Permanent Interstate
Committee for Drought
Control in the Sahel

Centre for International Cooperation (CIS)
vrije Universiteit amsterdam

The silent transformation of environment and production systems in the Sahel

Impacts of public and private investments in natural resource management






SYNTHESIS REPORT

CONTENTS

List of acronyms

SWC	Soil and Water Conservation
CILSS	Permanent InterState Commettee for Drought control in the Sahel
DGIS	Directoraat Generaal Internationale Samenwerking
DRS	Défense et Restauration des Sols
NRM	Natural Resource Mnaagment
GTZ	Gemeinschaft für Technische Zusammenarbeit
IRG	International Resources Group
FMNR	Farmer Managed Natural Regeneration
USAID	United States Agency for International Development
USGS	United States Geological Survey
SDC	Swiss Development Cooperation

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PREFACE

This report written by Chris Reij (VU University Amsterdam) and Dr Edwige Botoni (CILSS/Executive Secretariat), summarizes the findings of studies recently undertaken in four Sahel countries by teams of national researchers. The objective of the study was to identify impacts of investments in natural resource management and to identify trends in agriculture and environment. The four countries included in this Sahel study are Burkina Faso, Mali, Niger and Senegal.
At the end of this first phase, CILSS would like to express its gratitude to the financial and technical partners, enabling them to undertake this study. They are:

- the Directorate General for International Cooperation of the Netherlands (DGIS) and Swiss Development Cooperation (SDC) funded the study;
- USAID supported the study with high-level expertise in the fields of remote sensing and agro-economics;
- financial support from French Development Cooperation and USAID allowed CILSS to coordinate the study and to provide additional support to the study in Burkina Faso to enabling the team to study a larger sample of farmers;
- GTZ has a final workshop for the research team in Mali.

This synthesis report is based on work undertaken by four national research teams. CILSS wishes to express its gratitude to the researchers, who sometimes worked in difficult conditions, and also to the scientific committees, which accompanied the study. The composition of the research teams and the scientific committees was as follows :

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Only the authors of this synthesis report are responsible for the contents of this report, its imperfections and weaknesses, inherent to any effort to summarize findings. The four national reports of the study have been put on the CILSS website (www.cilss.bf) to make them accessible to anyone interested in consulting them.

EXECUTIVE SUMMARY

This synthesis report summarizes some of the major findings of studies carried out by CILSS and its partners in four countries (Niger, Burkina Faso, Mali and Senegal). The objective of these studies was to assess the impacts of investments in natural resource management and to analyze long-term trends in agriculture and environment in the Sahel from the early 1980s.

One of the findings of this Sahel study is the fact that the impacts of public (governments, financial partners, NGOs) and private (farmers) investments have often been underestimated. For instance, the large-scale efforts to rehabilitate degraded land have increased crop yields, improved food security, contributed to local groundwater recharge, increased the number of on-farm trees and their productivity as well as other impacts which were often been overlooked or ignored during project evaluation.

A significant trend in all four countries is the investment of farmers in agroforestry, which contributes to the development of more complex and more productive farming systems. The scale on which this was done varies from country to country. In some densely populated regions of Niger, farmers have protected and managed on-farm natural regeneration since the middle of the 1980s. The scale of this on-farm re-greening is at least 5 million hectares (12.5 million acres), making it the biggest environmental transformation in the Sahel, and perhaps in Africa (chapter 6). The scale of this transformation has been uncovered by this study. Besides quantifiable impacts, this re-greening has produced a number of environmental services, which are not easy to quantify. For instance, trees help farmers to adapt to climate change. A conclusion is also that protecting and managing natural regeneration of trees is often cheaper and more efficient than planting them. This conclusion is highly relevant because one of the standard actions proposed to reverse degradation is planting trees. The economic rates of return to investments in different natural resource management (NRM) techniques are high, even though indirect impacts (externalities) are not taken into account (chapter 14).

The Sahel continues to face major challenges: high rates of demographic growth, climate change and environmental degradation continues in many regions. However, as this study makes clear, much has been achieved. Experience shows that adaptation to climate change, reduction of rural poverty and improvement of food security is possible in the Sahel.



1. Introduction

Since the beginning of the 1970s, the Sahel countries have been confronted with drought and desertification. The degradation of natural resources, and in particular a decline in soil fertility, has contributed to a decrease in crop yields and in a weakening household food security in the regions.

The governments of the Sahel countries, their populations and their technical and financial partners have dealt with this environmental crisis, which had a negative impact on the economic and social development of this region. They have tried to reverse environmental degradation and desertification amongst others by investing in natural resource management activities, including soil and water conservation, tree planting and management of natural forests. In the 1970s, but in particular in the 1980s and even in the 1990s, governments supported by their financial partners, invested significant resources in the fight against desertification. At certain moments in time, CILSS reviewed different actions and their impacts. For example, at the end of the 1980s, and supported by GTZ, CILLS undertook 21 case studies across five countries of natural resource management techniques and approaches supposed to be successful in the fight against desertification. This led to the publication in 1989 of a seminal book on the fight against desertification in the Sahel (Rochette et al, 1989). This state-of-the-art review of field experience at the end of a decade of investment showed that much had been learnt and much had been accomplished in the 1980s. It showed that an increasingly wider range of technical solutions to fight land degradation had been developed and that some of them were well mastered by farmers. Some techniques required external support to be implemented on scale, but others could be implemented by farmers using their own means.

As a follow-up to these earlier efforts to review experience, CILSS and its partners initiated a regional study in 2005, which was baptized « Sahel study ». This study was initiated to try to answer a number of key questions often raised by national and international policymakers, who had supported the fight against desertification in the Sahel. These key questions included:

- What have been the impacts of investments in natural resource management?
- How have agriculture and environment evolved since 1984?
- Have the impacts of these investments been sustainable?
- What have the investments produced in economic terms?

It is obvious that these questions were triggered by a growing sense of doubt, if not despair, that despite decades of external support, little or no progress had been made in the Sahel and that the Sahel essentially remained a region in permanent crisis. The drought and the locust infestations, which afflicted the Sahel in 2004 leading to significant food shortages in 2005, certainly reinforced this gloomy perception.

The first phase of this review has covered four countries: Niger in 2005-2006, Burkina Faso, Mali and Senegal in 2007-2008. The study was mainly focused on assessing the biophysical and socio-economic impacts of investments in soil and water conservation and in agroforestry.

This report summarizes the major findings of the study in the four countries. It also contains a number of thematic chapters, each of which analyzes a specific impact of investments in NRM. However, the report begins with a short description of the environmental crisis in the Sahel in the 1970s and 1980s and a short presentation of the methodologies used by the national research teams.

2. Context : the environnemental crisis in the 1970s and 1980s and the reactions to the crisis

An environmental and socio-economic breakdown

Drought, famine, chronic food shortages, dust storms, wind and water erosion, decreasing crop yields as a result of depletion of soil fertility, livestock mortality, high demographic growth rates, growing competition for access to natural resources....this is what the Sahel looked like in the aftermath of the droughts of the 1970s and 1980s.

To quote farmers : « The bush has disappeared, there are no longer wild animals, people have become too numerous, rainfall has decreased, the land is exhausted » (Luxereau et Roussel, 1997).

Land degradation in the Sahel is a complex phenomenon which is influenced both by human action (for instance, expansion of cultivated land over soils marginal to agriculture) and by nature (for example, drought).

After a long period of relatively abundant rainfall (1950 - 1968), rainfall dramatically decreased in the early 1970s and remained below the long-term average for about 25 years. This decrease in average rainfall by about 200 mm is also marked by a reduction in number of rainfall days and by an increase in the number of long dry spells during the rainy season with negative effects on crop yields.

The demographic explosion after 1960 (growth rates of about 3%) in most Sahel countries has led to an increased pressure on available natural resources. In the regions of Maradi and Zinder (Niger), fallow, the traditional system of restoring soil fertility, disappeared and elsewhere in the Sahel, fallow periods were shortened drastically. This contributed to an even further impoverishment of already naturally poor soils.

