-effect chain, is called the ‘attribution gap’ (Vahlhaus and Kuby, 2001). Douthwaite et al. (2003) suggest that this attribution gap may be bridged by the evaluator identifying ‘plausible links’ between project outputs an higher-level development changes. Although they acknowledge the importance of the bridging the attribution gap during project implementation, they foresee this bridging as an ex-post impact assessment.

The challenge: adjusting monitoring for timely evaluations

The objective of this paper is to make recommendations for the monitoring system of future SWC projects allowing a more timely evaluation, during project implementation. The SWC project in southern Mali will be used as case study. From the five aspects of a complete evaluation, our focus will be on effectiveness, intended impact and efficiency. This means that somehow we need to 'fill' the attribution gap between project outcome and impact.

Although some authors have defined effectiveness as the project ability to achieve what was planned, comparing targets and achievements within one horizontal level in the logframe (Binnendijk, 2001; Guijt and Woodhill, 2002), we prefer the definition of effectiveness as the contribution of project activities and outputs in achieving project purposes (van Leeuwen et al., 2000; MDF, 2003).

The intended impact is the project contribution to the achievement of the goal. In the remainder of this paper we will not look at unintended impact.

Evaluating the efficiency includes a comparison of input costs with benefits of output, outcome or impact (de Graaff, 1996; Guijt and Woodhill, 2002; OECD, 2002).

We follow the three evaluations of 1) effectiveness, 2) impact and 3) efficiency. For each of these evaluations we assess: a) the availability of monitoring data in relation to the logical framework of the SWC project in southern Mali, b) the possibility of evaluation of the SWC project in southern Mali, and c) the lessons learnt for timely evaluation in future SWC projects.

10.2 Methods: the SWC project in southern Mali as case study

The SWC project in southern Mali

In the framework of a Dutch bilateral aid programme, a SWC project was initiated in 1986, known under the name '*Projet Lutte Anti-Erosive*' (PLAE). It was incorporated in the CMDT (*Compagnie Malienne pour le Développement des Textiles*), the semi-government Malian organisation for cotton production and marketing and rural development. In 1992, the project became an institutionalised SWC Unit of the CMDT (IOV, 1994). In 1998, most donor funding to the SWC programme had stopped (IOB, 2000). Although in 1996 the project approach was replaced by a programme approach, and the SWC programme continued even after donor funding had stopped, we refer to this whole period of SWC activities as 'the SWC project'.

The project objectives

Although the SWC project in southern Mali did not use the same planning format during its evolution over the years, the concept of the logical framework will be used to facilitate the discussion of the M&E system applied. The reconstructed logical framework of the SWC project can be summarised as follows (PLAE, 1986; PLAE, 1989; van Mourik et al., 1993; CMDT, 1995):

- The goal was to reduce the degradation of the ecosystem, to increase agricultural production (crop yields) and to intensify agriculture (increasing inputs and outputs per ha).
- Four purposes contributed to the goal: capacity building of the CMDT extension service, awareness raising of the rural population, farmer adoption of improved practices, and documentation and dissemination of experiences. Our focus is on the farmer adoption of stone rows and live fences.
- The project outputs that contribute to farmer adoption concerned an enhanced capacity of farmers for adopting SWC measures. The main output was the presence of a trained SWC

village team: 5 – 8 farmers that formed a relay between the project and other farmers. Villages with a trained SWC village team will be referred to as 'SWC villages'.

- Several project activities were involved. One of the main activities was the installation and training of a 'SWC village team'. The first activity of the SWC village team was the elaboration of an 'erosion inventory and assessment' indicating which areas of the village suffered from erosion, and a 'land management scheme' indicating where erosion control measures should be installed.

Project monitoring and external monitoring

Internal project monitoring by the SWC Unit was complemented by external monitoring by the Statistics Unit and the M&E Unit. Although the latter two units work within the larger CMDT, they were not involved in the implementation of SWC activities.

The SWC Unit monitored SWC training and farmer adoption of SWC measures at the village level. In annual activity reports annual work plans were being compared with annual achievements. From 1986 to 1995, only targeted SWC villages were monitored. From 1996 onwards, SWC activities in all villages were monitored, distinguishing targeted (SWC villages) and un-targeted villages (non-SWC villages).

The Statistics Unit collected agronomic data in all villages, and aggregated results to regional and national level.

The M&E Unit monitored more detailed agronomic data in a sample of 54 villages. Data were stored in an un-aggregated database so that more complex analysis and evaluations could be made upon demand. The M&E Unit monitored also the actual adoption of SWC practices at the farm level (which is the cumulative result of activities in previous years).

Data analysis

We compared the logical framework of the SWC project with the availability of data from internal and external monitoring, distinguishing baseline data, annual targets, long-term targets, annual achievement and cumulative achievements. For the purpose of this paper, we focussed on the output, purpose, and goal levels. At the output-level, we considered the number of villages with a trained SWC village. At the purpose-level, we considered farmer adoption of stone rows and live fences, two SWC measures that we had ample information of. At the goal level, we considered all tree aspects—land degradation, productivity and intensification—although we had sufficient data only for productivity (crop yield).

With the logical framework and the available data, we evaluated the effectiveness, impact and efficiency of the SWC project. Effectiveness was evaluated by comparing farmer adoption of erosion control in villages with and without a SWC village team. Impact—here limited to cotton yield—was evaluated by two methods. The first method compared cotton yield in fields with and without erosion control measures. The second method is the so-called virtual time series. It compared the cotton yield of three groups of villages: 1) villages without a SWC programme; 2) villages where the SWC programme had run less than 4 years; and 3) villages where the SWC programme had run at least 4 years. Efficiency was evaluated by comparing the annual farmer benefits of improved cotton production (project impact) with the average annual SWC project costs (project inputs).

10.3 Results

10.3.1 Monitoring of the SWC project

The monitoring framework is given in Figure 10.1. We discuss three levels of monitoring: at the output level (M1), at the purpose level (M2) and at the goal level (M3). We will not discuss monitoring at the activity level (M0) or the (financial) input level.

Monitoring involves the comparison of achievements with plans and, preferably, also with baseline and long-term targets. The SWC annual work plans gave details for the output and purpose level. Based on the annual work plan, progress can be monitored following simple indicators.

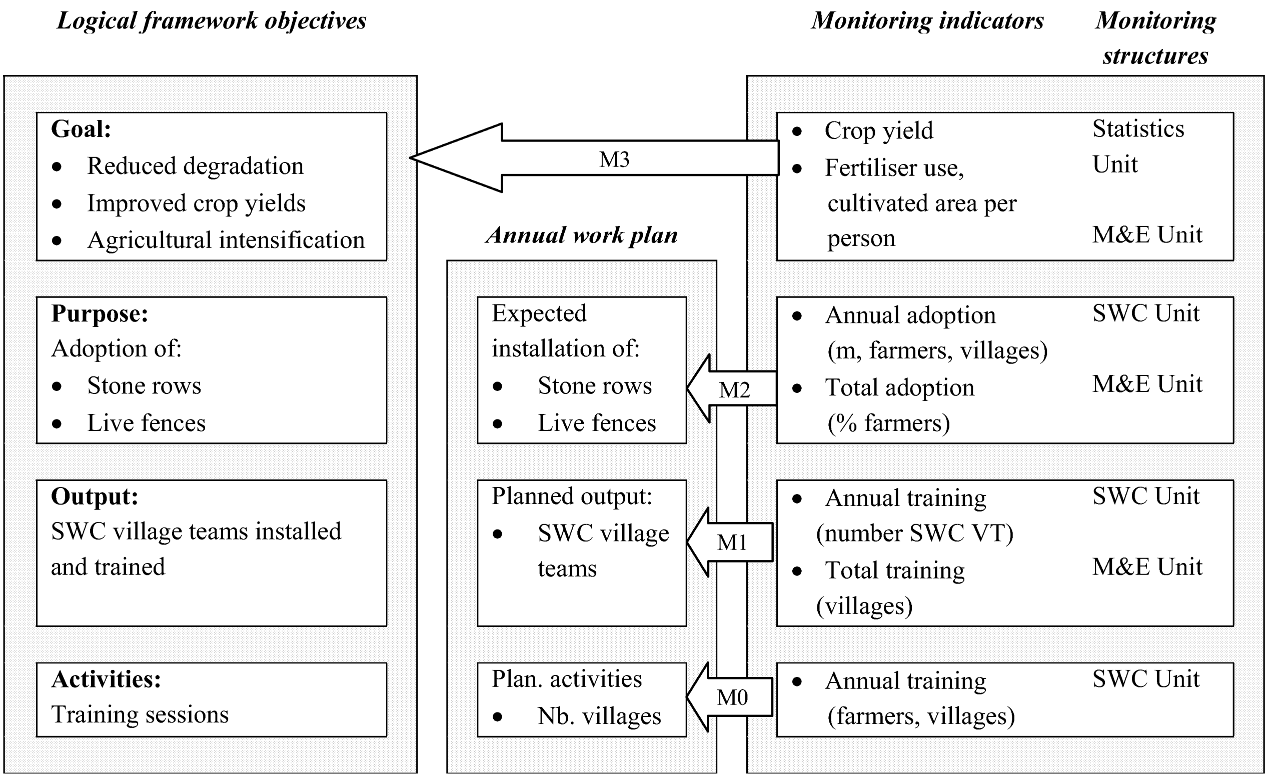

Figure 10.1. Monitoring in relation to the logical framework of the SWC project in southern Mali: monitoring indicators at the levels of activity (M0), output (M1), purpose (M2) and goal (M3).

Monitoring project outputs: SWC village teams installed and trained (M1)
The output indicator, the percentage of villages with SWC village team, has clear reference values: the baseline at the start of the SWC project was 0% and the long-term target was 100%. The SWC annual work plan can be quite certain about the project outputs, which are, by definition, under project control. Annual targets were set according to personnel and budget available.

Annual achievements are reported in the SWC annual activity reports. Taking the annual activity report of 1998/1999 as an example, 763 SWC teams were installed and trained. Cumulative achievements can be calculated by adding up annual achievements. SWC village teams have been trained in 2,562 villages, or 51% of all villages in southern Mali, between 1986 and 2000 (PLAE, 1987; PLAE, 1988; PLAE, 1992; PLAE, 1995; Schrader and Wennink, 1996; CMDT, 1997; CMDT, 1998b; CMDT, 1999b; CMDT, 2001). In the M&E Unit sample of 54 villages, 60% of the villages had a SWC village team in 1999/2000 (CMDT, 2000a).

Monitoring indicators related to the project purpose: farmer adoption of SWC measures (M2)
The baseline adoption of erosion control measures, at the start of the project, was negligible.

Setting long-term targets for the adoption of erosion control measures, both in terms of percentage of farmers and in terms of quantity of erosion control measures, would need an inventory of erosion and erosion risk. This was done at the village level, where, after making an erosion inventory, a land management scheme was made with long-term targets for erosion control measures to be installed. It is at the village level where the relation between area to protect from soil erosion and quantity of erosion control measures is clear. However, the village land management schemes were not documented nor were they aggregated to long-term targets for the whole SWC project.

The SWC annual work plan could not be so certain about the project outcome (by definition not under project control). Farmers adopt SWC measures on a voluntary basis and for different reasons. Nevertheless, the annual work plan did include the expected quantitative results, based on the participatory village planning of SWC activities.

As an example, the annual activity report 1998/1999 is presented, where annual achievements are compared with annual plans (Table 10.1). A distinction is made between achievements in 'SWC villages' and 'Non-SWC villages'.

Table 10.1. Comparing annual achievements with annual targets for the installation of live fences, stone rows and cattle pens. Annual Activity Report SWC Unit 1998/1999

		Planned	Realised			% Realised
			SWC villages	Non-SWC villages	Total	
	Villages		2,400	2,654	5,054	
Live fences	Meter	2,940,957	2,345,029	1,004,807	3,349,836	114%
	Farms		11,455	4,448	15,903	
	Villages		1,379	1,025	2,404	
Stone rows	Meter	770,234	484,596	32,552	517,148	67%
	Farms		4,028	544	4,572	
	Villages		814	97	911	

Source: SWC Unit (CMDT, 1999b)

Cumulative achievements of physical achievements can be calculated by adding up figures of the different annual activity reports. About 23,000 km of live fence and 7,500 km of stone rows have been installed between 1986 and 2000. In fact, the total length of live fences actually present in 2000 was lower because part of the live fences had died or had been replaced and was thus double counted.

No cumulative adoption in terms of number of farmers can be derived from the annual activity reports from the SWC Unit. We may know the number of farmers having installed live fences in a certain year, but we don't know whether these farmers are 'new adopters' installing for the first time that year, or 'old adopters' continuing the installation they had started in previous years. Similarly, no cumulative adoption can be calculated for the number of villages.

Cumulative adoption is presented in the annual reports by the M&E Unit. Their sample is relatively small and they regularly change part of their sample villages and their sample fields. Therefore, an average over several years, 1997-2000, gives a more reliable estimation of the adoption. According to their reports 15% of the farmers have installed live fences and 10% have fields protected by stone rows (CMDT, 1998a; CMDT, 1999a; CMDT, 2000a).

However, without long-term targets, the cumulative achievements are difficult to interpret.

Monitoring indicators related to project goal (M3)

The project goal consisted of three aspects: a) to reduce land degradation, b) to increase crop yields and c) to intensify agriculture. For each aspect, we discuss the availability of baseline data and monitoring results. Generally, no targets were set for the goal-level indicators, which are affected also by other, non-project factors.

a) For land degradation, no baseline data were available, except from a few specific or localised studies (Jansen and Diarra, 1992; van der Pol, 1992). The erosion inventory done in SWC villages could have served as a “first measurement at starting point” baseline survey but this information was not documented. Land degradation was not monitored at all.

b) For crop yields, no specific baseline information was collected in targeted SWC villages. The Statistics Unit monitored total cultivated area, production and crop yields. As an example, in 1999/2000, there were 442,469 ha under cotton, producing a total of 429,990 tons of cotton, with an average yield of 972 kg cotton ha^{-1}. For the CMDT, the main reference values are the production and crop yield of the previous season and the production targeted for the current season (CMDT, 2000b). Yield trends show a decline in cotton and maize yields between 1993 and 2002, which can be attributed partly to a decline in rainfall (Chapter 4).

c) For agricultural intensification, no specific baseline information was collected in targeted SWC villages. In 1996, indicators related to agricultural intensification were included as performance indicators of the donor-funded SWC programme, which were accompanied by baseline data and targets for 1997 and 1998, aggregated per region. Chemical fertiliser doses on cotton should increase and the cultivated area per person (distinguishing total, cotton and cereal area) should not increase any further (Schrader, 1997). The M&E Unit monitored input use and cultivated area per person. On average, 125 kg complex fertiliser and 51 kg urea were used per ha cotton. On average, 0.62 ha was cultivated per person (CMDT, 2000a). Average fertiliser doses in the CMDT zone have increased between 1994 and 1997 due to the higher percentage of land area under fertilised cash crops cotton and maize and due to higher doses applied to these crops (Doucouré and Healy, 1999). However, the cultivated area per person has increased as well, following the increased level of mechanisation and encouraged by the devaluation of the currency in 1994, which resulted in a more profitable ratio of cotton prices versus fertiliser and labour prices (Giraudy and Niang, 1996). This shows how project impact is affected by non-project factors.