In the 1970s and 1980s farmers were obliged to expand their cultivated land to compensate for declining yields and also to be able to feed a strongly increasing population. One of the main consequences was a progressive destruction of natural vegetation and a physical, chemical and biological degradation of soils. This led to the emergence and expansion of barren, denuded and crusted soils. The degradation of vegetation reduced the availability of firewood and as a result women had to walk increasingly longer distance to collect it, forcing them substitute firewood by crop residues and manure. This reinforced the process of declining soil fertility.
The 1970s and 1980s revealed a disbalance in agricultural production systems caused by climatic, socio-economic and demographic factors. During these years many researchers characterized this situation with strong words as the "faillite" (breakdown) of the agricultural system (Raynaut (1975 ; Marchal, 1985). De Miranda (1980) characterized this as an agricultural and ecological imbalance.

Dumont (1985), a former French presidential candidate and well-known Africa specialist submitted in 1985 a report to the government of Burkina Faso with his analysis of the environmental and agricultural situation of the country. The title of his report was nothing less than : « Burkina Faso is not a developing country, but a country which is disappearing« ("le Burkina n'est pas un pays en voie de développement, mais un pays en voie de disparition")

Disbalance, breakdown... all these terms characterize an overexploitation of the environment with often dramatic economic and social consequences.

Reactions to the environmental crisis

Faced with an unprecedented environmental crisis, local, national and regional initiatives were developed to reduce or even inverse the degradation of natural resources.

The Sahel countries, supported by their technical and financial partners, initiated a series of major projects to fight desertification and to promote rural development.

In Niger, for instance, the combined actions of different projects led to the rehabilitation of at least 250.000 ha of strongly degraded land between 1985 and 2005. These projects used a wide range of simple water harvesting techniques, such as: contour stone bunds, improved traditional planting pits (zaï), half moons, trenches and earthen bunds with upward sloping wings.

On Burkina Faso's Central Plateau different projects and programs to fight desertification were initiated in the 1980s (Rochette, 1989). Their combined actions have led to the rehabilitation of up to 300 000 ha of degraded land (Ouedraogo 2005 [2]).

Parallel to this, most Sahel countries have adapted relevant national policies and legislation which influenced natural resource management. These included policies of decentralisation, land tenure legislation and forestry laws, which increasingly delegated responsibilities for the management of natural resources to local communities.

Role of interventions and innovations

At local level the interventions of NGOs and of bilateral and multilateral projects have often acted as a trigger. This aspect will be discussed in another chapter. Their support for soil and water conservation and for agroforestry, encouraged producers to rehabilitate strongly degraded land and to protect and manage on-farm trees. Almost all new projects decided to build on innovations on technical breakthroughs in soil and water conservation, which emerged in the early 1980s. Over the years simple techniques, such as improved traditional planting pits or zaï and contour stone bunds have been adopted by hundreds of thousands of farmers and agropastoralists across the Sahel as well as projects have played a key role in this process of spreading. Many projects have funded study visits by farmers so they could see with their own eyes what farmers elsewhere, working under similar conditions, had achieved. This kind of farmer-to-farmer exchange visits has become a proven tool for spreading innovations.

It is important to notice here the innovative capacity of farmers and of NGOs. For instance, the improvement of traditional planting pits (zaï) to rehabilitate strongly degraded land is the work of a farmer innovator in the Yatenga region of Burkina Faso. This technique has led to the rehabilitation of tens of thousands of hectares of strongly degraded land in the Yatenga region as well as in parts of Niger. Contour stone bunds is a technique used successfully in all four countries studied and it was developed around 1980 by an NGO in the Yatenga region (Reij, 1983)

The conclusion seems justified that the investments in natural resource management (NRM) by different actors have contributed to reduce the process of environmental degradation and in some regions even to reverse it. This has happened in an often unfavourable climatic, demographic and socio-economic context

1 The Tahoua Rural Developpement project, the Agro-Sylvo-Pastoral project, the IFAD project in the Illéla district, the Keita project, etc.,
2 Reij and Thiombiano (2003) estimated that till 2002, only on the northern part of the Central Plateau, at least 100,000 ha had been treated with soil and water conservation techniques
3 With the invaluable support of Gray Tappan of USGS South Dakota (USA)

3. Methodologies

In 1989, CILSS and GTZ published a seminal book called « Le Sahel en Lutte contre la Désertification : leçons d'expériences » (Rochette, 1989). The objective of this book, which reviewed the experience with actions to control desertification in the Sahel, was to inform all those interested in the development of the Sahel about achievements and to identify and analyze reasons for success and for failure. As part of this study, a number of cases analyzed by Rochette and collaborators were re-visited almost 20 years later. Other cases that emerged after 1989 have been included in this study.

A wide range of research techniques has been used in this study. They include remote sensing (the analysis of aerial photos and satellite images for different years to identify changes in land use and in vegetation in the same villages[3]), vegetation transects, semi-structured surveys aimed at specific target groups (women, herders, etc.) as well as detailed surveys aimed at a stratified random sample of farm households classified according to wealth level. This classification has been based on criteria used by villagers to define poverty and wealth. These criteria are often dominated by the level of household food security. The researchers also analysed secondary data (demographic census data ; agricultural statistics, reports and books about studies carried out in the 1970s and 1980s) to get a reliable picture of past and present.

The study has tried, in particular in Niger, Burkina Faso and in Senegal, to identify and analyze the cumulative impacts of investments in NRM, as well as to draw conclusions about the economic benefits of investing in NRM. One of the key points of the methodology of the study was a comparison of situations before and after interventions and with and without intervention. This enabled us to identify environmental impacts (evolution of vegetation cover, changes in biodiversity, changes in soil fertility, etc.), impacts on agricultural production, social and institutional impacts (land tenure security, tree tenure, access to land, emergence of local institutions, effects of national policies, etc.) and about economic impacts.

This study has neither been easy nor flawless. The picture that has emerged does not overestimate, but most likely underestimates the development dynamics in the Sahel and the impacts of investments in NRM. The reason behind this is simple. Like so many project evaluations and other studies it has not been possible to adequately express all impacts of investments in monetary terms in an adequate way.

Practice shows that it is difficult to find good control villages for this kind of study, because some techniques have spread spontaneously to villages without interventions. Examples are techniques like zaï and farmer-managed natural regeneration. The question of attribution of impacts is also complex. The research teams have found higher crop yields in fields treated with soil and water conservation techniques than in fields without. They also found higher water levels in wells after soil and water conservation was undertaken (5 meters, 10 meters or even more) and less labour migration. Can these changes really be attributed to investments in NRM only or should they also, at least in part, be attributed to national policies or to the construction of new roads or to changes in rainfall since the middle of the 1990s? It is evident that not all positive changes can be attributed to investments in NRM only, but as the different thematic chapters will show, the investments in NRM have had major impacts and have often played a catalyzing role.

Some research hypotheses

1. The investments in NRM have contributed significantly to the improvement of agricultural production and have reduced the vulnerability of local land users to drought.

2. The investments in NRM have contributed significantly to rural poverty reduction.

3. The investments in NRM have contributed to an increase in biodiversity.

4. The investments in NRM have produced above average economic rates of return.

5. The investments in NRM have strengthened social capital and the sustainability of social action.

The regions studied represent a diversity of agro-ecological situations and a wide range of desertification problems across the Sahel