Summarised, most gaps in the monitoring system occur at the goal level, especially for land degradation (Table 10.2).

Table 10.2. Availability of information on planning and monitoring in relation to the logframe of the SWC project of southern Mali

Logical framework levels		Planning			Monitoring	
		Baseline data	Long-term targets *	Annual targets *	Annual achievements	Cumulative achievements
Goal:	• Reduced degradation	v	(-)	(-)	-	-
	• Improved crop yields	-	(-)	(x)	+	o
	• Agricultural intensification	-	(1996)	(1996)	+	+
Purpose:	• Adoption of erosion control	+	v	+	+	o
Output:	• Villages with SWC village team	+	+	+	+	+
Activity:	• Training sessions	+	+	+	+	+

* A SWC project is not expected to quantify targets at the goal level.

v: Only at the village level, not documented and not aggregated to regional level;

+: Sufficient; -: Insufficient; o: Monitored but not compared with targets;

x: Annual targets for production were set by the CMDT, but not in relation to SWC.

1996: Targets set in 1996 for 1997 and 1998;

10.3.2 Evaluation of the SWC project

We distinguish three evaluation steps: effectiveness – the contribution of project output to project purposes (E1); impact – the contribution of project purposes to the project goal (E2); and efficiency – comparing project costs with benefits of improved production (E3) (Figure 10.2).

Evaluating effectiveness: the effect of farmer training on the adoption of SWC measures (E1)

Up to 1995, no comparison was possible between SWC villages and non-SWC villages, which were not monitored by the SWC Unit.

In 1994, the SWC Unit and the M&E Unit undertook a joint study, comparing performances in villages with and without a SWC village team (Giraudy et al., 1996). Adoption in villages with SWC village team was systematically higher than in villages without SWC village team.

From 1996 onwards, the SWC Unit distinguished achievements in villages with and without SWC team, which allowed evaluating the effect of the SWC village team on the adoption of SWC measures. However, part of the adoption in untargeted villages can be attributed to the SWC project as well, especially because adoption of erosion control measures was negligible before the project started.

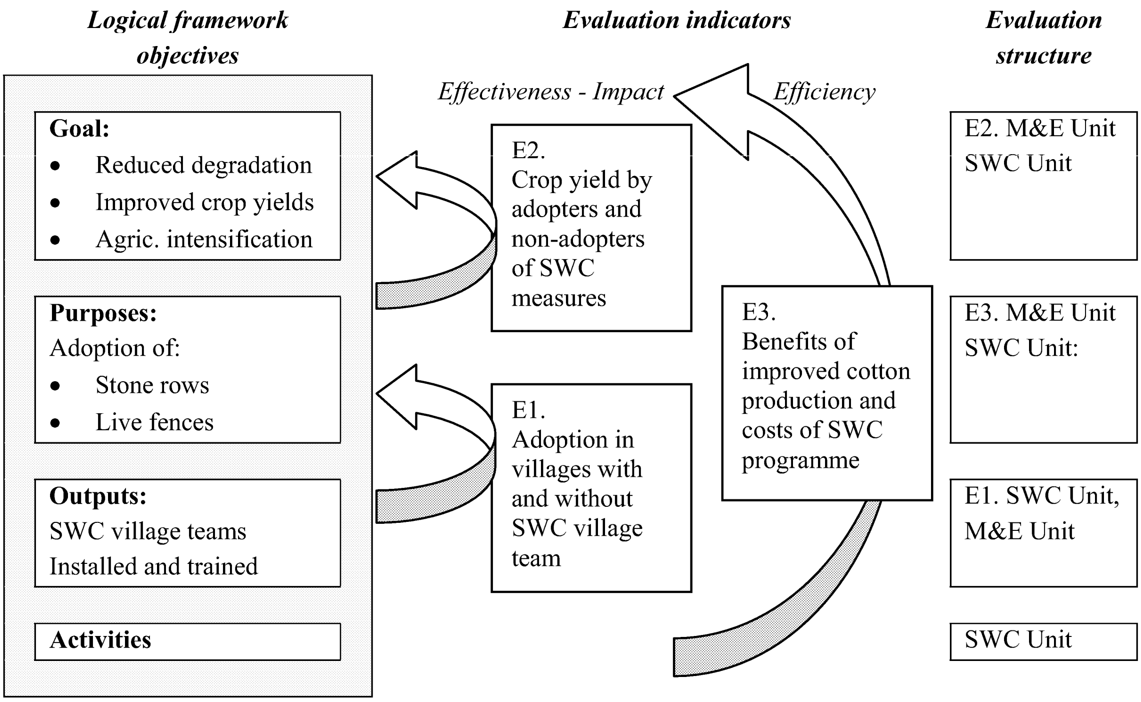

Figure 10.2. Evaluation in relation to the logical framework of the SWC project in southern Mali: evaluating effectiveness (E1), impact (E2), and efficiency (E3).

Using the M&E Unit data, averaged over 3 years, a positive effect is found of the specific SWC village approach and the presence of a trained SWC village team on the cumulative adoption of SWC measures (Table 10.3). Adoption of erosion measures in villages with SWC village team is more than twice as high as adoption in non-SWC villages.

Table 10.3. The effect of a SWC village team on the adoption of some erosion control and compost making measures, in percentage of farmers, averaged for 1997-1999

	Non-SWC villages	SWC villages
Number of villages in sample	22	32
Live fences	5%	24%
Stone rows	7%	11%
Any erosion control measure	16%	40%

Source: additional analysis by M&E Unit, (CMDT, 1998a; CMDT, 1999a; CMDT, 2000a)

Attribution of change to the project requires a comparison of "with-without" or "before-after" project intervention. In the initial phases of adoption, we compared adoption in SWC villages with adoption in non-SWC villages and attributed the difference in adoption to the project. However, adoption in untargeted villages picked up under influence of neighbouring targeted villages, informal information networks between farmers and trained general extension workers. In 2001 and 2002, the difference in adoption between targeted and untargeted villages had disappeared; adoption of erosion control measures reached about 54% (Chapter 5). Because adoption before the SWC project was negligible, we may attribute adoption of erosion control measures in all villages to the SWC project.

Evaluating project impact: the effect of adoption of SWC on cotton production (E2)

If we only compare achievements with targets within one level of the logframe, but without attributing change to project activities, we can say little about project impact. When, in 1996, the Dutch donor and the CMDT agreed on a number of performance indicators also at the goal level, they did not foresee in analyses to identify factors, among which SWC activities, that could explain the change. For example, fertiliser use and cultivated area per person increased, but we do not know whether and how this was affected by SWC activities: the attribution gap remained.

From the three aspects of the goal: to reduce degradation, to increase agricultural production and to intensify agriculture, we focus here on cotton production. What has been the impact of the adoption of erosion control measures on cotton production? We present the results of two methods used to evaluate the effect of erosion control on crop yield (Chapter 9).

The first method is the comparison of fields with and without erosion control measures in linear regression analyses including other yield-affecting factors (rainfall, fertilisation, crop management, farmer and field characteristics) as covariates (Table 10.4).

Table 10.4. Cotton yields and effects of erosion control measures, in wet, average and dry rainfall years; average yield effect and adoption of erosion control measures

Type of year	Wet		Average	Dry	All	Adoption
Year	1999		2000 & 2001	2002	1999-2002	% Fields
Data source	Field Work	M&E	M&E	M&E	FW+M&E	M&E [a]
Rainfall (mm)	1179	957	832	682		
Without EC (kg ha^{-1})	1092	1002	1018	936	1005	78%
Veg. barrier (kg ha^{-1})	+67	+22*	+74*	+107**	+75	14%
Stone row [b] (kg ha^{-1})	+187**	+163**	-51	-60	+3	5%
Check dams (kg ha^{-1})		+46*			+6	3%

[a] Average adoption figures 2000-2002 on cotton fields

[b] Stone rows installed above the cultivated area to protect from run-on are more effective in wet years.

Significance: ** p<0.01; * p<0.05; otherwise p<0.10

Source: Chapter 9, based on M&E and fieldwork data

Combining the average effects with the adoption rates of the three erosion control measures, we find with erosion control measures an average cotton yield increase of 48 kg ha-1, or 4.8% compared to the average cotton yield without erosion control measures. The advantage of this method is that it separates the effect of erosion control from other effects; the disadvantage is that we are comparing fields with and without erosion control measures, from which we can assume that the situations before installation of erosion control measures were not the same.

The second method is the construction of a virtual time series in which crop yields of 'new SWC villages', where the SWC programme had run for less than 4 years (on average 2 years), were compared with crop yields of 'old SWC villages', where the SWC programme had run at least 4 years (on average 8 years). Average cotton yield in new SWC villages was 8.8% lower than in non-SWC villages. Cotton yield in old SWC villages was 12.5% higher than in new SWC villages and 2.7% higher than in non-SWC villages (Table 10.5). In 2002, the average number of years the SWC programme had run in all SWC villages (old and new) was 6 years. We can therefore assume that the average yield increase in SWC villages since they started SWC activities is about the same as the 12.5% yield difference between new and old SWC villages. The advantage of this method is that it considers the less favourable situation of SWC villages at the start of SWC activities; the disadvantage is that the effect of erosion control is not separated from other factors that may result from the SWC programme, such as increased organic fertilisation.

Table 10.5. Cotton yield (kg ha^{-1}) in non-SWC villages, new SWC villages and old SWC villages, corrected for differences in rainfall, between 1997 and 2002

	1997	1998	1999	2000	2001	2002	Average
Non-SWC villages	1232	1072	1060	996	1146	1000	1084
New SWC villages	1116	1091	997	823	917	992	989
Old SWC villages	1266	1185	1035	1095	1121	978	1113

Differences in 1997 and 1998 were not tested on significance; differences are significant for 2000 and 2001, not for 1999 and 2002.
N: 22 non-SWC, 10 new SWC and 22 old SWC villages
Source: Chapter 9, based on M&E data.

From the results of both the with-without comparison and the virtual time series we conclude that erosion control measures significantly increased cotton yield in southern Mali.

Evaluating efficiency: comparing the benefits of improved cotton production with the costs of the SWC project (E3)

No regular evaluations have been undertaken to assess the efficiency of the SWC project. After having analysed the impact in the previous section, we can extrapolate this impact to southern Mali and try to assess the efficiency of the SWC project, comparing the value of the additional cotton production with the costs of the project. The basis for this evaluation is weak, and the results described below serve only as an illustration of how the efficiency of such a SWC project could be evaluated.

The annual additional cotton production is estimated using the results from the two evaluations described in the pervious section: the small effect found in the with-without comparison and the large effect found in the virtual time series. If we extrapolate the yield increase of 48 kg ha^{-1} in the 22% cotton fields with erosion control measures (see Table 10.4) with the 453,000 ha under cotton in 1999/2000, we find an additional cotton production due to erosion control measures of 4,784 tons per year. If we extrapolate the 12.5% yield increase (see Table 10.5) that the 51% SWC villages have achieved with the 453,000 ha under cotton in 1999/2000, we find an additional cotton production due to erosion control measures of 28,649 tons per year.

The annual operational costs of the SWC project are estimated for three different periods: the project period from 1986 to 1992 with extensive external assistance, the "programme period" from 1996-1998, still with Dutch donor funding, and the programme period after donor funding to the CMDT had stopped, with limited German-funded technical assistance.

- During the first two project phases, with several expatriates assisting the development of the SWC project, € 3,484,000 was spent from 1986 to 1992, or an average of € 581,000 per year (IOV, 1994).
- During the donor-funded "programme approach" period from 1996 to 1998, about €920,000 was spent on technical assistance and general SWC extension costs, about €460,000 per year (Schrader, pers. comm.).
- In 2000/2001, 46 full time Malian staff where involved in the SWC programme and about 630 extension staff spent an estimated 10% of their time on SWC. The total salaries and operating costs were budgeted at € 817,000 including the German-funded technical assistance estimated at € 55,000. However, not all that was budgeted was actually spent (Derlon, pers. comm.).

On the basis of these rough data, a simple comparison can be made between the annual costs of the SWC project and the annual financial benefits for farmers (Table 10.6).

Table 10.6. Estimated annual benefits (1999/2000) for farmers and annual costs of the SWC project (1986-1992 and 2000/2001).

Estimated annual benefits: cotton production and farmer income	
• Additional cotton production – low estimate	4,784 t y^{-1}
• Additional cotton production – high estimate	28,649 t y^{-1}
• Average cotton price for farmers (1999-2001)	€ 263 t^{-1}
• Additional cotton value for farmers – low estimate	€ 1,258,000 y^{-1}
• Additional cotton value for farmers – high estimate	€ 7,535,000 y^{-1}
Estimated annual cost of the SWC project	
• Average cost SWC project 1986-1992 (Donor)	€ 581,000 y^{-1}
• Average costs SWC programme 1996-1998 (Donor)	€ 460,000 y^{-1}
• Cost SWC programme 2000/2001 (CMDT)	€ 817,000 y^{-1}

Source: M&E Unit and SWC Unit, (IOV, 1994; CMDT, 2002)

From this simplified efficiency analysis, we conclude that the benefits to farmers seem to have largely exceeded the costs of the project, for either the donor or the CMDT, even in the case of the low estimate of the benefits.

A number of important aspects were not considered: the costs farmers make for SWC (mainly labour investments), the benefits for the CMDT (profit) and for the Malian government (taxes) through increased cotton export, and the long-term benefits from reduced land degradation.

10.4 Conclusions and recommendations for future SWC projects

Our objective was to make recommendations for SWC projects on how to improve the monitoring system for a timely evaluation of effectiveness, impact and efficiency. For each of these three evaluations, we will draw conclusions on the monitoring and the evaluation of the SWC project in southern Mali, followed by general recommendations for future SWC projects.

First of all, a general conclusion: the use of a logical framework, even though it had to be reconstructed afterwards, gave us a good overview of what data were needed and what data were available for evaluation. We recommend future SWC projects to use the logical framework and develop their monitoring system accordingly, in anticipation of evaluation. More emphasis on outcome and impact allows more flexibility in the activities and outputs.

Evaluating effectiveness

Evaluating effectiveness required monitoring output (number of villages with SWC village team) and outcome (farmer adoption of erosion control). Annual achievements were monitored internally by the SWC Unit and were compared with annual targets. Cumulative achievements were monitored externally by the M&E Unit, but were difficult to interpret due to the lack of long-term targets. Long-term targets on erosion control were planned in the 'land management schemes' at the village level, but these were not documented as baseline surveys.

Evaluating effectiveness required a comparison of situations with and without a SWC village team. Both the internal and external monitoring system monitored farmer adoption in villages with and without SWC village team, allowing such a comparison.

Future SWC projects should not only monitor indicators at the output and outcome level, but also establish reference values: baseline data and targets. SWC projects may be hesitant to set long-term targets at the outcome level because farmers install erosion control measures voluntarily: the outcome is out of project control. Nevertheless, cumulative achievements are irrelevant without long-term targets. If the project involves some sort of long-term erosion control planning at the farm or village level, these plans should be documented and aggregated to estimated long-term targets. SWC projects should include a comparison of situations with and without project, for which SWC projects could make used of external monitoring, also outside the project area.

Evaluating impact

Evaluating impact required monitoring of indicators at the goal level and comparing these with baseline data. There was no internal project monitoring of any indicator at the goal level. External monitoring considered crop yield, fertilisation and cultivated area per person—which happened to cover two aspects of the project goal: agricultural production and intensification. However, land degradation, the third aspect of the project goal, was not covered by external monitoring either. In the SWC project in southern Mali, erosion inventories were made at the village level, but these were not documented as land degradation baseline surveys.

Evaluating impact required a comparison of situations with and without farmer adoption of SWC. In southern Mali, this became possible only after the M&E Unit had adjusted their monitoring format and considered the SWC purpose (fields with erosion control measures). This allowed a comparison of crop yield in fields with and without erosion control and bridged the 'attribution gap' between internal and external monitoring.

Future SWC projects should assure monitoring indicators at the goal level. The goal of any SWC project is likely to include a land degradation aspect and an agricultural production aspect. It is understandable that SWC projects do not want to be trapped in ambitious targets at the goal level, because the impact is affected also by other influences out of project control. Nevertheless, even without setting targets, documenting a baseline situation and monitoring change is needed to validate assumptions of how the project purpose would contribute to the project goal. Because erosion control measures are taken especially in fields with erosion problems, often with lower crop yields, specific baseline data is needed for a good comparison of trends in fields with and without erosion control measures. If the SWC project involves some sort of erosion inventory, these could be documented to serve as baseline survey. Future SWC project should try to collaborate with external monitoring organisations, especially for the monitoring of indicators at the goal level, also outside the project area. Specific SWC impact indicators (e.g. land degradation) could then be monitored by SWC personnel in villages and fields that are in the sample of the external monitoring organisation.

Evaluating efficiency

Evaluating efficiency was simplified to comparing average annual project costs (inputs) with annual farmer benefits from additional cotton revenue (impact). A few notes of caution are needed. First, there are other costs and other benefits involved (the costs of farmers' labour; the benefits of reduced land degradation, profit for the CMDT, and export taxes for the Malian government). Second, the costs made many years ago (from 1986 to 2000) are compared with benefits obtained recently (in 2000), which should al least be corrected for inflation. Third, we compared one year of costs with one year of benefits. However, the costs are made over a limited period of 14 years, after which the SWC project had stopped, whereas the benefits are likely to continue and may even increase in the future.

Future SWC projects will benefit from efficiency evaluations comparing impact with inputs. Projects can benefit even more when the efficiency evaluation is split at the output level in two steps: comparing the input costs of different outputs, and comparing the impact benefits of different outputs. This allows the project to choose the most efficient outputs. The evaluation of efficiency will also draw the project's attention on the importance of sustainability: the longer benefits will continue to flow after project withdrawal, the more efficient the project will be.

Chapter 11

Synthesis

11 Synthesis

'Compared to the past, we now have to make more effort to obtain the same yields.'
(farmer's comment in a group discussion in Farakoro village, southern Mali, 2003).

The previous chapters presented methods to evaluate the impact of SWC, the agricultural development in southern Mali, the actual impact of the SWC project in southern Mali, and the link between monitoring and evaluation. In this chapter, the results of those chapters will be integrated into a more general synthesis. The first two sections will answer the research questions formulated in Chapter 1, distinguishing between the methodological aspects of monitoring and evaluation (11.1) and the actual impact of the SWC project in southern Mali (11.2). The third section will highlight what is new in the results of this study: the analysis of delays in project impact (11.3). Finally, in the last section the institutional and policy implications will be presented, in the form of recommendations for the monitoring and evaluation of SWC projects (11.4).

11.1 Impact evaluation methodology for the SWC project in southern Mali

A review of evaluations of other SWC projects in West Africa showed that it has been difficult to attribute impact to SWC activities (Chapter 1). In many cases, impact was affected by other, non-project factors that were not sufficiently taken into account in the analyses. In other cases, field-level effects from few or small plots could not be extrapolated to regional impact. Finally, correlations between project activity and impact, especially when found in a snapshot study, could not automatically be interpreted as cause-effect relations (Kunze, 2000; Nill, 2000; PATECORE, 2000; Schorlemer, 2000; Reij and Thiombiano, 2003). The difficulty of attributing impact to project activities can lead to unfounded conclusions that are over-optimistic or over-pessimistic. As a consequence, no lessons can be learnt.

In order to avoid such drawbacks this ex-post impact evaluation of the SWC project in southern Mali included the following specific features (Chapter 2):

a) in the evaluation use was made of smaller cause-effect steps;

b) matching took place of data from different sources and from a longer period of time;

c) use was made of a 'reconstructed baseline', and

d) 'virtual time series' were established.

The latter two methods were applied in order to overcome the problem of incomplete baseline data. These four features are briefly discussed hereunder.

a) In order to attribute impact to the activities of the SWC project in southern Mali, this study systematically analysed the cause-effect chain between project activities and impact. Hence a logical framework was reconstructed, although this was not used during project planning. Evaluating smaller cause-effect steps have the advantage that they require less non-project factors to be taken into account in the analyses and make a cause-effect relationship more plausible. The steps between the different levels in the logical framework are a good starting point for evaluation, but in some cases the steps are too large, especially between outcome and impact. Therefore, the relation between erosion control and yield (Chapter 9) is made more plausible by also evaluating two smaller steps: the effect of erosion control on erosion (Chapter 8) and the effect of erosion on yield (Chapter 7). Relationships could have been made even more plausible by distinguishing also parallel cause-effect steps. For example, SWC training affects adoption of both erosion control and compost use, which both affect yield.

b) During the evaluation, the reconstructed logical framework was gradually filled in by matching data from different sources and from additional fieldwork, taking into account their reliability (Chapter 3). In this way, the fieldwork in 2000 and 2003 could be limited to the major information gaps, focussing on erosion, erosion risk and farmer perception of the SWC programme, and this complemented the long-term data series from the SWC Unit, the M&E Unit and the SWC Unit (1986-2002).

In ex-post evaluations where the starting points of the 'treatment' and 'control' cannot be assumed to be the same, no conclusions can be drawn from simple 'with–without' comparisons. Instead, baseline data are needed for 'before–after' comparisons in order to reveal different trends for treatment and control. In the ex-post evaluation of the SWC project in southern Mali, for which baseline data were often missing, two new evaluation methods proved to be useful substitutes: the 'reconstructed baseline' and the 'virtual time series'.

c) A reconstructed baseline considers indicators reflecting the situation in the past. This method worked well when evaluating the period between SWC training and installation of erosion control measures. In interviews, farmers easily recalled the years of such activities (Chapter 5). It becomes more difficult to assess erosion in the past by observing (partly) reclaimed gullies. On the one hand, part of the reclaimed gullies will no longer be visible; on the other hand, enumerators may be tempted to look harder for reclaimed gullies in fields with erosion control (Chapter 8). Farmers were also asked to estimate crop yields 10-15 years ago, but these data showed very little relation to recorded yield data and were considered unsuitable to reconstruct a baseline.

d) A virtual time series presents observations made in one year as a function of the period that has elapsed since a treatment began. In fields with older vegetative barriers, erosion was lower (Chapter 8) and crop yields were higher (Chapter 9) than in fields with recently installed vegetative barriers. Similarly, in villages where farmers were trained a longer time ago, farmers had adopted more SWC (Chapter 5) and obtained higher crop yields (Chapter 9) than in villages where farmers were trained recently. The presentation of such results as virtual time series assumes that the situation at the start of the 'treatment' can be assumed the same, and this should be questioned. In southern Mali, villages and fields targeted for SWC suffered more from erosion and yielded less, so virtual time series underestimate the effect of SWC

In conclusion, the four methods described above have been necessary for this research and can be recommended for other ex-post evaluations of SWC projects with limited baseline data.

11.2 Impact of the SWC project in southern Mali

Before evaluating the impact of the SWC project, the general agricultural development in southern Mali was analysed, to provide a background against which project impact could be interpreted. A complete evaluation considers five aspects: effectiveness, impact, efficiency, relevance and sustainability (OECD, 2002). Although the focus of this thesis was on effectiveness and intended impact, some conclusions will also be drawn on efficiency, relevance and sustainability. This section ends with a discussion on how monitoring has affected impact and how a different monitoring system could have resulted in a different impact.

General agricultural development in southern Mali

Agricultural development in southern Mali was analysed in terms of expansion, intensification, productivity and sustainability (Chapter 4). Between 1988 and 2002, the greater availability of ploughing equipment enabled farmers to increase the per capita cultivated area. Meanwhile, they also intensified farming: they now grow more cash crops (cotton and maize) and apply more chemical and organic fertiliser. In spite of this, cotton and maize yield trends declined between 1993 and 2002 with 10 and 17%, partly due to decreasing rainfall and cultivation on more marginal land. Nutrient balances for the cultivated area were only slightly less negative in 2002 than they were in 1988 (-40 versus -58 kg N+P+K ha^{-1} y^{-1}), which shows that the agricultural system has not yet become sustainable.

So far two phases can be distinguished: 1) up to 1982, a phase of yield increase due to increased fertilisation and increased mechanisation, which probably resulted in accelerated mineralisation of soil organic matter; 2) from 1982 to 2002, a phase of yield stagnation and decline due to stagnated intensification, continued expansion, reduced fallowing and negative nutrient balances, all of which probably resulted in a decline in soil fertility. The next phase could be one of increasing crop yields, but this would require further intensification and a balance between soil organic matter mineralisation and replenishment (Section 11.3).

The overall trends in productivity and sustainability in southern Mali so far have been discouraging. Against this background, the relative effectiveness and impact of the SWC project is evaluated.

Effectiveness and impact of the SWC project

Following the cause-effect chain between project activities and project goal, various effects were evaluated: the effect of the SWC project approach on the number of villages where farmers have been trained in SWC, then the effect of farmer training on the adoption of SWC measures, and finally the effect of SWC measures on the three aspects of the goal: reduced degradation, agricultural intensification and improved productivity.

The SWC project invested heavily in building the capacity of the Malian agricultural extension service of the CMDT (Chapter 5). Once the SWC approach had been developed and the extension service had been trained, training of farmers was relatively simple. This enabled the CMDT extension staff to reach about half of the 5000 villages in southern Mali with the SWC training and support packages between 1986 and 2000. Farmers in other villages received general SWC information to a lesser extent, on an ad-hoc basis. Qualitative survey data showed that farmers who benefited from SWC extension still recommend this SWC approach for new villages.

The large-scale SWC training programme, combined with the decision to opt for simple SWC measures (vegetative barriers, stone rows) and the avoidance of direct incentives, resulted in the slow but steady adoption of SWC measures (Chapter 5) in targeted villages and eventually also in neighbouring untargeted villages. There is a positive feedback between the presence of vegetative barriers and the ease to install more from cuttings or slips. Besides, the choice for vegetative barriers is determined by the lower labour requirements for installation and not by a higher effectiveness. By 2002, erosion control measures had been installed in almost all villages, by 46% of the farmers and in 15% of the fields in southern Mali. The latter figure is deceptive, because not all fields need erosion control. It must be remembered that erosion control measures are especially installed in fields with erosion rills and gullies, and these are present in one-third of all fields. More erosion control is still needed. The majority of farmers, adopters and non-adopters, plan to install (more) erosion control measures in the future. Adoption was not only positively affected by the SWC project approach but also by a reduced availability of cultivable land, by the difficult circumstances in the non-cotton growing area, and by the possession of ploughing equipment and donkey cart (Chapter 6).

Chapter 7 demonstrated that erosion is a relevant problem in southern Mali. Although erosion gullies were found in only a minority of the fields, in almost all the fields symptoms of sheet erosion were found. The distinction of structural crusts and the newly defined *in situ* depositional crusts and runoff deposit of coarse sand proved useful in evaluating sheet erosion. Both erosion gullies and sheet erosion symptoms correlated significantly with decreased crop yields.

Erosion control decreased soil erosion (Chapter 8). In one village where erosion baseline data were available, estimated soil loss had reduced from 42 to 10 t ha^{-1} y^{-1} between 1988 and 2003 due to erosion control. Farmers in this village confirmed that land degradation had reversed and crop yields had improved. Where no erosion baseline data were available, analyses with reconstructed baseline data showed that line interventions and gully interventions reduced the number of gullies by 50-70%. Virtual time series showed that erosion gradually halved in 3 to 4 years and then halved again in 6 to 10 years after erosion control measures had been installed. The reconstructed baseline shows that erosion in the past was more than twice as severe in fields with erosion control measures than in fields without erosion control measures. Taking this into account, the erosion control measures installed in 15% of the fields would have reduced erosion in southern Mali as a whole by about 16% (Chapter 8). However, the increased area under cultivation has increased the slope lengths, and negative nutrient balances and soil organic matter depletion have increased soil erodibility (Chapter 4). Farmers think that on the whole erosion increases, except in localised areas were action is undertaken. Therefore, this study does not lead to the conclusion that erosion has decreased in southern Mali as a whole, but that with continuing adoption of erosion control erosion will gradually reduce. With respect to the project goal ‘to reduce land degradation’, it should be recalled that this study focused on SWC in cultivated fields whereas the SWC project had a wider scope and included two aspects not evaluated in this study: improved forest and pasture management.