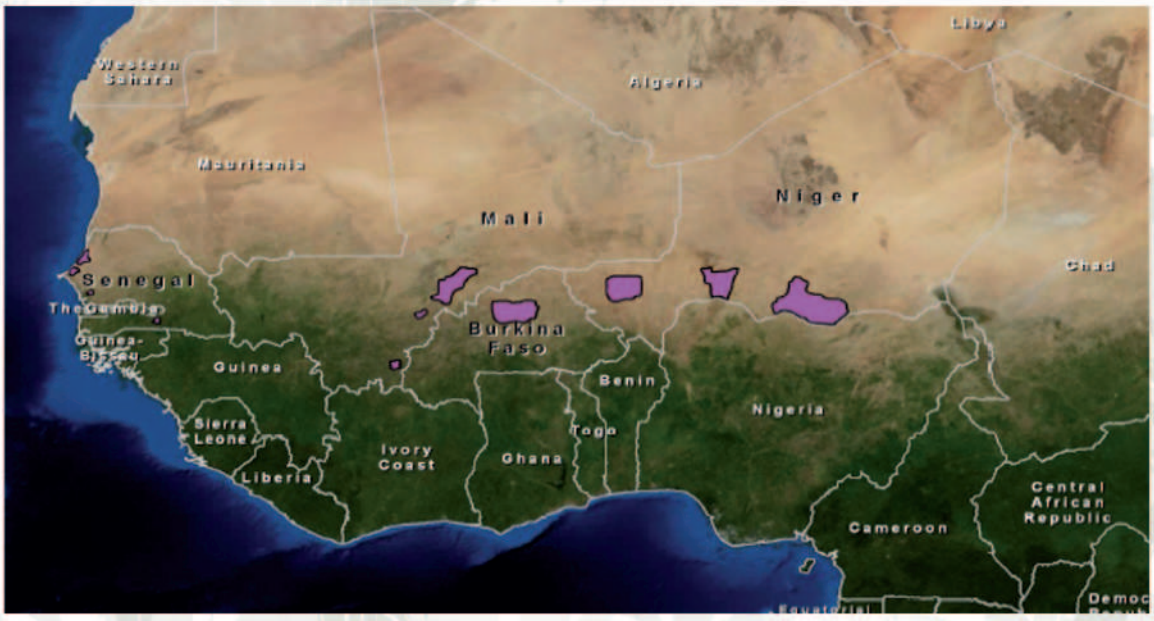
- ***The northern part of the Central Plateau of Burkina Faso***

The northern part of the Central Plateau of Burkina Faso (400 to 700 mm rainfall) was in 1980 considered to be the most degraded region of the country. This region is characterized by high population densities: more than 100 persons per km² in the Yatenga. The lateritic soils are naturally poor in nutrients. The cereal yields were low and declining. According to a study by ICRISAT (quoted by Brons, et al. 2000 :20), average yields of sorghum were only 293 kg/ha during the 1981- 1985 period. Marchal (1985) even spoke of the "déroute" of agriculture. The early 1980s were characterized by a succession of drought years with companying food shortages. The vegetation impoverished and water levels in wells fell by about one meter a year. It is not surprising that during this period, many villagers fled their homes and farms. For example, according to the demographic censuses of 1975 and 1985, the village of Ranawa lost 25 % of its population during this period (Reij et Thiombiano, 2003: 5-7).

- ***Niger : The regions of Tillabéri, Tahoua, Maradi and Zinder***

The regions studied in Niger are all characterized by a strong demographic pressure on the available resources. In particular the southern parts of the Maradi and Zinder Regions have population densities surpassing 100 inhabitants/km². In these regions natural forests have virtually disappeared and almost all space is occupied by permanently cultivated fields. In the Tahoua Region degraded plateaus and relatively fertile valleys alternate. But in the 1980s these fertile valleys were increasingly threatened by water rushing unimpeded from the barren plateaus and escarpments, which contributed to gully formation in the valleys. The gullies quickly evacuated runoff and prevented the spreading of floodwater across the valley bottoms, which in the past had contributed to maintaining soil fertility on cultivated fields in the valleys.

Figure 1 : Map of West Africa showing the study areas in the four countries



Source: Gray Tappan (USGS)

- ***Senegal : the Niayes, the peanut basin and the Sine Saloum***

The Niayes is the name for the narrow coastal strip of land (5 to 30 km wide and more than 180 km long) between Dakar and Saint-Louis. This zone has distinct ecological characteristics (depressions between sand dunes and a groundwater level which reaches the surface in these depressions or is at shallow depth) and it is the main area for vegetable production in Senegal. Up to 80% of all vegetables produced in the country is produced in this region, which was threatened by moving coastal sand dunes in the 1980s. Important tree planting efforts were made to stabilize the dunes. The key species planted was filao (Casuarina equisetifolia).
The northern parts of the peanut basin (Louga, Diourbel, Thiès) are characterized by sandy soils. The drought years of the 1970s and the first half of the 1980s contributed to a strong degradation of the vegetation and aggravated processes of wind and water erosion. This happened on soils which were already depleted by a long period of mono cropping of peanuts. The consequences of these processes were dramatic for the environment, for agriculture and for the land users. In this context a village forestry project was initiated in 1986. Its major objective was to restore the productive capacity of the farming systems.

The Sine Saloum region is characterized by the presence of estuaries which contribute to the intrusion of salt and the salinization of land. This region faces some environmental threats different from the two other regions studied : increasing soil salinity, degradation of mangrove forests and, like in most other regions, decreasing soil fertility. A project realized anti-salt dams to fight increasing salinity.

- ***The NRM techniques studied***

To fight land degradation different techniques have been developed and tested. Simple water harvesting techniques were developed in the early 1980s and used to rehabilitate strongly degraded land. It is important to bear in mind that until 1980 all efforts to rehabilitate land in the Sahel had been more or less unsuccessful, because they were not maintained and expanded by the local land users.

The newly developed or introduced techniques to collect rainfall and harvest runoff were already mentioned earlier in this report. They are: improved traditional planting pits, contour stone bunds and half moons. These techniques force water to infiltrate and they collect sediments transported by runoff water. The impacts of these techniques on crop yields has been documented in many publications (Reij, 1983 ; Marchal, 1986 ; Rochette, 1989; etc.).

In many Sahel regions farmers have begun protecting and managing trees and bushes regenerating spontaneously on their farms. Although there are different names for this technique, the most commonly used one is Farmer-Managed Natural Regeneration (FMNR). This technique is spreading in regions with a high population density, such as the Maradi and Zinder regions of Niger, the Plateau Dogon and the Seno plains in Mali, and also parts of the Central Plateau of Burkina have a higher on-farm tree density now than in the early 1980s..

The impacts of some of these water harvesting techniques and of farmer-managed natural regeneration has been evaluated by this study [4] .

The approaches to NRM have evolved towards greater responsibilities of the local population in priority setting, project design and implementation, with positive impacts on the sustainability of activities and impacts. The impact of institutional reforms and policy changes is not included in the current study. The emphasis in this report is on the identification and analysis of the multiple impacts of soil and water conservation/water harvesting techniques, which are used to rehabilitate degraded land and on agroforestry.

The zaï : farmers dig planting pits in crusted soils whioch produce high runoff rates. The pits have a diameter of 20 to 30 cm and a depth of 10 to 15 cm to collect rainfall and runoff. This means that more water infiltrates so that more water will be available to plant roots. Farmers put a handful of organic matter in the pits (about 600 gram/pit). The quantity and the quality of the organic matter applied, is variable. The concentration of water and soil fertility on the same spot creates favourable growing conditions for plants. Some farmers practise dry seeding in these pits. They sow the seeds of their cereal crops in the pits just before the onset of the rains. In this way the seeds will germinate after the first heavy rain. This improved traditional technique has spread to specific regions in the Sahel with a high population density and lateritic soils. The technique is known as « tassa » in Niger and towalen in Mali.
The advantages of zaï are mainly : the capture of rainfall and runoff, the efficient use of limited quantities of organic matter, the concentration of water and soil fertility at the beginning of the rainy season. They are dug during the dry season. This alleviates the labour burden for land preparation at the onset of the rains. Besides, they produce a crop where nothing could grow before.

[4] In this report the accent is on techniques which are used in at least 3 out of 4 countries studied and which have been reproduced by farmers.

Photo 1 : Zaï in the region between Djenné and Sévaré (Mali)

Photo 2 : Contour stone bunds on the Central Plateau help control runoff and induce infiltration. In this way they often contribute to local groundwater recharge

Contour stone bunds

Low barriers of stone constructed along contour lines, which slow down runoff, reduce soil erosion and induce infiltration of water. The bunds help retain manure on the fields, which used to be carried away by runoff. The stone lines are 'anchored' in a shallow trench to increase their resistance to runoff. They are usually about 20 – 30 cm high, depending on the quantities of stone available, their length usually varies from 25 to 100 m. The contour stone bunds are semi-permeable, which means that they don't stop all water. Some goes over the bunds or filters between the stones. This is considered a great advantage by those farmers who have fields downslope.