Farmers who adopt erosion control measures also produce more compost, use more chemical fertiliser, and grow crops more intensively (Chapters 6 and 9). This confirms that erosion control is part of agricultural intensification. Farmers indicated that nowadays erosion control and compost are indispensable for agriculture. This intensification, however, has not held farmers back from further expansion. It was found that the cultivated area per capita, mainly determined by farm equipment and farm size, is not affected by adoption of erosion control.

Erosion control has a positive effect on crop yield (Chapter 9). This has been proven after two different kinds of analysis: regression analyses and virtual times series. After yields had been corrected for differences in rainfall, fertilisation, farm type, crop management and field type, it was found that fields with erosion control measures yielded 4.8% more than fields without erosion control measures – a small but significant difference. However, farmers install erosion control measures mostly in fields with more than usual erosion problems, so the 4.8% is an underestimation of the effect of erosion control. The cotton yield in villages targeted by the SWC project increased gradually and was 12.5% higher in 'old SWC villages', on average 8 years after SWC training, than in 'new SWC villages', on average 2 years after SWC training. Considering all SWC villages, the average period elapsed since the SWC training happened to be 6 years. I therefore conclude that cotton yield in SWC villages has increased on average by 12.5% since SWC training. This yield increase is the combined effect of erosion control and increased compost use, both promoted by the SWC project. This virtual time series shows how important it is not just to compare fields but also to evaluate trends. The evaluation did not take into account the phenomena that some cotton fields were too degraded to grow cotton before SWC started, a situation reported by several farmers.

The 4.8% yield increase by erosion control alone extrapolated over the 22% cotton fields with erosion control represents 1.1% of total cotton production in southern Mali. The 12.5% yield increase by erosion control and compost use extrapolated over the 51% SWC villages represents 6.4% of total cotton production in southern Mali (Chapter 9).

In spite of the positive effects of SWC on crop yield, general yield trends were negative in southern Mali as a whole between 1988 and 2002, a discouraging fact (Chapter 4). This study concludes that crop yields would have declined even more without the SWC efforts, but that still more efforts are needed to reverse the yield decline.

In conclusion, the SWC project has been effective in reaching large numbers of farmers and achieving a steady farmer adoption, also in non-targeted villages and even after project withdrawal. However, the impact on erosion and crop yield has been insufficient to reverse overall land degradation and declining crop yields. Considering the farmer attitude towards SWC as part of the necessary agricultural intensification and the farmer plans to continue SWC efforts, the trends in land degradation and crop yields are likely to reverse in the near future.

Efficiency of the SWC project

There are different ways to evaluate efficiency and this study only presented a simple comparison between annual SWC project costs and annual farmer benefits from improved cotton yield (Chapter 10). The annual SWC project costs (Dutch donor-funded technical assistance and SWC operational costs), averaged for 1986-2001, are estimated at €580,000. Although the effect of the SWC project on cotton yield may seem modest (Chapter 9), the annual farmer benefits (gross margin) of increased cotton production, averaged for 2000–2002, are estimated between €1,260,000 (underestimated net effect of erosion control only) and €7,530,000 (overall effect of SWC project), and largely outweigh the annual SWC project costs (Chapter 10). Three aspects in this simplified comparison need discussion. Firstly, not all costs are considered: the costs of two German-funded local SWC projects in southern Mali that also contributed to the overall impact, and more importantly, the costs farmers made (mainly labour) for installing SWC. Secondly, not all benefits are considered: the CMDT and the Malian State made additional profit from increased and taxed cotton export, and the long-term benefits of reduced land degradation are not quantified. Thirdly, there is a delay between temporary donor investment (1986-2001) and gradually increasing and continuing farmer benefits, which were not corrected for inflation. The efficiency depends on the considered period: it is lower when only the period 1986-1989 is considered and it will be higher when in a future calculation for example the period 1986-2016 would be considered.

Improved production was only one aspect of the goal, and it would be interesting to evaluate the project efficiency in reducing land degradation. Unfortunately, there are no simple tools to express erosion in monetary terms. Additional techniques to valuate land degradation and conservation, besides the ‘effect on productivity’, include ‘preventive expenditure’ and ‘replacement costs’ (de Graaff, 1996). One example of replacement costs has been refined by Van der Pol (1992), who defined the ‘economic nutrient depletion / income ratio’, comparing the value of the negative nutrient balance with the gross margin from crop production. In 1988, about 40% of gross farm income in southern Mali was derived from soil mining. Considering the nutrient balance and prices for fertiliser and crops in 2002 (Chapter 4), that percentage would have fallen to about 20% in 2002. This decrease says little about increased sustainability but more about the crop / fertiliser price ratio being more favourable in 2002, making it cheaper for farmers to correct the nutrient deficit.

Not valuing land degradation is one of the difficulties and dangers recognised in the Millennium Ecosystem Assessment Synthesis Report:

> ‘Traditional national accounts do not include measures of resource depletion or of the degradation of renewable resources. As a result, a country could cut its forests and deplete its fisheries, and this would show only as a positive gain to GDP despite the loss of the capital asset.’ (Reid et al., 2005)

Alternative accounting methods have been developed for the national level (Repetto et al., 1989) and for the farm level (Faeth et al., 1991), but they require extensive quantitative data and were beyond the scope of this study.

In conclusion, without valuing land degradation, by simply comparing farmer benefits from increased yield with donor project costs, the SWC project in southern Mali can be considered efficient. It would be relevant to compare this efficiency with other SWC project approaches, for example in neighbouring countries.

Relevance of the SWC project

The project's relevance was evaluated by comparing project achievements with the needs and priorities of the beneficiaries, with the country policy and with the donor policy. A distinction must be made between the technical and extension aspects of the SWC approach, and the institutional aspect: the incorporation of the SWC project in the CMDT agricultural extension service.

Farmers consider SWC as a necessity nowadays and judge the SWC approach still relevant (Chapter 5). The farmers in the villages targeted by the SWC project recommend that the same SWC measures and extension methods be applied in untargeted villages in the future. The Malian government and the Dutch donor are still concerned about natural resource management.

More critical for the relevance of the SWC project is the changed policy towards the CMDT. At the time the SWC project started in 1986, both the Malian government and donors considered the CMDT to be the most effective organisation for rural development in southern Mali. At the time the donor support stopped, between 1998 and 2002, the CMDT had been heavily criticised by farmers, donors and the Malian government, mainly for their deteriorating financial management and the poor farmer representation in the decision-making in the cotton sector. This resulted in the CMDT being dismantled and privatised, with the result that agricultural extension was largely abandoned, even though the SWC extension programme in particular should have continued (Bodnár, 2002).

In conclusion, SWC is still relevant but the SWC extension programme has lost its position because of its institutional embedment in an organisation that is being dismantled.

Sustainability of the SWC project

The recent policy changes not only made the project less relevant, they also affected the project's sustainability. A project's sustainability is evaluated by assessing whether benefits continue after project closure (Chapter 5). World Bank (2001) and MDF (2003) suggest considering six aspects of sustainability: 1) whether the country policy will allow for continuation; 2) whether the responsible organisations will continue to function; 3) whether beneficiaries can use the technology without external support; 4) whether the benefits will outweigh the costs without external support; 5) whether positive environmental effects will continue; and 6) whether all members of the target group will continue to participate.

The sustainability of the SWC project was reviewed as follows. As mentioned earlier, policy changes did not allow the CMDT SWC programme to continue (1^{st} and 2^{nd} aspect of sustainability). The SWC village teams were not yet sufficiently strong and integrated in the village organisations for collective SWC activities to be continued (2^{nd} aspect). However, the choice of techniques and extension methods, plus the limited dependence on external incentives, made it possible for individual farmers to continue adopting and applying SWC measures (3^{rd} aspect). The continuing adoption proves that farmers see the benefits of SWC as outweighing the costs (4^{th} aspect). The positive effects of SWC at the field level gradually increase over time (5^{th} aspect). The project withdrawal has not prevented any farmer from continuing with SWC; on the contrary, even farmers in untargeted villages have taken up SWC to a level comparable to that in targeted villages (6^{th} aspect).

In conclusion, the continuing farmer adoption of SWC proves the sustainability that was built in the SWC project approach. In the future however, a changing situation may need a modified SWC approach. This requires that the role the SWC project played in between extension and research organisations be taken over by another player.

Interaction between the monitoring and evaluation system and project impact

Having discussed the five aspects of a complete evaluation in the previous sections, in this section the interaction between the M&E system and project impact is discussed. Timely evaluation yields feedback for project improvements, so how has project monitoring and evaluation affected project impact in southern Mali? The SWC project monitoring emphasised the SWC training of staff and farmers, and the adoption of SWC measures. When achievements for certain SWC measures were disappointing (e.g. collective action, stone rows), the flexible approach gave room for a shift in emphasis (e.g. individual assistance, vegetative barriers). The monitoring system reflected and strengthened the strategy of large-scale training and adoption.

Improved monitoring and evaluation would have affected impact differently in the following ways:

- If the availability of plant material had been monitored systematically, more emphasis could have been given to the multiplication and distribution of *Andropogon* grass seed. This species is the most preferred for vegetative barriers, but its availability is still limited.
- If erosion gullies, considered during erosion control planning, had been documented and regularly monitored, more emphasis could have been given to the quality and effectiveness of erosion control measures. The gully reclamation measures (stone or crop residue check dams) in particular were often of poor quality, diverting the erosion to the adjacent area.
- If, in addition to erosion gullies and rills, sheet erosion indicators had been taken into account when planning and evaluating erosion control measures, the action taken could have been greater and applied earlier, and greater emphasis could have been given to cultivation along the contour. This would also require the monitoring of the direction of cultivation in relation to the slope. Except in few villages with exceptionally high adoption of erosion control measures, in most villages the farmers make little effort to cultivate along the contour.
- If the sustainability, expressed in a nutrient balance and a balance for soil organic matter, had been evaluated regularly – for example, every three years – more emphasis could have been given to other means to increase inputs and reduce losses of nutrients and organic matter. Perhaps the soil amelioration potential of compost and manure is insufficient and other complementary practices such as mulch, green manure, improved fallow and reduced tillage need to be applied.

In conclusion, if the monitoring system were set up to evaluate more impact indicators during the project implementation, the project could have had more impact.

11.3 New elements in impact evaluation and the importance of delays in project impact

There are three new elements in this research. The first element is already discussed in 11.1, and concerns the (ex-post) evaluation method applied, with its four new features: small cause-effect steps; matching data from different sources and over a long period of time; and the use of reconstructed baseline and virtual time series. The second element, discussed in 11.2, is the actual impact evaluation of the SWC project in southern Mali, by itself. The SWC project approach has worked: farmers continue SWC without external support, SWC reduces erosion and increases crop yield, and farmer benefits outweigh the project costs. This is one of the rare thorough impact evaluations of a large-scale and long-term SWC project with positive results. The third element is of a more general nature, and consists of the concept of “delays in project impact”, which will be discussed here.

The dynamics of changes over time have received particular emphasis in this thesis. Several types of delays were experienced in the various steps between project inputs and project impact. A schematic presentation of the simplified time series for project input, farmer training, farmer adoption of SWC, nutrient balance, soil quality and crop production is presented in Figure 11.1. The dotted lines in the figure constitute the start and the end of the project period.

Firstly, there are delays between project financial inputs (on bottom of figure), the development of a project approach, and training of staff and training of farmers. This is in line with what Hudson (1991) found in his evaluation of SWC projects: projects generally underestimate the time needed to get the project on track and therefore long-term (>5 years) SWC projects have been more successful than short-term projects. Secondly, there are delays between farmer training, adoption in targeted villages, and adoption in untargeted villages. Thirdly, there is a delay between the adoption of SWC and improved nutrient balances (decreased erosion, increased fertilisation). At the moment the project stops, it is possible that although land degradation has decreased and nutrient balances have improved, nutrient balances are still negative. The moment at which nutrient balances achieve equilibrium will coincide with stabilised soil organic matter content. However, to halt the soil organic matter decline, not only should nutrient balances achieve equilibrium, but also more biomass is needed to replenish soil organic matter. Finally, there can be a delay between changes in nutrient balance and soil quality, and production. With no fertiliser increase, a stable soil organic matter content will be required to halt the yield decline. However, increased fertilisation often camouflages soil fertility decline.

These delays explain the apparent contradiction between the successes of the SWC project in reducing erosion and increasing yields in fields with SWC measures, and the overall picture of southern Mali with continuing erosion and declining crop yields. A scant consolation is to realise that the situation would have been worse without SWC project, and that if more SWC efforts are made, the trends in erosion and yield will eventually reverse.

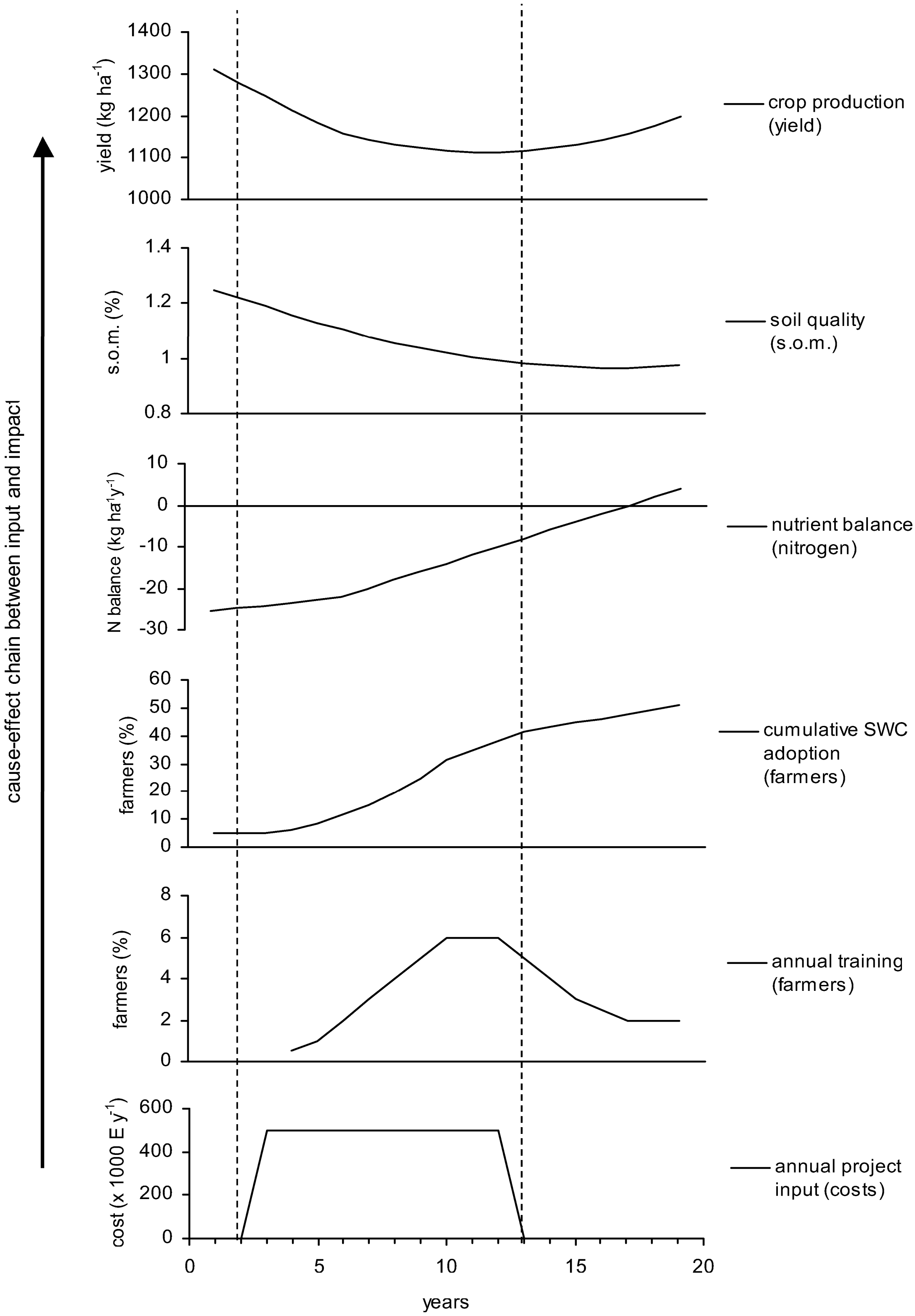

Figure 11.1. Delays between trends in project input, training, SWC adoption, nutrient balance, soil quality and productivity.

This problem of inertia and delays is well recognised in the Millennium Ecosystems Assessment Synthesis Report:

> 'Different categories of ecosystem services tend to change over different time scales, making it difficult for managers to evaluate trade-offs fully. As a consequence, impacts on more slowly changing supporting and regulating services [e.g. erosion control] are often overlooked by managers in pursuit of increased use of provisioning services [e.g. food production]'. (Reid et al., 2005)

These delays in project impact have serious implications for the monitoring and evaluation of future SWC projects, which will be discussed below.

11.4 Recommendations for monitoring and evaluation in future SWC projects

As seen in a previous section (11.2), a good monitoring and evaluation system is of the utmost importance in order to draw the right conclusions, improve the project strategy and activities, and maximise the project impact. Based on the lessons learnt from the SWC project in southern Mali, some recommendations for future SWC projects can be made. These are presented below.

Monitoring for impact

The first recommendation is not new – the logical framework has been used for decades. It is that SWC projects should be encouraged to complete the logical framework, including indicators and baseline data up to the goal level, and including long-term targets up to the purpose level. Impact evaluations should be simple and timely so that they contribute to project improvements during implementation. Timely impact evaluations allow the logical framework to be used more flexibly, keeping attention focused on the higher-level objectives while allowing greater flexibility in the lower-level activities and outputs.

To avoid an enormous monitoring workload for the SWC project, the project should link up with external monitoring institutes or organisations. It is possible that with relatively simple adaptations to both project monitoring and external monitoring, project impact can be evaluated relatively simply (Chapter 10).

Proxy and derivative indicators for land degradation

The relationship between activities and impact is complicated by the difficulty of capturing land degradation in simple indicators. Which indicators should SWC projects use for land degradation, besides erosion indicators? The complex relationships between proxy and derivative indicators will be discussed here, because these relationships have caused debate and misunderstanding in the various 'land degradation narratives' (Elias and Scoones, 1999; Mazzucato and Niemeijer, 2000; Gray and Kevane, 2001; Mortimore and Harris, 2005).

If an SWC project is interested in soil quality, soil organic matter would be a good proxy indicator. However, the annual change in soil organic matter is very small compared to the soil organic matter content itself and its variability between fields (Gachimbi et al., 2005), which makes the reserves of soil organic matter an insensitive and thus unsuitable indicator for short-term SWC projects. Even when researchers have compared current soil fertility with the results from soil analyses done decades ago by others (Mazzucato and Niemeijer, 2000), the results have not convincingly proved sustainability, soil degradation or soil improvement.

Two derived indicators have been widely used to predict or to assess land degradation: nutrient balances (Stoorvogel and Smaling, 1990; van der Pol, 1992) and trends in crop yield (Elias and Scoones, 1999; Mazzucato and Niemeijer, 2000; Benjaminsen, 2001). Nutrient balances are not very useful if the nutrient reserves are not known (Lesschen et al., 2004). That the relation between nutrient balance, soil quality and crop yield is complex can be seen in Figure 11.1: crop yield is affected by both soil quality and nutrient balance. Taking southern Mali as an example, one can imagine a situation in which increased fertilisation and erosion control have resulted in a less negative nutrient balance, but in which biomass production and recycling have been insufficient to halt a continuing decline in soil organic matter. The reduced nutrient release from the mineralisation of soil organic matter is compensated by increased fertilisation. This shows that in theory, crop yields can increase in spite of soil fertility decline and negative nutrient balances. As Vierstra (1994) stated: 'increased fertilisation camouflages soil fertility decline'.

This example of camouflaged soil fertility decline shows that it is difficult to capture land degradation or soil fertility decline in simple indicators. Acknowledging the importance of soil organic matter and the need for a sensitive indicator of change, it is recommended to expand the use of nutrient balances to include carbon balances. Although soil carbon modelling is more complex, the current interest in soils as a carbon sink for mitigating climate change is accelerating the development of user-friendly 'carbon balance' tools (Ponche-Hernandez, 2004) which, hopefully, could also be used by SWC projects.

Change indicators for delayed impact

The successive delays between project inputs and project impact, which add up to several years, complicate the timely evaluation of project impact. This has various implications for the planning, monitoring and evaluation of an SWC project. For example, it is likely that some of the impact indicators will not show the long-term targeted values in the relatively short project period. A project will thus need proxy indicators that forecast the desired impact. These proxy indicators should reflect change, rather than status, that point the direction of achieving the desired impact in the future.

At the moment that project support ceases, the degree to which farmer training is continuing is more important than the number of farmers that have already been trained. This underlines the importance of a short-term donor-funded project being embedded in a long-term national programme that continues to assist farmers, even with reduced means. Similarly, the rate at which the adoption continues to increase when project support has withdrawn is more important that the adoption rate at the moment the project ceases. This highlights the importance of simple and cheap SWC measures that farmers can replicate without project assistance. And it underlines Hudson's recommendation (1991): projects aiming at changing agricultural systems should have a time horizon of at least 10 years and should therefore catalyse a change that becomes self-spreading and self-sustaining.

Not only do change indicators say more about future impact than status indicators: change indicators are also often more sensitive than status indicators. For example, nutrient balances are more sensitive indicators of a change in sustainability than soil fertility.

Proxy impact indicators do not replace indicators of real impact. Just as a project should be embedded in a longer-term programme, a project monitoring and evaluation system should be embedded in a continuing national monitoring system that enables the evaluation of delayed impact after project closure.

'Is this field fertile? That depends on my own efforts.'
(Yacouba Sanogo in Mamarila village, southern Mali, 2003).

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Summary

Chapter 1: Introduction

Southern Mali, where total crop production has shown a spectacular increase over the last decades, has a number of land degradation problems. Expanding agriculture, increasing livestock numbers and increasing firewood demand have led to localised overexploitation of the soil and forest resources. Although slopes of agricultural fields are gentle, 1-2% on average, the long slope length, low soil cover and poor soil structure result in substantial runoff and soil erosion. Furthermore, nutrient balances for the cultivated area are generally negative.

In the framework of a Dutch bilateral aid programme, a soil and water conservation (SWC) project was initiated in 1986, known under the name '*Projet Lutte Anti-Erosive*'. The project was built in the Malian semi-government organisation for cotton and rural development: '*Compagnie Malienne pour le Développement des Textiles*' (CMDT). The overall project goal was to reduce land degradation, intensify agriculture and increase production. Activities aimed at capacity building of the CMDT extension service, organising and training of farmers, and farmer adoption of SWC practices.

The SWC practices consisted of erosion control measures and soil fertility measures. The erosion control measures included line interventions (live fences, stone rows, grass strips), gully interventions (of stones, wood and crop residues) and contour cultivation. The soil fertility measures included compost production in improved cattle pens with addition of crop residues, and in compost pits.

In 1998, I was employed as technical assistant at the SWC Unit by the CMDT, where I worked until 2002. Training activities and farmer adoption were regularly monitored and several evaluations had indicated the effect of farmer training on adoption of SWC measures.

Donor funding was gradually withdrawn between 1998 and 2002 and SWC extension activities by the CMDT had virtually stopped in 2003. However, no final evaluation of project impact had been done in spite of the interesting lessons that can be learnt from this long-term and large-scale experience. This shortcoming was the starting point for my research.

The research objectives were: 1) to develop an ex-post impact evaluation methodology for the SWC project in southern Mali; 2) with this methodology, to evaluate the effectiveness and intended impact of the long-term SWC project in southern Mali and to infer the lessons for future SWC activities in Mali and elsewhere; and 3) to make recommendations for the planning, monitoring and evaluation of future SWC projects in order to have a more timely feedback on impact during project implementation.

Chapter 2: Impact evaluation methodology for the SWC Project

The first part of this chapter describes the theory of project planning, monitoring and evaluation, using a 'logical framework'. It emphasises the difficulty to attribute change at the goal level to project activities, the so-called attribution gap. An evaluation can partly bridge this attribution gap by comparing 'with-without' and 'before-after' project situations. Ex-post evaluations, often handicapped by missing baseline data, can use 'reconstructed baseline data' or 'virtual time series' to allow a before-after comparison.

The second part of Chapter 2 describes the practice of planning, monitoring and evaluation of the SWC project in southern Mali. An overview of the evaluations done so far reveals the additional analyses needed to complete an ex-post evaluation. This also showed the need for additional fieldwork, which I did in 2003.

Chapter 3: Material and methods

This chapter first describes the project area in southern Mali. It then presents the fieldwork and the additional analyses. The fieldwork in 2000 and 2003 included observations on erosion and erosion risk, which had not been done by the regular monitoring. The evaluation of the cause-effect chain between project activities and project impact is split into three steps: from farmer training to adoption of erosion control, from erosion control to reduced erosion, and from reduced erosion to improved crop yields.

Chapter 4: Expansion, intensification, productivity and sustainability

This chapter describes the agricultural development in southern Mali between 1988 and 2002 in terms of respectively expansion, intensification, productivity and sustainability. The cultivated area per person increased from 0.44 ha in 1988 to 0.61 ha in 2002. Meanwhile, farmers have intensified farming: they grow more cash crops (cotton and maize) and have almost doubled chemical and organic fertiliser doses. In spite of intensification efforts, cotton and maize yields have decreased with 10% and 17% between 1993 and 2002, partly due to decreasing rainfall and cultivation on more marginal land. However, expansion compensated declining crop yields so production per person increased. The nutrient balance, expressed in kg N+P+K ha^{-1} y^{-1}, has become only a little less negative in 2002 (-40) than it was in 1988 (-58). Further intensification is needed to increase both productivity and sustainability.

Chapter 5: How project approach influences adoption of SWC

The choice of a project approach affects the continuation of SWC practices after project withdrawal. This chapter describes the SWC project approach in southern Mali and the adoption during and after the project. The main features of this SWC extension project were:

- The promotion of cheap and simple SWC measures.
- A participatory village approach with limited use of incentives.
- The incorporation of the SWC programme into an existing extension service.

Farmers in the SWC-targeted villages still recommend this SWC extension approach for farmers in untargeted villages. There was a steady increase in adoption, which led to a gradually decreasing difference between targeted and untargeted villages. Between 1986 and 2000, farmers in half the 5000 villages in southern Mali had been trained in SWC. By 2002, erosion control measures had been installed in 94% of the villages, by 46% of farmers and in 15% of the fields. Though external donor support has stopped and SWC extension has decreased, farmer adoption is still continuing.

Chapter 6: Factors influencing adoption of SWC

Five factors are analysed that influenced farmer adoption of SWC—erosion control measures and soil fertility measures—in southern Mali:

1) In the high land-pressure areas, farmers adopt more soil fertility measures.

2) In the cotton-growing area, farmers adopt less SWC measures than farmers in the dryer, non-cotton growing area.
3) Farmers with more ploughing equipment adopt more SWC measures.
4) Farmers with a donkey cart, which facilitates transport of crop residues and compost, adopt more soil fertility measures.
5) Farmers trained by the SWC project adopt more erosion control measures.

There is a strong correlation between the adoption of erosion control measures and the adoption of soil fertility measures that could not be explained by these five factors alone. This suggests that there are additional factors that trigger the adoption of SWC measures.

Chapter 7: Soil crusts and deposits as sheet erosion indicators

Land degradation and soil erosion had not been regularly monitored by the SWC project. However, these were important aspects of the project goal, so this research required suitable indicators to evaluate soil erosion. Rills are indicators of erosion, easily recognised by farmers and extension workers. However, they are rare on fields in Mali with slopes of 0 – 3%, even though runoff and sheet erosion may be a problem. The suitability as erosion indicators of three other soil surface features is therefore investigated:

- Structural crusts formed by rainfall impact without lateral soil movement.
- *In situ* depositional crusts, formed by sedimentation leaving the finest particles on top.
- Runoff deposits of fine and coarse sand, formed after the removal of finer particles.

Soil cover with a runoff deposit of coarse sand proves to be a suitable indicator. This deposit is well explained by erosion risk: a 2% increase in slope results in a 9% increase in deposit cover. It also relates well to cotton yield: a 30% increase in deposit cover is reflected in a decrease in cotton yield of about 25%.

Only a few farmers confirmed that these symptoms were produced by erosion. It is recommended that soil and water conservation programmes pay more attention to the presence of crusts and deposits.