Photo 3 : Half moons in the region of Tahoua (Niger)

Half moons

soil is excavated in the form of a half open circle; the excavated soil is used to construct a bund. The opening of the half moon should always be pointed upstream allowing it to capture runoff. Cultivation takes place in the excavated part, which also receives runoff and organic matter. The non-cultivated land upstream serves as catchment, which generates runoff. The diameter of the half moons is highly variable. Farmers use diameters ranging from 1 m to 4 m. The depth of the excavated part varies from 20 to 30 cm. Although digging of half moons is labour-intensive, they are becoming increasingly popular. Like zaï they are used to rehabilitate degraded land.

Photo 4 : A young Faidherbia albida parkland in southern Zinder (Niger)

Farmer-Managed Natural Regeneration (FMNR)

FMNR concerns protecting and managing trees and bushes, which regenerate spontaneously. Farmers decide which species they want to protect for what purposes and how many they find acceptable on their fields. FMNR helps farmers to develop agroforestry fairly quickly. The cultivated fields will be less windswept early in the rainy season by the presence of trees with as a result, less damage to the young crops. FMNR produces multiple benefits : fodder, firewood, fruit, soil fertility, etc.

The Sahel study in Senegal has analyzed two other techniques, which are specific to Senegal : the construction of small anti-salt dams and coastal sand dune fixation. They will be briefly discussed in the thematic chapters.

After having mentioned the main NRM techniques which have spread across parts of the Sahel during the last 25 years, it is time to look at their different impacts.

4. Impacts of investments in Soil and Water Conservation on crop yields

A study by ICRISAT about cereal yields in Burkina Faso over the period of 1981 to 1985 (drought years) showed average yields of sorghum of 293 kg/and of millet of 232 kg/ha (Brons, et al. 2000 :20). These very low yields reflect a situation characterized by drought and poor soil fertility. They explain the chronic food shortages of the 1970s and the first half of the 1980s which is a major reason why so many farm families fled the Central Plateau to regions with better soils and higher rainfall.

Increasingly complex production systems

Water harvesting techniques, like zaï, contour stone bunds and half moons, slow down runoff. The digging of zaï and half moons requires breaking the crusted soils. This facilitates the infiltration of water and increases the quantities of water available to crops. Fine soil particles are trapped in the planting pits or are retained by stone bunds. The retention of soil particles, as well as of manure applied by farmers, helps improve soil fertility.

The adoption of these simple water harvesting techniques enabled farmers to grow crops on land that used to be unproductive. The manure they used also contained seeds of trees and shrubs. Research shows that the number and the diversity of trees on these rehabilitated fields is higher than on existing fields (Belemvire, 2002). The trees produce fruit and fodder and a better integration of agriculture, farm forestry and livestock has led to increasingly complex production systems in which both trees and livestock contribute to maintaining and improving soil fertility. Trees produce litter, which contributes to the organic matter content of the soils and some species fix/bind nitrogen. An increase in fodder availability makes it easier to keep livestock.

The impact of investments in soil and water conservation, in combination with an increase in the quantity and the quality of organic matter used for soil fertility management, has locally increased crop yields and agricultural production.

Impacts of soil and water conservation on cereal yields

The case of Niger and Burkina Faso

In Niger as well as in Burkina Faso, the studies conducted by the research teams clearly show that soil and water conservation leads to the rehabilitation of degraded land. This does not only increase cereal yields, but also allows farmers to expand cultivated land.

In Niger, the increase in cereal yields thanks to investments in soil and water conservation varies from 15 to 50 % for millet and 20 to 85 % for sorghum. The cereal yields in some control villages without such investments in soil and water conservation show a decline.

It should be noted here that that the way farmers and researchers evaluate the impacts of land rehabilitation can differ. Farmers tend to compare the situation before land rehabilitation (0 kg/ha) with the situation after land rehabilitation (400 to 1200 kg/ha or even more depending on rainfall, soil fertility management and crop management. To farmers every kilo produced on these fields is a net gain. Researchers tend to compare yields on rehabilitated fields with those obtained on other cultivated fields. For instance, Hassane, et al. (2000) compare yields on rehabilitated fields with average yields obtained at district level instead of with the situation without investment (0 kg/ha). Farmers would interpret the data in table 1 below, quite differently from researchers.

Table 1 : Impact of zaï and half moons on cereal yields in Illéla district, Niger (1991 – 1996 (kg/ha)

Rainfall Badaguichiri Illéla	1991 726 mm 581 mm	1992 423 mm 440 mm	1993 369 mm 233 mm	1994 613 mm 581 mm	1995 415 mm 404 mm	1996 439 mm 440 mm	Average 1991 – 1996
Zaï							
T0	----	125	144	296	50	11	125
T1	520	297	393	969	347	553	513
T2	764	494	659	1486	534	653	765
Half moons							
T0	----	86	77	206	28	164	112
T1	655	293	416	912	424	511	535
T2	1183	538	641	1531	615	632	857
Average Illéla district	386	241	270	362	267	282	301

Key: T0 = without situation; T1 = SWC technique + manure; T2 = SWC technique + manure + fertilizer
Source : Hassane et al. (2000)

These data show that 1994 was an outstanding year with average millet yields approaching 1 ton/ha when only manure was used to fertilize the plots. The average yields hide important variations between plots. On some fields yields reached almost 2 ton/ha (Hassane et al., 2000: 26). To farmers every single kilogram harvested on a field rehabilitated with zaï and half moons is a net gain, as they have used these techniques to rehabilitate barren, degraded land.

In 2007, cereal yields were measured in some of the study villages in Burkina Faso. The rainy season that year was highly erratic. The rains arrived late, which meant that farmers were forced to plant late. Rainfall in August was very high, which led to flooding, and rains already stopped early September. Although total rainfall in 2007 was/ in many places/ higher than the long-term average in many places, its distribution was so poor that it deeply depressed crops yields.

Since the middle of the 1990s, average annual rainfall has increased in many parts of the Sahel. However, farmers observe more long dry spells during the rainy season (14 days or more). Water harvesting techniques reduce drought stress and help crops tide over drought spells, as more water is stored in the top soil and consequently available to plant roots. However, in years of extremely low rainfall, even the use of water harvesting techniques may not prevent crop failure. In 2007, yields on fields without soil and water conservation were in the order of 400 to 500 kg/ha and on fields with SWC they ranged from 800 to 1100 kg/ha. In general, investments in SWC on the Central Plateau of Burkina Faso lead to increases in cereal yields between 30% and 100%. Such high increases in cereal yields occur despite the fact that less than 5% of the farmers in this region use improved crop varieties.

Table 2 : Impact of soil and water conservation techniques on cereal yields in 4 groups of villages in 2007 (kg/ha)

Villages	Without Situation	Zaï	Yield Increase	Contour stone bunds	Yield increase	Stone bunds + zaï* or grass strips**	Yield increase
Ziga	434	772	+ 346	574	+ 130	956*	+ 522
Ranawa	376	804	+ 428	531	+ 155	922*	+ 546
Noh	486	700	+ 214	706	+ 220	980**	+ 494
Rissiam	468	716	+ 248	649	+ 181	992**	+ 524

Source: Sawadogo, 2008

Senegal : positive changes in the peanut basin

In Senegal, several projects have invested in soil and water conservation, but adequate information about the scale at/on which this happened, was not uncovered by the research team. As a part of the Sahel study in Senegal, some villages were studied on the northern part of the peanut basin. The researchers found impacts similar to those in Niger and Burkina Faso: the rehabilitation of unproductive land and an increase in crop yields. For instance, in the middle of the 1980s, the village of Baback was confronted with increasing water erosion and with gully formation. The soils of this village were already poor after several decades of cultivation of mono-cropping of peanuts. The erosion processes impoverished the already poor soils even further. Baback benefitted from the intervention of a project supporting the construction of contour stone bunds and of level rock dams used to control and rehabilitate gullies.
Between 2000 and 2004, 200 ha of unproductive land were rehabilitated in Baback. This led to an expansion of crop land with 150 ha and of land under fruit trees with 50 ha.