Chapter 8: Ex-post evaluation of erosion control

Ex-post evaluations of erosion control are often handicapped by lack of baseline data. In one village, a baseline situation from 1988 was available and compared with the situation in 2003, after farmers had installed stone rows, live fences and grass strips, and had started cultivating across to the slope. Estimated annual soil loss had decreased from 42 to 10 t ha^{-1} y^{-1}. However, baseline data on erosion were not available for other villages. A simple 'with-without' comparison is not correct because farmers install erosion control measures especially in fields with more erosion. Two alternative methods are used.

Using the reconstructed baseline, looking not only at active gullies but also at (partly) reclaimed gullies, the study concludes that line interventions, gully interventions, and a combination of both, reduced the proportion of active gullies by 50 – 70%.

Using a virtual time series, comparing erosion in fields with erosion control measures installed in different years, the study concludes that erosion gradually decreased by 50% during the three years after installation of erosion control measures.

The study also concludes that sowing on contour reduces sheet erosion. A reduction of the slope of the sowing direction by 1% reduced the cover of runoff deposit of coarse sand with 8%.

Extrapolation over the 15% fields with erosion control, taking into account the higher initial erosion in these fields, shows that erosion control reduced erosion in southern Mali by 16%.

Chapter 9: Impact of erosion control on crop yield

The same handicap of missing baseline data applies to the evaluation of the effect of erosion control measures on crop yield. Two alternative methods are used: 1) expanding the 'with-without' comparison with several farm and field characteristics as covariates in linear regression analyses; 2) constructing a virtual time series, comparing fields with erosion control measures installed in different years, and comparing villages targeted by the SWC programme in different years.

Results from linear regression analyses show a positive interaction between stone rows (installed above the cultivated area) and rainfall in their effect on crop yield. The effect of vegetative barriers did not seem to depend on rainfall. Cotton yield in fields with erosion control measures was 4.8% higher than in fields without erosion control measures. Extrapolation over the 22% cotton fields with erosion control shows that the impact represents 1.1% of the cotton production in southern Mali.

Results of virtual time series show that stone rows have an immediate effect on crop yield whereas the effect of vegetative barriers gradually increases over the years after installation. Cotton yield in old SWC villages, trained on average 8 years ago, was 12.5% higher than in new SWC villages, trained on average 2 years ago, indicating a gradual yield increase after the start of SWC. Extrapolation over the 51% villages that received SWC training shows that the impact represents 6.4% of the cotton production in southern Mali.

Chapter 10: Linking monitoring to evaluation

In contrast to the previous chapters that analysed one particular step between project activity and impact, this chapter synthesises to what extent the monitoring system enables the overall evaluation of the SWC project. Three aspects are highlighted:

The effect on the adoption of SWC. The project has been effective in farmer training and adoption of SWC.

The impact on land degradation and agricultural production. The evaluation of impact on land degradation was hindered by the lack of monitoring at this level. The impact on production was calculated by extrapolation of results in chapter 9 and chapter 5. SWC resulted in an additional cotton production of 5.000 to 28.000 tons per year (average 2000 – 2002) in southern Mali.

The efficiency, comparing project costs with farmer benefit. The evaluation shows that farmer benefits (gross margin) of increased annual cotton production valued between €1.260.000 and €7.530.000, averaged for 2000 – 2002. This largely outweighs the annual project costs (donor funded technical assistance and SWC operational costs) of about €580.000, averaged for 1986 – 2001.

Chapter 11: Synthesis

This chapter integrates the results of the previous chapters, emphasises what was new in this research, and gives recommendations for future SWC projects.

The ex-post evaluation of the SWC project in southern Mali has been possible by combining various methods, on the one hand the theoretical concepts (the logical framework, the reconstructed baseline and the virtual time series) and on the other hand the practical work of collecting data from different existing sources and fieldwork, and additional analyses.

Besides the effectiveness, impact and efficiency, already discussed in the previous chapters, the relevance and sustainability are discussed here. At the time the project stopped, the project had become less relevant, due to changes in donor and host country policies. However, the project's sustainability scores reasonably well because farmers are continuing SWC activities after project withdrawal.

New about this study is the consideration of delays in project impact. The delays between project inputs, farmer training, farmer adoption of SWC, improved sustainability, reduced land degradation and improved crop yields, add up to many years.

The following recommendations are made to improve the evaluation of SWC projects. Monitoring should include indicators and reference values at all levels in the logical framework, and project monitoring should be complemented by external monitoring. Achieving impact may take longer than the project life span. Therefore the project should be embedded in an ongoing national programme and promote practices that farmers can replicate after project closure. Delayed impact also requires proxy impact indicators reflecting change rather than status. However, proxy impact indicators do not replace real impact indicators. Therefore, the project monitoring should be embedded in an external national monitoring system that enables the evaluation of delayed impact after project closure.

Résumé

Chapitre 1 : Introduction

Le Mali Sud, où la production agricole a augmenté de façon spectaculaire les dernières décennies, connaît des problèmes de la dégradation des terres. L'expansion agricole, l'augmentation du cheptel et la demande croissante de bois de feu ont résulté en une surexploitation locale des terres et des forêts. Malgré les faibles pentes de 1-2% en moyenne sur les parcelles cultivées, la longueur des pentes, la couverture pauvre du sol et la faible structure du sol résultent en un ruissellement pluvial et une érosion importants. En plus, les bilans minéraux pour la zone cultivée sont généralement négatifs.

Dans le cadre d'un programme d'appui bilatéral néerlandais, un projet de conservation de l'eau et du sol (CES) est mis en place en 1986, connu sous le nom 'Projet Lutte Anti-Erosive'. Le projet était incorporé dans l'organisation semi-étatique pour le coton et développement rural : la CMDT (Compagnie Malienne pour le Développement des Textiles). L'objectif global était de diminuer la dégradation des terres, intensifier l'agriculture et augmenter la production. Les activités étaient axées sur la formation d'un service de vulgarisation de la CMDT, sur l'organisation et la formation des paysans, et sur la mise en œuvre des mesures CES par les paysans.

Les mesures CES consistent en des mesures anti-érosives et des mesures de production de compost. Les mesures anti-érosives appliquées étaient les barrières en ligne (lignes en cailloux, haies vives, bandes enherbées), les barrières de rigoles (en tiges, bois, cailloux), et la culture perpendiculaire à la pente. Les mesures de production de compost appliquées étaient sont les parcs en bétail améliorés avec l'application des résidus de récolte, et les fosses fumières.

En 1998, j'ai été engagé comme assistent technique à ce projet par la CMDT, ce que j'ai fait jusqu'en 2002. Les formations et l'installation des mesures CES étaient suivies régulièrement et plusieurs évaluations ont montré l'effet positif de la formation sur l'application des mesures CES.

Le financement des bailleurs de fonds a diminué graduellement depuis 1998 et s'est arrêté complètement en 2002. Et la vulgarisation en CES par la CMDT a pratiquement cessé en 2003. Ainsi, ce projet de longue durée et à grande échelle a pris fin sans qu'on n'ait eu la possibilité d'une évaluation finale de l'impact de ce projet et de tirer des conclusions pour les activités de CES en générale. Le point de départ de mes recherches a été de remédier à ce manque.

Ainsi, les objectifs de la présente recherche ont été: 1) développer une méthode pour évaluer rétrospectivement l'impact du projet CES au Mali Sud ; 2) avec cet instrument, évaluer l'effectivité et l'impact du projet CES et tirer des conclusions pour les activités CES futurs au Mali et ailleurs ; 3) faire des recommandations pour la planification, le suivi et l'évaluation des projets CES futurs, à fin d'avoir un feed-back sur l'impact plus vite, déjà pendant l'exécution du projet.

Chapitre 2 : Méthode d'évaluation de l'impact du projet CES

La première partie de ce chapitre traite la théorie sur la planification, le suivi et l'évaluation de projets en général, en utilisant un 'cadre logique' de planification par objectif (*logical framework).* L'accent est mis sur la difficulté d'attribuer des changements qui se produisent au niveau de l'objectif global aux activités du projet : 'la lacune d'attribution'. On peut y remédier en partie par

des comparaisons avant et après le projet, et en comparant des sites avec et sans support du projet. Les évaluations rétrospectives, souvent gênées par l'insuffisance des données sur la situation initiale, peuvent utiliser les méthodes de 'situation initiale reconstruite' et de la 'succession virtuelle', qui permettent une sorte de comparaison avant et après le projet.

La deuxième partie du chapitre traite la pratique de la planification, du suivi et de l'évaluation du projet CES au Mali Sud. Un aperçu des évaluations déjà faites montre quelles analyses supplémentaires étaient nécessaires pour une évaluation complète. Ceci a montré également la nécessité de recherches supplémentaires sur le terrain, ce que j'ai fait en 2003.

Chapitre 3 : Méthodologie

Ce chapitre décrit d'abord la région du Mali Sud. Ensuite sont présentées les recherches sur le terrain faites en 2000 et en 2003, ainsi que des analyses supplémentaires. Les recherches sur le terrain de 2000 et 2003 incluaient des observations sur l'érosion et le risque d'érosion, ce qui n'était pas observé dans le suivi habituel. L'évaluation de la chaîne cause-effet entre les activités du projet et l'impact global a été analysée en trois étapes: de la formation des paysans jusqu'à l'installation des mesures CES, des mesures CES jusqu'à la réduction de l'érosion, et de l'érosion réduite jusqu'aux rendements améliorés.

Chapitre 4 : Expansion, intensification, productivité et durabilité

Ce chapitre décrit le développement agricole au Mali Sud entre 1988 et 2002 en termes d'expansion, intensification, productivité et durabilité. La superficie cultivée par habitant a augmenté de 0,44 ha en 1988 à 0,61 ha en 2002. En même temps, les paysans ont pratiqué une intensification agricole: ils cultivent davantage de coton et de maïs, qui sont des produits commerciaux, et ils ont presque doublé leurs doses d'engrais minéraux et de compost. Malgré cette intensification, les rendements par ha en coton et en maïs ont baissé respectivement de 10% et 17%, en partie à cause de la pluviosité diminuée et de la mise en culture des terres marginales. Cependant, l'augmentation de la superficie cultivée par habitant a compensé la baisse du rendement, de sorte que la production par habitant a augmenté. Le bilan minéral, exprimé en kg N+P+K par ha par an, est devenu légèrement moins négatif en 2002 (-40) qu'en 1988 (-58). Une plus grande intensification est encore nécessaire pour augmenter la productivité et la durabilité.

Chapitre 5 : Comment l'approche du projet influence l'application des mesures CES

La contiuation des mesures CES après l'arrêt du projet dépend en grande partie de l'approche adoptée pendant le projet. Ce chapitre décrit quelle était l'approche adoptée pour le projet CES au Mali Sud, et dans quelle mesure les paysans ont mis en pratique les mesures CES pendant et après le projet. Les caractéristiques essentielles du projet étaient:

- la promotion des mesures CES peu coûteuses et simples,
- une approche villageoise et participative avec peu de mesures incitatives,
- l'incorporation du programme CES dans un service existant de vulgarisation.

Les paysans aux villages qui ont reçu le support CES ont apprécié cette approche et la recommandent toujours pour le support aux autres villages. L'application des mesures CES a augmenté progressivement, aussi dans les villages qui n'ont pas reçu le support du projet. Le résultat est une diminution progressive de la différence entre les villages qui ont reçu le support du projet, et les villages voisins qui n'ont pas reçu ce support directement. Entre 1986 et 2000, le support CES a été donné dans la moitié des 5000 villages au Mali Sud. Or, en 2002, des mesures CES ont été installées dans 94% de tous les villages, pratiquées par 46% des paysans, et dans 15% des parcelles. Malgré l'arrêt du financement des bailleurs de fonds et la diminution de la vulgarisation en CES, l'application des mesures CES par les paysans continue toujours.

Chapitre 6 : Facteurs influençant l'application des mesures CES

Cinq facteurs ont été analysés, qui influencent l'application des mesures CES au Mali Sud:

1) Pression sur la terre : dans les zones où les terres sont cultivées en permanence, les paysans produisent proportionnellement plus de compost;
2) Culture de coton ou autre: les paysans dans la zone cotonnière appliquent moins de mesures CES que les paysans dans la zone plus sèche, sans coton;
3) Equipement agricole disponible: les paysans qui possèdent plus de bœufs de labour et de charrues appliquent davantage de mesures CES;
4) Moyen de transport disponible: les paysans qui possèdent une charrette, qui facilite le transport des résidus de récolte et du compost, produisent plus de compost.
5) Formation CES: les paysans qui ont reçu la formation CES appliquent plus de mesures anti-érosives.

On a constaté une corrélation très élevée entre l'application de mesures anti-érosives et l'application de mesures de production de compost, qui n'est pas expliquée par ces cinq facteurs. Il semble donc qu'il y ait d'autres facteurs qui incitent à l'application des mesures CES.

Chapitre 7 : Croûte de sol et sédiment comme indicateurs de l'érosion en nappe

La dégradation des terres et l'érosion des sols n'étaient pas régulièrement suivies par le projet CES. Pourtant, ces phénomènes jouent un rôle essentiel dans l'objectif global, c'est pourquoi ils ont été l'objet de recherches dans le cadre de l'étude ici présente. Il fallait donc trouver des indicateurs appropriés pour évaluer l'érosion. Des rigoles sont des indicateurs d'érosion facilement reconnaissables par les paysans et les vulgarisateurs. Mais les rigoles ne sont pas fréquentes sur les parcelles au Mali, avec des pentes entre 0 et 3%, alors que le ruissellement et l'érosion en nappe peuvent néanmoins être un grand problème. C'est pourquoi trois autres symptômes de la surface du sol ont été testés pour leur utilité comme indicateur d'érosion:

- La croûte structurale, formée par la pluie, sans que les particules du sol se soient déplacées latéralement;
- La croûte de déposition *in situ*, formée par sédimentation, déposant les particules les plus fines à la surface;
- Les dépôts, après ruissellement, de sable gros et de sable fin, formés par décantation après l'évacuation des particules fines.

La surface de dépôt de sable gros s'avère un indicateur d'érosion valide: une augmentation de la pente de 2% résultait en une augmentation de la surface de dépôt de 9%. Cet indicateur est relié aussi au rendement: une augmentation de la surface de dépôt de 30% était reliée à une diminution du rendement de coton de 25%.