Photo 5 : Situation after introduction of SWC techniques

Situation après les aménagements

Case of BABAK: Contour stone bunds

By slowing the water velocity, the contour stone bunds have reduced water erosion

Mitigation of erosion phenomena has resulted in land reclamation upstream of the structures and re-formation of woody and herbaceous vegetation cover

The populations realize they have the capacity to address the challenges posed to them by nature, through collective organization and mobilization

The scale of adoption of SWC techniques in the Sahel

In the early 1980s, the northern part of the Central Plateau of Burkina Faso, and in particular the Yatenga region, was a kind of laboratory for SWC techniques. This is understandable as the earthen bunds constructed in the 1970s were too fragile to cope with runoff and farmers considered their maintenance requirements too big a burden. It may seem surprising now, but before 1980, not a single effective SWC technique could be found in this region. No SWC technique was spontaneously adopted by farmers to fight water erosion and to intensify agriculture. This changed radically between 1980 and 1985 when farmers and NGOs began improving and testing planting pits (zaï) and contour stone bunds. From 1985 every new SWC project on the Central Plateau has promoted these techniques.

The study carried out on the Central Plateau used a sample of 700 farm households. 53% of these households has adopted SWC techniques. Most farmers combine several techniques, for instance zaï and contour stone bunds or stone bunds reinforced by strips of Andropogon grass or stone bunds in combination with mulching. The first combination mentioned is the one used most frequently. About 67% of the farm households apply manure to their fields and since the early 1980s farmers have significantly increased the use of manure and have also improved the quality of the manure. As mentioned earlier in this report, SWC techniques help keep the manure on the land as it is no longer carried away by runoff, moreover SWC projects have also systematically and successfully promoted the use of compost pits to improve the quality of the organic matter used to fertilize the soils. Tens of thousands of compost pits are now in use on the Central Plateau compared to very few compost pits in the early 1980s.

The intervention by different SWC projects in the 1980s and 1990s led to the rehabilitation of about 250,000 ha of strongly degraded plateaus. Farmers confirm that they have adopted zaï and half moons to expand their cultivated land. Some projects used machinery to rehabilitate large blocks of degraded land. Large earthen bunds with upward sloping wings was one of the techniques commonly used by SWC projects in Niger. These bunds were covered with stones to increase their resistance against rainfall and runoff. Farmers were usually given food-for-work for the work they provided during construction of these bunds. Without external support, in the form of food-for-work or cash-for-work, this kind of bunds will not be collectively constructed by farmers.

Other projects tried to promote simple techniques (zaï and half moons). The promotion of these techniques created considerable dynamics in some regions. For instance, in 1989, 13 farmers from the Region of Tahoua (9 men and 4 women) made a study visit to Burkina Faso (Yatenga) where they learnt about zaï. Upon return, some of the participants in this study visit, began trying out the technique on their own fields. In 1989 they rehabilitated 4 ha along the road between Badaguichiri and Illéla. The harvest was good which was observed by those who travelled along this road. In 1990, farmers rehabilitated about 50 ha. 1990 was a drought year and only those farmers who used zaï got a reasonably good harvest. This convinced even the most sceptical farmers of the potential of this technique. In the following years zaï spread spontaneously. The farmers transformed thousands of hectares of degraded plateaus into productive land and even today they continue to rehabilitate degraded land . In the early 1990s, a land market emerged in this region. Farmers began buying and selling degraded land to rehabilitate it with zaï or half moons (Hassane et al.,2000). A study in Niger shows that the costs of buying one hectare of rehabilitated land varies from village to village; the costs range from 100 to 400 euro (Abdoulaye and Ibro, 2006).

The market value of the crops produced on one hectare of rehabilitated land depends on crop prices, which fluctuate annually. However, it is reasonable to assume that their annual market value varies from 100 to 200 euro/ha/an. This implies that the investment costs will be earned back very quickly. Although the emergence of a market for buying and selling degraded as well as rehabilitated land indicates that farmers are aware that it is profitable to do so, it should be noticed here that in general the rich will buy and the poor will sell land. This land market is likely to increase inequality.

On the Central Plateau of Burkina, farmers are aware that water harvesting techniques produce multiple benefits. They help rehabilitate degraded land, increase production and improve yield security in particular in years of average or below average rainfall. A disadvantage is that their construction requires a considerable labour investment. Richer farmers tend to have bigger families and can hire labour more easily than poor farmers. Cases are known of poor farmers investing in land rehabilitation, but they face constraints due to lack of labour and of cash.
If stones are only found at larger distances from the fields, the transport of stones for the construction of bunds requires a donkey cart. Most poor farm families don't have such a cart. Unless they hire one, the construction of contour stone bunds will be impossible or very slow.
The labour investments in digging zaï are usually high. They require an average investment of 300 hours/ha (Barro et al, 2005). If this labour investment is expressed in monetary terms, the costs of managing one hectare vary from 150 to 230 euro. In Niger the costs of one hectare of rehabilitated land are up to 150 euro more expensive than one hectare of degraded land (Abdoulaye and Ibro, 2006).

Partial conclusion about the impact of investments in NRM on cereal production

Before 1980, the battle against land degradation in the Sahel did not produce tangible results. The soil and water conservation projects did not produce lasting results and some were even failures. It meant that erosion by water and wind continued unabated, crop yields were poor and in decline and farmers expanded their fields over land marginal to agriculture. Not surprisingly the performance of the agricultural sector was characterized by words as « breakdown ». However, two major changes occurred early in the 1980s. First, farmers and NGOs began to experiment) with conservation techniques. This led to some technical breakthroughs in soil and water conservation allowing farmers to begin a process of agricultural intensification. Second, governments and their financial partners significantly increased their investments in soil and water conservation in Burkina Faso, Niger, Mali and Senegal.

This chapter has given some examples of the impact of soil and water conservation on crop yields. In general, many studies have limited themselves to studying impacts of these investments on crop yields. In the following chapters, the accent will shift to other forms of impacts triggered by investments in soil and water conservation. This will show whether or not there has been a tendency to under-estimate the impacts of these investments in the Sahel. Before drawing attention to analyzing different impacts of investments in soil and water conservation, it is important to move away from rainfed agriculture and to look briefly at the dynamics of small-scale irrigation.

The increase in vegetable production

In the early 1980s, Burkina Faso produced green beans around some natural lakes (mainly around Bam), some of which was exported to Europe, (and)Niger produced about 100,000 tons onions and other vegetables, mainly in the Tahoua Region. Since then, vegetable production in both countries has grown spectacularly. In Burkina Faso this growth was induced by the growing demand of Ouagadougou and to some extent also by the coastal markets. In 1980 Ouagadougou had barely 150,000 inhabitants, but in 2009 its population is probably close to 1,300,000 inhabitants. The growth in vegetable production in Niger is a reaction to growing demand exerted by the major urban markets of Nigeria.

In several regions, investments were made in small dams to store water or in improved water management. In Senegal, sand dune fixation along the coast beween Dakar and St.Louis helped increase the area under small-scale irrigation. In Niger, the construction of water spreading dams in several valleys of the Ader Doutchi Maggia (Tahoua Region) enabled an expansion of irrigation based on shallow wells. The water spreading dams contributed to recharging the ground water table. This facilitated small-scale irrigation during the dry season. This is, for instance, the case in the Adouna valley where several water spreading dams constructed during the last 20 years have increased the production of onions, tomatoes, pepper and other vegetables. In combination with other investments in natural resource management, this contributed to reversing the proces of environmental degradation and economic decline.

According to FAO statistics the production of dry onions in Niger increased from 107,800 tons in 1980 to 270.000 tons in 2005. The region of Tahoua alone produces more than 80% of all onions produced in the country. It is important to be aware of the fact that in the 1970s and 1980s, the region of Tahoua was strongly affected by desertification. Several major SWC projects were initiated in the 1980s. Taken together, they rehabilitated thousands of hectares of degraded plateaus and improved water management.

Photo 6 : Since 1980, vegetable cultivation in Niger has increased spectacularly

Small-scale irrigation projects in valley bottoms in the southern parts of the Zinder region has also contributed to increasing vegetable cultivation. During the dry season, hundreds of trucks from Nigeria arrive in this region to transport vegetables across the border.

During the last 50 years, a belt of filao (Casuarina equisetifolia) was planted in Senegal along a narrow coastal strip between Dakar and Saint Louis. This not only helped fix sand dunes, which risked invading valleys producing almost 80% of Senegal's vegetables, but also created conditions favourable for the expansion of irrigated land. Average farm size increased from 0.4 ha in 1986 to 1.2 ha in 2006.

Farmers have not only invested in wells to expand irrigation, they also diversified their production system by planting fruit trees. As income from fisheries declined along the coast, the development of small-scale irrigation helped diversify income and avoid a crisis.

The strong expansion of small-scale irrigation in parts of the Sahel has not only increased cash income of farmers, it also motivated thousands of farmers, who would otherwise have left to earn an income elsewhere, to stay in their village. Small-scale irrigation has a positive impact on the quality of nutrition at village level. Although most of the vegetables are destined for urban markets, what cannot be sold, is consumed locally.

In Senegal, the planting of a belt of filao (Casuarina equisetifolia) to stabilize sand dunes along the coast between Dakar and Saint-Louis, helped expand market gardening. It removed or reduced the threat of sand dunes risking to encroach upon depressions used for market gardening (see photo 7). The sand dune stabilisation created favourable conditions. Villagers began investing more in the construction of permanent houses; they significantly increased the area under cultivation. Between 1986 and 2006, the average area cultivated by farm households increased from 0.4 ha to 1.2 ha. Farmers also began investing considerably more money in the construction of permanent wells for irrigation.

Photo 7 : Before coastal dune fixation

Environmental and socio-economic impacts of the CTL Project

A hostile environment, not only for the development of economic activities but also for the survival of the populations

Silting (burying) of basins: 1/5th of the land used

Situation after SWC techniques were introduced

Photo 8 : After coastal sand dune fixation

Situation after SWC techniques were introduced

The Casuarina equisetifolia (filao) belt helped protect (through sand dune fixation) market gardening areas, create conditions more conducive for economic activities (agriculture) and secure living environment with permanent settlement of the populations (permanent housing structures)

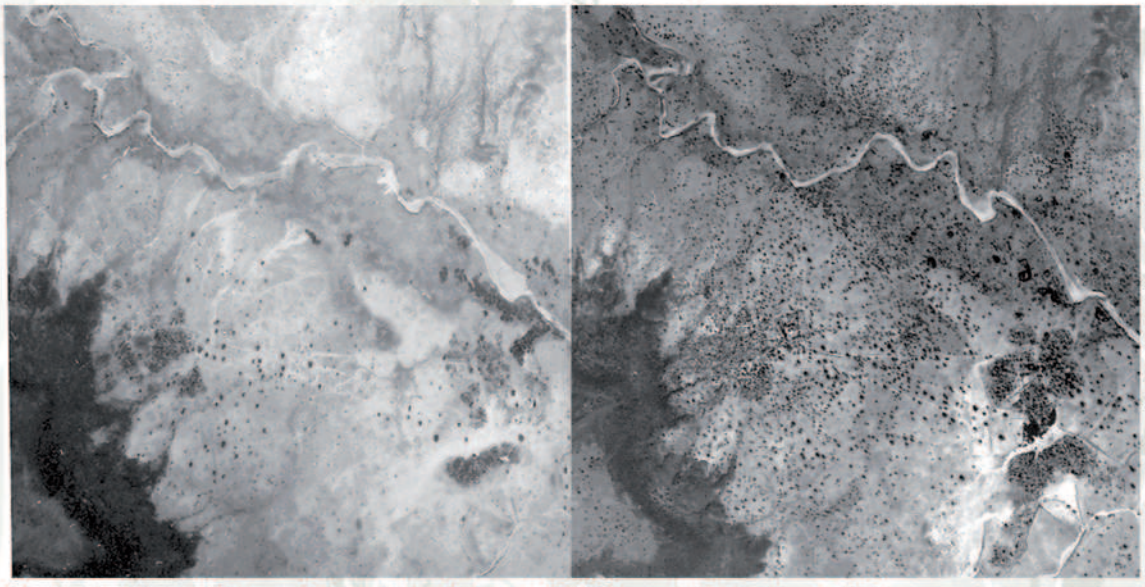
Not only has market gardening increased, farmers also invested more in fruit trees and by doing so, they diversified their sources of income. The depletion of fisheries along the coast, in combination with sand dune encroachment, threatened livelihoods in this region. However, coastal sand dune fixation enabled villagers to develop more complex production systems. Farm income increased and some people would rather stay in the villages than settle in Dakar or Saint-Louis.

5. More people, more trees : development of agroforestry systems in the Sahel

One of the most surprising findings of the study is the scale on which farmers are developing agroforestry systems. This phenomenon is strongest in regions with high population densities where most of the village land is cultivated and where natural vegetation has almost disappeared. For instance, the densely populated parts of the Maradi and Zinder regions of Niger, on the northern part of the Central Plateau of Burkina Faso, and on the plains around Bankass in Mali between the Plateau Dogon and the border with Burkina Faso, show significant increases in the number of on-farm trees. Also in the two villages studied in Senegal's peanut basin, farmers have invested in agroforestry.

In Niger the scale of this trend is spectacular. The comparison of aerial photos of 1975 with satellite images of 2005 shows a strong increase in on-farm tree densities in many villages. In most cases the number of on-farm trees is 15 to 20 times higher in 2005 than in 1975. The scale of this on-farm re-greening is at least 5 millions hectares. This makes it the largest environmental transformation in the Sahel, and possibly even in Africa

Photo 9 : The village of Galma (Niger) in 1975 (left) and in 2003 (right).



The black dots are big trees. The number of trees in 2005 is much bigger than in 1975.

Tree densities per hectare (all species and age classes taken together) vary from 20 to 120 trees. Using an average number of 40 new trees per hectare, the total number of new trees in Niger is in the order of 200 million. Other studies have also identified this process of increasing on-farm tree densities. For instance, the synthesis report of a study on the long-term evolution of the Maradi department between 1960 and 2000 mentions that the area under natural forests declines steadily, but that on-farm tree densities are increasing strongly (Mortimore et al. 2001 : 45).

Until the Sahel study in Niger was undertaken in 2005/2006, no other study had observed the scale on which farmers in Niger have already developed and continue to develop new agroforestry parkland. The comparison of aerial photos and high-resolution satellite images combined with field visits for groundtruthing made it possible to determine the scale of on-farm re-greening.

It is important to emphasize that the 200 million trees were not planted, but (they) regenerated spontaneously, because farmers protected and managed them. An exploratory survey of this phenomenon of so-called Farmer-Managed Natural Regeneration was undertaken in June 2006 in the densely populated southern part of the Zinder Region (the so-called 3M or the three departments of Magaria, Mirriah and Matameye) (Larwanou, Abdoulaye and Reij, 2006). The Farmer-Managed Natural Regeneration in this region is an almost general phenomenon. The farmers have constructed agroforestry parklands on about one million hectares. These cultivated parklands are dominated by Faidherbia albida with densities ranging from 20 to 120 trees per hectare. It is surprising that this major transformation has largely escaped the attention of researchers .