Jusqu'à maintenant, peu de paysans reconnaissent ces symptômes comme étant le résultat de l'érosion. Il est donc important que les programmes CES mettent l'accent davantage sur la présence de dépôts et de croûtes comme indicateurs d'érosion.

Chapitre 8: Evaluation rétrospective des mesures anti-érosives

Les évaluations rétrospectives sont souvent gênées par l'insuffisance des données sur la situation initiale. Dans un seul village, les données sur la situation initiale en 1988 étaient disponibles et sont comparées avec la situation en 2003, après que les paysans ont installé des lignes en cailloux, des haies vives et des bandes enherbées, et ont commencé à cultiver perpendiculairement à la pente. La perte en sol, estimé par le volume des rigoles, avait diminué de 42 à 10 tons par ha par an. Mais pour d'autres villages il n'y avait pas de données sur la situation initiale disponibles. C'est pourquoi on a eu recours à deux méthodes alternatives: l'utilisation de la situation initiale reconstruite et la succession virtuelle.

A l'aide de la situation initiale reconstruite, dans laquelle non seulement les rigoles actuellement actives mais aussi les anciennes rigoles (non-actives) sont considérées, on a pu conclure que les barrières en ligne, les barrières de rigoles et la combinaison des deux types de barrières réduisent la proportion des rigoles actives avec 50 – 70%.

A l'aide de la succession virtuelle, dans laquelle on compare l'érosion des parcelles où les mesures anti-érosives ont été installées dans des années différentes, on a pu conclure que l'érosion diminue progressivement avec 50% dans les trois premières années après l'installation des mesures.

Ces recherches ont montré également que le semis perpendiculaire à la pente réduit l'érosion en nappe. Une diminution de la pente de la direction de semis de 1% réduit la surface du dépôt de sable gros de 8%.

Avec une extrapolation des effets au niveau des parcelles, prenant en compte que 15% des parcelles ont des mesures anti-érosives et que l'érosion initiale était plus élevée sur ces parcelles, on conclue que les mesures anti-érosives ont diminué l'érosion au Mali Sud de 16%.

Chapitre 9 : Impact des mesures anti-érosives sur les rendements des cultures

La même difficulté provenant de l'insuffisance des données sur la situation initiale se pose quand on évalue l'effet des mesures anti-érosives sur les rendements des cultures. Deux méthodes alternatives ont été utilisées : 1) élargir la comparaison 'sans-avec mesures anti-érosives' avec différentes caractéristiques des paysans et des parcelles comme co-variables dans les analyses de régression linéaires ; 2) établir une succession virtuelle, dans laquelle on compare des parcelles avec des mesures anti-érosives installées dans des années différentes, et dans laquelle on compare des villages qui ont reçu le support CES dans des années différentes.

Les résultats des analyses de régression linéaires montrent que l'effet des lignes en cailloux (en amont des parcelles) sur le rendement est positivement lié à la pluviosité. L'effet des barrières végétatives ne semble pas dépendre de la pluie. Le rendement du coton dans les parcelles avec des mesures anti-érosives était de 4,8% plus élevé que dans les parcelles sans mesures. L'extrapolation, prenant en compte que 22% des parcelles ont des mesures anti-érosives, montre que l'impact représente 1,1% de la production de coton au Mali Sud.

Les résultats de la succession virtuelle montrent que les lignes en cailloux ont un effet immédiat sur le rendement, tandis que l'effet des barrières végétatives augmente progressivement pendant les années après l'installation. Le rendement du coton dans les 'anciens' villages CES, ayant reçu le support du projet il y a 8 ans en moyenne, était de 12,5% plus élevé que dans les 'nouveaux' villages CES, qui avaient reçu ce support il y 2 ans en moyenne. Cela indique l'amélioration progressive des rendements pendant les années après le démarrage de la CES. L'extrapolation, prenant en compte que 51% des villages ont reçu le support CES, montre que l'impact représente 6,4% de la production de coton au Mali Sud.

Chapitre 10 : Lier le suivi à l'évaluation

Contrairement aux chapitres précédents, qui chacun ont analysé une étape entre les activités du projet et l'impact, ce chapitre discute dans quelle mesure les résultats du suivi ont permis une évaluation complète du projet. L'accent est mis sur trois aspects :

L'effet sur l'application des mesures CES. Le projet CES a été efficace en la formation des paysans et en l'application des mesures CES par les paysans.

L'impact sur la dégradation des terres et sur la production. L'évaluation de l'impact sur la dégradation des terres a été empêchée par le manque de suivi à ce niveau. L'impact sur la production a été calculé par l'extrapolation des résultats présentes en chapitres 9 et 5. La CES a résulté en une production additionnelle de 5.000 à 28.000 tons de coton par an (en moyenne 2000 – 2002) au Mali Sud.

L'efficacité en termes de coûts de projet et de bénéfices pour les paysans. L'évaluation montre que les bénéfices annuels pour les paysans (marge brute) de la production de coton augmentée valent entre €1.260.000 et €7.530.000, en moyenne pour 2000 – 2002. Ceci dépasse largement les coûts annuels du projet (assistance technique et vulgarisation CES payé par le bailleur de fonds) qui valaient environ €580.000, en moyenne pour 1986 – 2001.

Chapitre 11 : Synthèse

Ce chapitre intègre les résultats des chapitres précédents, met l'accent sur ce qui était nouveau dans cette recherche, et fait des recommandations sur le suivi et l'évaluation dans des projets CES futurs.

L'évaluation rétrospective du projet CES au Mali Sud est le résultat du concours de procédés et techniques divers, d'une part les techniques théoriques (l'utilisation du `cadre logique', des notions de situation initiale reconstruite et succession virtuelle), d'autre part les démarches concrètes: rassembler et analyser les différentes données déjà présentes, complétées avec les observations et recherches supplémentaires sur le terrain.

Outre l'efficacité, l'impact et le rendement, traités dans les chapitres précédents, ce chapitre discute aussi la pertinence du programme CES, ainsi que sa permanence. Au moment où le projet a cessé, le programme CES était devenu moins pertinent à cause des changements politiques des bailleurs de fonds et du gouvernement malien. Par contre, la permanence fait un bon score puisque les paysans continuent la CES après l'arrêt du projet.

Un aspect nouveau de cette recherche est l'attention portée sur les délais qui s'écoulent entre les différentes étapes, jusqu'à l'impact recherché. Depuis l'utilisation des moyens du projet, la formation des paysans, l'application des mesures CES, la durabilité améliorée, la dégradation

réduite, et finalement les rendements augmentés, s'écoulent à chaque étape des délais qui, ensemble, s'élèvent à plusieurs années.

Les recommandations suivantes peuvent améliorer le suivi et l'évaluation des projets CES: le suivi doit se faire à tous les niveaux du `cadre logique', des activités du projet jusqu'à l'objectif global, et le suivi dans le cadre du projet doit être complété par un suivi externe. L'impact peut se faire attendre au-delà de la durée du projet. Pour cela le projet doit être ancré dans un programme national continu et doit utiliser des mesures que les paysans peuvent continuer après l'arrêt du projet. Les délais de l'impact exigent aussi des indicateurs dérivés qui reflètent un changement plutôt qu'une situation. Bien sûr: les indicateurs dérivés ne remplacent pas les vrais indicateurs d'impact. C'est pourquoi le système de suivi du projet doit être ancré également dans un système de suivi permanent et national pour que l'impact retardé puisse être évalué après l'arrêt du projet.

Samenvatting

Hoofdstuk 1: Introductie

Zuid-Mali, waar in de afgelopen decennia de landbouwproductie sterk is toegenomen, heeft een aantal landdegradatie problemen. De zich uitbreidende landbouw, de groeiende veestapel en de stijgende vraag naar brandhout hebben geleid tot lokale overexploitatie van de landbouw-, bos- en weidegronden. Ook al zijn de hellingen flauw, gemiddeld 1-2%, de lange hellingen, de geringe grondbedekking en de zwakke bodemstructuur leiden tot aanzienlijke waterafstroming en bodemerosie. Bovendien zijn de nutriëntenbalansen voor het bebouwd areaal over het algemeen negatief, wat tot bodemuitputting leidt.

In het kader van een Nederlands bilateraal hulpprogramma is er in 1986 een bodem- en waterconserveringsproject (BWC) gestart, bekend onder de naam *'Projet Lutte Anti-Erosive'*. Het project was ingebed in de Malinese semi-overheidsorganisatie voor katoen en rurale ontwikkeling: *'Compagnie Malienne pour le Développement des Textiles'* (CMDT). De algemene doelstelling was het verminderen van landdegradatie, het intensiveren van landbouw en het verhogen van de landbouwproductie. Activiteiten richtten zich op de capaciteitsopbouw van de voorlichtingsdienst van de CMDT, het organiseren en trainen van boeren, en het toepassen van BWC door boeren.

De BWC-maatregelen bestaan uit erosiebeheersmaatregelen en bodem-vruchtbaarheidmaatregelen. Erosiebeheersmaatregelen omvatten lijnbarrières (stenenrijen, levende hagen en grasstroken), geulbarrières (van stenen, hout en gewasresten), en het verbouwen volgens hoogtelijnen. Bodemvruchtbaarheidmaatregelen omvatten het composteren in een kraal voor het vee met gewasresten op de grond, en het composteren in compostkuilen.

In 1998 ben ik door de CMDT in dienst genomen als technisch assistent van dit project, waar ik tot 2002 gewerkt heb. De trainingsactiviteiten en het toepassen van BWC werden regelmatig en systematisch bijgehouden en verschillende evaluaties hadden het positieve effect van het trainen van boeren op het toepassen van BWC aangetoond.

Tussen 1998 en 2002 werd de donorfinanciering geleidelijk afgebouwd. Daarbij stopten de BWC-voorlichtingsactiviteiten door de CMDT in 2003 vrijwel geheel. Zo kwam er een eind aan dit grootschalige en langdurende project zonder dat er een eindevaluatie van de impact was uitgevoerd, terwijl er interessante conclusies uit te trekken zouden zijn voor BWC projecten in het algemeen. Dit manco is mijn uitgangspunt geweest voor dit promotieonderzoek.

De doelstellingen van dit onderzoek waren: 1) het opzetten van een methode voor het ex-post (achteraf) evalueren van de impact van het BWC-project in Zuid-Mali; 2) met behulp van deze methode de effectiviteit en de impact van het BWC-project in Zuid-Mali evalueren en conclusies trekken voor toekomstige BWC-activiteiten in Mali en elders; 3) het doen van aanbevelingen voor de planning, monitoring en evaluatie van toekomstige BWC-projecten om sneller, nog tijdens de projectuitvoering, feedback te krijgen over de impact.

Hoofdstuk 2. Methode voor de evaluatie van impact van het BWC-project

Het eerste deel van dit hoofdstuk beschrijft de theorie van projectplanning, monitoring en evaluatie aan de hand van een `logisch kader' (*logical framework)*. Het benadrukt de moeilijkheid om veranderingen die zich voordoen op het niveau van het algemeen doel, toe te schrijven aan projectactiviteiten, de zogenaamde 'toeschrijvingkloof'. Een evaluatie kan deze kloof deels overbruggen door situaties met/zonder project, of situaties voor/na project te vergelijken. Ex-post evaluaties, vaak belemmerd door ontbrekende baselinegegevens, kunnen gebruik maken van 'gereconstrueerde baselines' en 'virtuele tijdreeksen' om zo toch een vergelijking voor/na project te kunnen maken.

Het tweede deel van het hoofdstuk beschrijft de praktijk van planning, monitoring en evaluatie van het BWC-project in Zuid-Mali. Een overzicht van de al uitgevoerde evaluaties laat zien welke aanvullende analyses nodig zijn voor een volledige ex-post evaluatie. Tevens bleek de noodzaak van aanvullend veldwerk, hetgeen ik in 2003 heb gedaan.

Hoofdstuk 3: Materiaal en methoden

Dit hoofdstuk beschrijft eerst het projectgebied in Zuid-Mali. Daarna worden de methoden beschreven van het veldwerk dat ik in 2000 en 2003 heb gedaan, alsook de aanvullende analyses. Het veldwerk in 2000 en in 2003 omvatte ook waarnemingen van erosie en erosierisico, die niet waren gedaan tijdens de gangbare monitoring. De evaluatie van de oorzaak-gevolgketen tussen projectactiviteiten en projectimpact heb ik opgesplitst in drie stappen: van het trainen van boeren tot het toepassen van erosiemaatregelen, van erosiemaatregelen tot verminderde erosie, en van verminderde erosie tot verbeterde gewasopbrengsten.

Hoofdstuk 4: Expansie, intensivering, productiviteit en duurzaamheid

Dit hoofdstuk beschrijft de landbouwontwikkeling in Zuid-Mali tussen 1988 en 2002 aan de hand van expansie, intensivering, productiviteit en duurzaamheid. Het bebouwd areaal per inwoner is toegenomen van 0,44 ha in 1988 tot 0,61 ha in 2002. Tegelijkertijd zijn boeren ook intensiever gaan telen: ze verbouwen meer handelsgewassen (katoen en maïs) en hebben de dosering van kunstmest en compost bijna verdubbeld. Ondanks deze intensivering zijn de opbrengsten per ha van katoen en maïs tussen 1993 en 2002 gedaald met 10%, resp. 17%, deels door verminderde regenval en het in cultuur nemen van meer marginale gronden. Echter, de toename in bebouwd areaal per inwoner compenseerde de dalende opbrengsten zodat de productie per inwoner is toegenomen.
De nutriëntenbalans, uitgedrukt in kg N+P+K per ha per jaar, is iets minder negatief geworden in 2002 (-40) dan het was in 1988 (-58). Verdere intensivering is dus nodig om zowel de productiviteit als de duurzaamheid te verhogen.

Hoofdstuk 5: Hoe de aanpak van het project de toepassing van BWC beïnvloedt

De continuering van BWC-maatregelen nadat het project is gestopt, hangt in belangrijke mate af van de gekozen aanpak. Dit hoofdstuk beschrijft de BWC-projectaanpak in Zuid-Mali en de toepassing van BWC door boeren, tijdens en na het project. De voornaamste kenmerken van het project waren:

- het promoten van goedkope en simpele BWC-maatregelen,
- een participatieve aanpak, op dorpsniveau, met slechts beperkt gebruik van extrinsieke aanmoedigingsmaatregelen,
- het verankeren van het BWC programma in een bestaande voorlichtingsdienst.

Boeren in dorpen die BWC-projectondersteuning hebben gekregen, waren hier enthousiast over en raadden deze BWC-aanpak ook aan voor dorpen die deze ondersteuning nog niet gehad hebben. De toepassing van BWC is gestaag toegenomen, ook in dorpen die niet rechtstreeks projectondersteuning hebben gehad, wat er toe heeft geleid dat het verschil tussen dorpen die wel en niet BWC-ondersteuning hebben gekregen, geleidelijk aan afnam. Tussen 1986 en 2000 is er in de helft van de 5000 dorpen in Zuid-Mali BWC-training gegeven. In 2002 blijken er BWC-maatregelen te worden toegepast in 94% van alle dorpen, door 46% van de boeren en op 15% van de velden. Ondanks dat externe donorfinanciering gestopt is en BWC-voorlichting sterk verminderd is, gaan boeren nog steeds door met het toepassen van BWC.

Hoofdstuk 6: Factoren die de toepassing van BWC beïnvloeden

Vijf factoren zijn geanalyseerd die het toepassen van BWC — erosiemaatregelen en het gebruik van compost — in Zuid-Mali beïnvloeden:

1) Landdruk: in gebieden waar land meer permanent bebouwd wordt maken boeren meer compost;
2) Katoenteelt of niet: boeren in het katoengebied passen minder BWC toe dan boeren in het drogere gebied zonder katoen;
3) Beschikbaarheid van materieel: boeren met meer trekossen en ploegen passen meer BWC-maatregelen toe;
4) Beschikbaarheid van transportmiddelen: boeren met een ezelskar, die het vervoer van gewasresten en compost vergemakkelijkt, produceren meer compost;
5) Training: boeren die BWC-training hebben gehad passen meer erosiemaatregelen toe.

Er is een hoge correlatie gevonden tussen het toepassen van erosiemaatregelen en het maken van compost, die niet verklaard kon worden door deze vijf factoren alleen. Dit suggereert dat er nog andere factoren zijn die het toepassen van BWC op gang brengen.

Hoofdstuk 7: Bodemkorsten en sediment als indicatoren voor oppervlakte-erosie

Landdegradatie en bodemerosie werden niet regelmatig gecontroleerd in het BWC-project. Toch zijn ze van essentieel belang in het kader van de globale doelstellingen van het project. Daarom heb ik ze betrokken bij dit onderzoek. In de eerste plaats waren er geschikte indicatoren nodig om bodemerosie te evalueren. Geulen zijn erosie-indicatoren die gemakkelijk door boeren en voorlichters herkend worden. Ze komen echter niet veel voor op de velden in Mali, met hellingen van 0 tot 3%, terwijl waterafstroming en oppervlakte-erosie wel een probleem zijn. Daarom zijn drie andere symptomen van het bodemoppervlak getest op hun bruikbaarheid als erosie-indicatoren:

- Structuurkorsten, gevormd door regen zonder dat de bodemdeeltjes zich zijwaarts verplaatsten.
- *In situ* depositiekorsten, gevormd door sedimentatie waarbij de fijnste bodemdeeltjes boven komen.
- Afstromingssediment van grof en fijn zand, bezonken nadat de fijnste bodemdeeltjes zijn afgevoerd.

De bodembedekking met afstromingssediment van grof zand blijkt een bruikbare erosie-indicator. Dit sediment wordt goed verklaard door erosierisico: een hellingtoename van 2% gaf een toename in sedimentbedekking van 9%. Er is ook een verband geconstateerd met de gewasopbrengst: een 30%-toename van sedimentbedekking hing samen met een 25% lagere katoenopbrengst.

Tot nu toe zien slechts enkele boeren in deze symptomen het gevolg van erosie. BWC-programma's zouden dus meer aandacht moeten schenken aan de aanwezigheid van bodemkorsten en sedimenten.

Hoofdstuk 8: Ex-post evaluatie van erosiemaatregelen

Ex-post evaluaties worden vaak belemmerd door het gebrek aan baselinegegevens. In één dorp was de baselinesituatie van 1988 beschikbaar en kon deze worden vergeleken met de situatie in 2003, nadat boeren stenenrijen, levende hagen en grasstroken hadden aangelegd en waren begonnen met het verbouwen volgens hoogtelijnen. Het geschatte bodemverlies was afgenomen van 42 tot 10 ton per ha per jaar. Echter, voor andere dorpen waren geen baselinegegevens beschikbaar. Een simpele vergelijking van met/zonder erosiemaatregelen is niet correct omdat boeren vooral erosiemaatregelen nemen in velden met meer erosie. Twee alternatieve methoden zijn gebruikt: een gereconstrueerde baseline en een virtuele tijdreeks.

Met behulp van een gereconstrueerde baseline, waarbij niet alleen de huidige actieve erosiegeulen maar ook de inmiddels gedichte, niet meer actieve erosiegeulen werden bekeken, heeft het onderzoek uitgewezen dat lijninterventies, geulinterventies en een combinatie van beide het aandeel actieve geulen vermindert met 50 – 70%.

Met behulp van een virtuele tijdreeks, waarbij erosie werd vergeleken in velden met erosiemaatregelen die in verschillende jaren zijn aangelegd, is het onderzoek tot de conclusie kunnen komen dat erosie geleidelijk aan afneemt met 50% gedurende de eerste 3 jaar na aanleg van erosiemaatregelen.

Het onderzoek heeft ook aangetoond dat het zaaien loodrecht op de helling de oppervlakte-erosie vermindert. Een afname van de helling van de zaairichting met 1% verminderde de bedekking met afstromingssediment van grof zand met 8%.

Door middel van extrapolatie van de effecten op veldniveau, rekeninghoudend met dat erosiemaatregelen aanwezig zijn op 15% van de velden en dat de initiële erosie op deze velden hoger was dan op andere velden, kunnen we concluderen dan erosiemaatregelen de erosie in Zuid Mali met 16% hebben verminderd.

Hoofdstuk 9: Impact van erosiemaatregelen op gewasopbrengst

Dezelfde belemmering van ontbrekende baselinegegevens doet zich voor bij de evaluatie van erosiemaatregelen op gewasopbrengsten. Twee alternatieve methoden zijn gebruikt: 1) het uitbreiden van de met/zonder vergelijking met verschillende boer- en veldkenmerken als co-variabelen in lineaire regressieanalyses; 2) het opzetten van virtuele tijdreeksen, waarbij velden vergeleken worden die in verschillende jaren zijn begonnen met erosiemaatregelen, en waarbij dorpen worden vergeleken die in verschillende jaren BWC-ondersteuning hebben gehad.

De resultaten van de lineaire regressieanalyse laten een positieve interactie zien tussen stenenrijen (boven de velden) en regenval in hun effect op gewasopbrengst. Het effect van vegetatieve barrières leek niet af te hangen van regenval. De katoenopbrengst in velden met erosiemaatregelen was 4,8% hoger dan in velden zonder erosiemaatregelen. Een extrapolatie, rekening houdend met dat er erosiemaatregelen zijn op 22% van de katoenvelden, laat zien dat de impact overeenkomt met 1.1% van de katoenproductie in Zuid Mali.

De resultaten van virtuele tijdreeksen laten zien dat stenenrijen een direct effect hebben op gewasopbrengst, terwijl het effect van vegetatieve barrières geleidelijk toeneemt in de jaren na aanleg. De katoenopbrengst in 'oudere' BWC-dorpen, die gemiddeld 8 jaar geleden projectondersteuning hebben gekregen, was 12,5% hoger dan in 'nieuwe' BWC dorpen, die gemiddeld 2 jaar geleden deze ondersteuning hebben gehad. Dit duidt op een geleidelijke opbrengstverbetering in de jaren na de start van BWC. Een extrapolatie, rekening houdend met dat 51% van de dorpen BWC-ondersteuning hebben gehad, laat zien dat de impact overeenkomt met 6.4% van de katoenproductie in Zuid Mali.

Hoofdstuk 10: Het koppelen van monitoring aan evaluatie

In tegenstelling tot de voorgaande hoofdstukken, waarin steeds één specifieke stap tussen projectactiviteit en impact geanalyseerd is, behandelt dit hoofdstuk de mate waarin het systeem van monitoring een volledige evaluatie mogelijk maakte. Drie aspecten zijn er uitgelicht:

Het effect op het toepassen van BWC. Het project is effectief geweest in het trainen van boeren en de toepassing van BWC-maatregelen door boeren.

De impact op landdegradatie en landbouwproductie. De evaluatie van de impact op landdegradatie werd belemmerd door het gebrek aan monitoring op dit niveau. De impact op productie is berekend met behulp van resultaten van hoofdstuk 9 en hoofdstuk 5. BWC resulteerde in een extra katoenproductie van tussen de 5.000 en 28.000 ton per jaar (gemiddeld over 2000 – 2002) in Zuid Mali.

De efficiency waarbij de project kosten met de baten voor boeren zijn vergeleken. De evaluatie laat zien dat de baten voor de boeren (bruto marge) van de verhoogde jaarlijkse katoenproductie tussen de €1.260.000 en €7.530.000 waard was, gemiddeld voor 2000 – 2002. Dit overtreft ruim de jaarlijkse projectkosten (donorgefinancierde technische assistentie en BWC-voorlichtingskosten) van ongeveer €580.000, gemiddeld over het tijdvak 1986 – 2001.

Hoofdstuk 11: Synthese

Dit hoofdstuk integreert de resultaten van de voorgaande hoofdstukken, belicht wat nieuw was in dit onderzoek, en doet aanbevelingen voor monitoring en evaluatie in toekomstige BWC-projecten.

De ex-post impactevaluatie van het BWC-project in Zuid-Mali is mogelijk geweest door diverse methoden en technieken te combineren, enerzijds theoretische technieken (het gebruik van een 'logisch kader' *logical framework,* van de begrippen gereconstrueerde baselines en virtuele tijdreeksen); anderzijds concrete onderzoeksmethoden, zoals het verzamelen en analyseren van reeds aanwezige gegevens, aangevuld met observaties en analyses van aanvullend veldonderzoek.

Naast de effectiviteit, de impact en de efficiency, die al in vorige hoofdstukken belicht zijn, worden hier ook de relevantie van het project zelf en de invloed ervan op de langere termijn bediscussieerd. Op het moment dat het project stopte, was het project minder relevant geworden vanwege beleidsveranderingen bij het donorland en het gastland. Daarentegen scoort de 'projectduurzaamheid', de invloed op de langere termijn, goed, want boeren gaan door met BWC nadat het project gestopt is.

Nieuw in deze studie is de aandacht voor het vertraagd optreden van het gewenste projectimpact. De tijd die de diverse stappen vergen, vanaf het eerste gebruik van projectmiddelen, het trainen van boeren, het toepassen van BWC, toegenomen duurzaamheid, verminderde landdegradatie, tot en met verbeterde gewasopbrengsten, loopt op tot vele jaren.

De volgende aanbevelingen kunnen de monitoring en evaluatie van BWC-projecten verbeteren. De monitoring moet indicatoren op alle niveaus in het logisch kader bekijken, van activiteit tot impact, en de projectmonitoring moet worden aangevuld met externe monitoring. De gewenste impact kan langer op zich laten wachten dan de duur van het project. Daarom moet een project worden verankerd in een doorlopend nationaal programma en gebruikmaken van maatregelen die boeren kunnen voortzetten na afloop van het project. De vertraging in impact vereist ook afgeleide indicatoren, die een verandering weergeven in plaats van een situatie. Natuurlijk kunnen afgeleide indicatoren niet de werkelijke impactindicatoren vervangen. Daarom moet het projectsysteem van monitoring worden verankerd in een extern nationaal systeem van monitoring dat de evaluatie van de vertraagde impact na het sluiten van het project mogelijk maakt.

Curriculum Vitae

Ferko Bodnár was born on 5 August 1965 in Utrecht, The Netherlands. He studied biology at Utrecht State University from 1984 to 1987. After an orientation trip in Latin America on the possibilities to work abroad, he continued with an MSc Tropical Crop Science in Wageningen in 1988. He graduated in 1993 on two subjects: the effect of fallow clearing on subsequent weed growth in Ivory Coast, and the possibilities of agroforestry in the humid tropics in Nicaragua. From 1994 to 1998 he worked at the Malawi Agroforestry Extension Project—between research, extension, NGOs, and farmers—first for Voluntary Service Overseas, later for Washington State University. From 1998 to 2002 he worked at the Soil and Water Conservation Division (*Division Défense et Restauration des Sols*) of the Malian semi-government organization for cotton and rural development (*Compagnie Malienne pour le Développement des Textiles*), first for the Royal Tropical Institute in Amsterdam, later for the German Development Service (*Deutsche Entwicklungsdienst*). In Mali he started an impact evaluation in 1999 that resulted in a preliminary report in 2002. In 2003, he joined the Erosion and Soil & Water Conservation Group of Wageningen University to do additional fieldwork in Mali, analyse data from fieldwork and from Malian databases, and write this thesis. He has undertaken a number of project evaluation and identification studies in Mali and Turkey. Since November 2004, he works for Agro Eco Consultancy on organic agriculture as climate change mitigating strategy.
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PE&RC PhD Education Statement Form

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resource Conservation (PE&RC) which comprises of a minimum total of 22 credits (= 32 ECTS = 22 weeks of activities)

Review of Literature (4 credits)

- Monitoring and evaluation documents Mali project at KIT, Amsterdam (2003)
- Monitoring and evaluation theory at ESW, WUR, Wageningen (2003)

Writing of Project Proposal (5 credits)

- Evaluation of 20 years soil and water conservation in southern Mali (2002)

Post-Graduate Courses (2 credits)

- Change management (1999)
- Land Science: concepts, tools and uncertainties in land use studies and landscape dynamics (2005)

Deficiency, Refresh, Brush-up and General Courses (6 credits)

- Natural resource management and decentralisation, Fana, Mali (2001)
- Scientific Writing (2004)
- Impact assessment of land and water management (2005)

PhD Discussion Groups (4 credits)

- Sustainable land use and resource management with focus on the tropics (2003-2004)
- Natural resource management – four 2-day professional forums organised by DED, Mali (2000-2001)

PE&RC Annual Meetings, Seminars and Introduction Days (1 credit)

- PE&RC annual meeting: Global Climate Change and Biodiversity (2003)
- Seminar series ESW: Advances in land and water management (2004)

International Symposia, Workshops and Conferences (4 credits)

- Improved fallows, ICRAF, Lilongwe, Malawi (1998)
- SWC and Biomass Management, CMDT Mali (1999)
- Effect of land use management on erosion and carbon sequestration, IRD, Montpellier, France (2002)