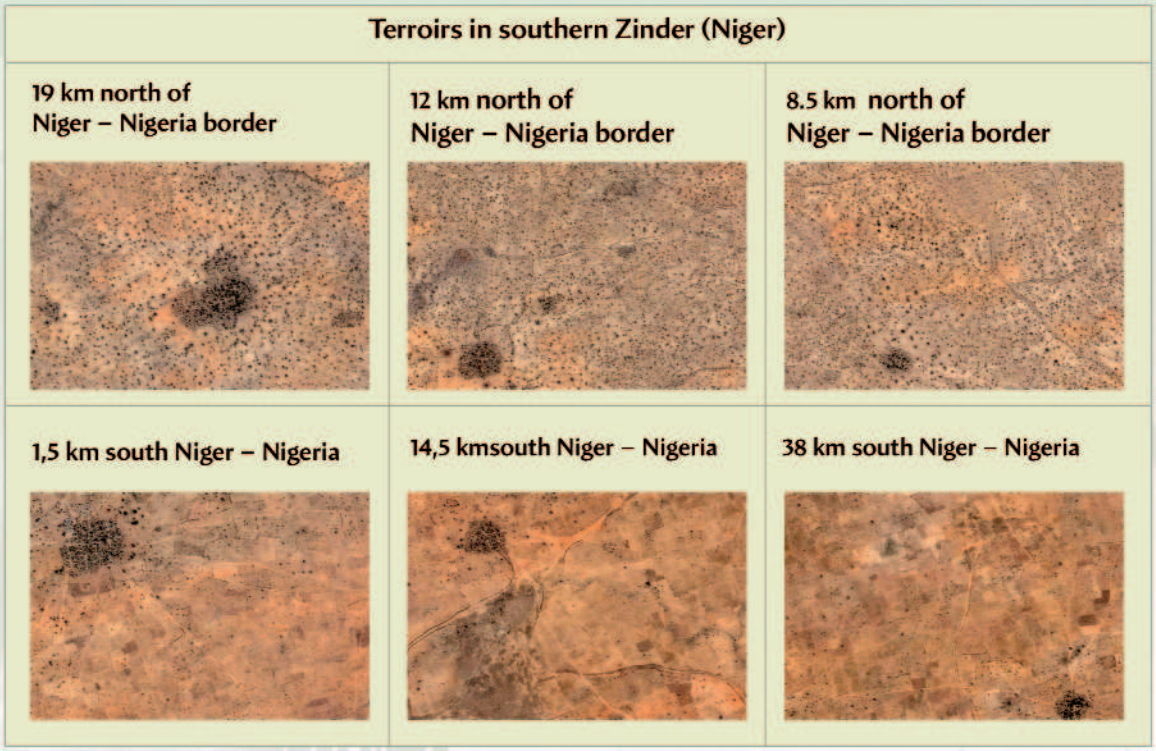
The re-greening of the Sahel and the evolution of rainfall

After the dry 1970s and 1980s, the average rainfall has increased again from the middle of the 1990s. It is therefore logical to ask the question: "should the re-greening of parts of the Sahel be attributed to an increase in rainfall?" It will be clear that higher rainfall facilitates the regeneration of vegetation, but farmers in the Maradi region began protecting and managing natural regeneration on their fields during the drought years in the middle of the 1980s. Gray Tappan of the US Geological Survey analyzed satellite images from Google Earth (2005) along a transect from southern Zinder into northern Nigeria. Photo 10 compares village territories on both sides of the border. It is clear that on-farm tree densities are much higher in southern Zinder than in northern Nigeria, despite higher rainfall in the latter region. This does not mean that rainfall is not important for re-greening, but human management is apparently more important than rainfall.
The study by Hermann, et al. (2005) also supports this view. They used satellite images to analyze the evolution of vegetation in the Sahel in relation to rainfall. Their study shows that vegetation cover in northern Nigeria is less developed than could be expected on the basis of rainfall and more developed in Southern Niger than can be expected on the basis of rainfall. A recent analysis by Tappan (2009) shows that increases in rainfall in Southern Niger are not the driving re-greening (personal communication).

Olsson et al (2008) have drawn the same conclusion. They studied 40 rainfall stations across the Sahel in regions showing re-greening. One of their findings was that the Normalized DVI increased under conditions of decreasing rainfall. This implies that rainfall alone does not explain the re-greening of parts of the Sahel.

Although an increase in rainfall from 1994 may have facilitated regeneration of vegetation, human action, including natural resource management projects, has been a major determining factor, too.

Figure 2 : Comparison of three terroirs on each side of the Niger – Nigeria border



Source: Google Earth (courtesy Gray Tappan)

What has induced farmers to protect and manage natural regeneration on their farms?

There is not one single factor which explains why farmers in Niger began protecting on-farm natural regeneration, but there are several factors behind it. During the survey in the Zinder Region in June 2006, farmers mentioned different reasons for protecting natural regeneration.

1. The environmental crisis: « we had to fight the Sahara »

Almost all of the 400 farmers met individually or in groups during the survey mentioned the environmental crisis of the 1970s and 1980s. The major droughts of this period are anchored in the memories of farmers in the Sahel in general and of farmers in Niger in particular. The drought years strongly reduced the productive capacity of the land and farmers had expanded their fields to compensate for declining yields. By doing so they removed vegetation. They also cut trees and bushes to cover firewood needs and to sell wood to earn some cash. The drought years caused a lot of hardship and many families fell into a poverty trap. In economic terms these were decades of de-capitalisation.

The farmers in Zinder often mentioned the word Sahara and they did not refer to sand dunes moving southwards, but to strong winds and dust storms. The strong winds early in the rainy season caused a lot of damage to the young crops. These were often covered or damaged by wind-blown sand. As a result farmers often had to plant three or four times to establish their crops. Faced with this crisis, farmers decide to act and to protect natural regeneration of trees and bushes on their farms.

2. A strong demographic growth induced a process of agricultural intensification

The southern part of the Zinder region belongs to the most densely populated areas of the country. Population densities in many places exceed 100 persons/km². The rapid population growth since the beginning of the 20th century has led to the occupation of all arable land. Nowadays, 70% to 80% of all village land is under cultivation. The French term for this is « saturation foncière ». One of the consequences of this expansion of cultivated land was the progressive disappearance of grazing areas and of natural forests. During/ a certain period, this process of extensification may have enabled a number of farmers to temporarily increase food production. However, the combined impacts of the environmental crisis, the decreasing yields and rapid population growth, induced farmers to intensify agriculture. Labour migration generated some cash income and a temporary reduction in household food needs, but neither expansion of cultivated land, nor fallow to restore soil fertility, could be used to delay intensification. Farmers had to increase crop yields per unit of land. How to achieve this in a situation in which many farm families are too poor to buy chemical fertilizers and wind and sun are scourging the almost denuded soil?

The only pathway to intensification feasible in this kind of situation is to increase the number of on-farm trees and to achieve a better integration of trees, crops and livestock. In this context, nitrogen-fixing trees play a key role. The role of trees is not limited to the production of firewood, however, they play an essential role in strategies used by farmers to diversify food production and to adapt to erratic climatic conditions. Trees are a fundamental component of production systems in the Sahel (Raynaut et al, 1997). Farmers in Tigray (Ethiopia) remarked that "Trees are our backbone" (Waters-Bayer and GebreMichael, 2009). This is also true for farmers in Niger and other Sahel countries.

In southern Zinder the highest tree densities are found in areas with the highest population densities. This phenomenon can be characterised as "More people, more trees". The agroforestry parkland of this region is in some places largely dominated by Faidherbia albida (gao,) a nitrogen-fixing tree, but elsewhere a diversity of situations is found. In some areas baobob (Adansonia digitata) dominates, elsewhere Prosopis Africana is relatively abundant and in other areas Piliostigma reticulatum, Combretum species or Guiera senegalensis are dominant species dominate and last but not least, in certain villages tree diversity is much higher than 20 years ago and increasing. The increase in on-farm tree densities is also found in other regions with high population densities. At the same time, farmers are increasingly aware that demographic growth undermines their achievements. In several interviews they literally said « we produce more than 20 years ago, but we also have more mouths to feed and this is diluting our gains ».

3. The appropriation of trees by farmers

In 1985, the State considered itself owner of all the natural resources, including the trees. This did not stimulate farmers to manage and protect on-farm trees. However, from 1985 a gradual change has occurred in the perceptions of farmers. They increasingly regarded themselves as the de facto owners of their on-farm trees. It should be mentioned here that the forestry law of 2004 does not yet officially recognize farmers' rights to trees.

4. External interventions

In some regions, the process of farmer-managed natural regeneration was catalyzed by external interventions. For instance, in the Maradi Region, an NGO called Serving-in-Mission (SIM), systematically promoted farmer-managed natural regeneration during the drought years of 1984 and 1985. SIM suggested that the farmers would protect on-farm natural regeneration and in return it offered farmers food aid. Not surprisingly, many farmers grabbed this opportunity to receive food aid. However, as soon as rainfall returned to normal and farmers had a good harvest, SIM stopped food aid. About half of the farmers, who had protected natural regeneration on their fields, cut their young trees, yet, the other half continued to protect and manage them. Farmers who had cut their trees, soon regretted this, as the multiple benefits of on-farm trees became clear quite soon

5. The multiple benefits of on-farm trees help induce a « process of spreading »

Once farmers observe the multiple benefits of an increasing number of on-farm trees, many begin to protect and manage trees and bushes regenerating spontaneously. The benefits they indicate themselves, include: 1. an increase in the quantity of firewood available on the cultivated fields at a relatively short distance from their homes; 2. some trees produce fodder and more fodder means that farmers can keep more livestock; 3. trees produce leaves and fruit, which help improve nutrition; 4. farmers now plant crops only once instead of three or four times twenty years ago, because trees have reduced wind speed. This lengthens the growing season, which has a positive impact on crop yields. Many farmers do not hesitate to try out themselves, good practice(s)they observe on the fields of fellow farmers working under similar agro-ecological and socioeconomic conditions. Although farmer-managed natural regeneration produces multiple benefits, it will not be adopted automatically in all villages. Farmer-managed natural regeneration requires concerted action by groups of farmers and villages divided by internal conflict or lack of organisation, are less likely to protect and manage natural regeneration. In such cases, efforts aimed at reducing constraints to farmer-managed natural regeneration, such as conflict resolution and social capital building, are a precondition for spreading of re-greening.

Burkina Faso: the rehabilitation of degraded land has created conditions favourable for developing tree-based production systems

In Niger, the process of re-greening occurred mainly in regions with sandy soils and high population density. On the Central Plateau of Burkina Faso, on-farm re-greening has occurred mainly in regions with high population density and lateritic soils. These soils were heavily degraded, but nevertheless, productivity was restored using the simple water harvesting techniques mentioned earlier in this report. The breaking of the soil crust allowed more water to infiltrate and roots of crops and trees to penetrate the soil.. Techniques, such as contour stone bunds and zaï, have been used on up to 300,000 hectares (Ouedraogo, 2005). This has allowed the natural regeneration of trees at/on a similar scale. This does not imply, however, that natural regeneration does not occur on existing cultivated land. It is found, but it is more important on rehabilitated land.

Photo 10 : Before stone bunds and zaï were introduced in 1984/85, these fields were barren

Mali : farmer-managed natural regeneration on the Gondo plains

Photo 11 : Farmers in the region around Bankass (Mali) began to protect natural regeneration after 1994

How can this fairly recent process of re-greening in this region be explained? In 1994, Mali adopted new forestry legislation. The new law stipulated that the forestry service has to be responsible for managing natural forests and farmers have to own their on-farm trees. Not surprisingly, farmers were not aware of the contents of this new law. The NGO SOS Sahel UK decided to use radio Bankass to explain its contents. As a result, farmers began to understand that they could refuse access to firewood traders, who with a permit delivered by the forestry service, had the habit of cutting their on-farm trees. From that moment, they decided to refuse access to anyone exploiting their trees. This soon led to higher on-farm tree densities. Table 3 shows that 69 percent of almost 500 farmers interviewed, protect and manage natural regeneration.

Tableau 3 : Number of farm households in the Bankass region protecting and managing natural regeneration

Villages	Farmers with FMNR				Farmers without FMNR				Total number of farm households
	Rich	Poor	Total	Rate of adoption (%)	Rich	Poor	Total	Rate of household Without FMNR (%)	
Endé	78	54	132	86%	9	13	22	14%	154
Kourou dé	12	28	40	54%	12	22	34	46%	74
Wol	75	156	231	100%	0	0	0	0 %	231
Walia	3	10	13	38%	9	12	21	62%	34
Total	168	248	416	84%	30	47	77	16%	493
Average				69%				31%	

Source : SahelECO (2008)

Senegal : farmer-managed natural regeneration and the development of cashew plantations in the peanut basin

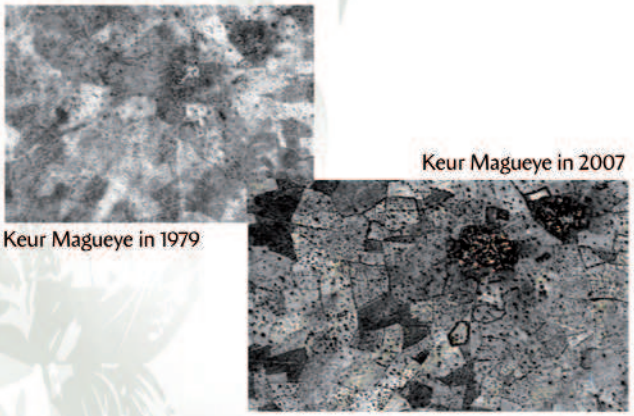
In the villages studied in the peanut basin, the area under cultivated parkland increased significantly on land treated with soil and water conservation techniques. Farmers (have) invested in cashew trees (Anacardium occidentale) and subsequently, women developed a market chain for cashew. They play a key role in the collection and marketing of cashew fruit and nuts. The average quantity of cashew fruit marketed per farm household evolved from 15,000 kilograms in 2002 to almost 35,000 kilograms in 2004. This yields average annual incomes ranging from 400,000 to 800,000 F CFA (600 to 1,200 euros). Besides the fruit and the nuts, the cashew trees provide firewood and construction wood, too.

The income from the sale of cashew is far higher than from annual crops. The sale of fruit and nuts constitute the main source of cash income for 75 percent of the women. During the last few years, 72 percent of the persons interviewed, mentioned that their income has increased, whereas 25 percent mentioned a decrease in income.

To summarize the changes as a result of the investments in soil and water conservation:

- a strong reduction in wind erosion thanks to an increase in the number of trees both in-field and along field boundaries (Euphorbia balsamifera and Anacardium occidentale) (see the aerial photos for Keur Magueye in 1979 and in 2007)

Photo 12 and and Photo 13 : the village of Keur Magueye in 1979 and in 2007



Keur Magueye in 1979

Keur Magueye in 2007

- The improvement of the woody vegetation cover as well as of the grass cover, has had positive impacts on crop yields and on the availability of non-timber forest products.
- More fodder is available to livestock.
- The use of chemical fertilizers has increased, which is most likely related to higher cash income.
- An increase in the availability of firewood (pruning of Anacardium occidentale) has reduced the labour burden of women.
- The planting of Eucalyptus camaldulensis and of Anacardium occidentale has increased cash income from the sale of construction wood.
- The quantities of cashew fruit and nuts harvested, enabled the development of a commercial market chain. The accompanying increase in cash income has had a positive impact on the local economy. The development of cashew plantations has reduced interest in growing conventional crops, such as millet and peanut. A growing number of fields is converted from growing annual crops to growing cashew trees in association with cowpea and sometimes manioc.

6. Impact of NRM investments on the livestock sector

The studies in Niger, and also in Burkina Faso, show that the investments in NRM have had a positive impact on the livestock sector. For instance, in parts of Niger fodder is less a constraint now than it used to be 20 years ago, because many trees produce pods or leaves which are high quality fodder. In Burkina Faso, farmers who have invested in soil and water conservation have also improved soil fertility management. They wanted more manure to fertilise their fields and this could only be achieved by adapting the management of their livestock. This induced a transition from extensive to semi-intensive forms of livestock management. Farmers, who used to entrust part of their livestock to Fulani herders, no longer do so. They keep their livestock in the village now, because they want to benefit optimally from its manure. They can now keep livestock in the village, as the production of crop residues as well as of tree fodder has increased. Fulani herders seem to lose in the process, because they do longer benefit from the livestock that used to be entrusted to them. However, in certain regions on the Central Plateau (Burkina Faso) a "manure market" emerged, which means that Fulani herders sell manure to Mossi farmers. This may offset losses incurred because of changes in livestock management.

The majority of agro-pastoralists and pastoralists affirmed that investments to rehabilitate degraded land have increased the quantity and improved the quality of grasses for their livestock. This is not only the case on land rehabilitated specifically for grazing, but also on land rehabilitated for agriculture. In the latter case, there is an increase in the production of crop residues (leaves of cowpea and peanuts as well stalks of millet and sorghum).

The Sahel study in Burkina Faso produced data showing increases in crop residues in the order of one ton per hectare on fields treated with soil and water conservation measures in comparison to fields without such measures (3.84 ton/ha compared to 2.81 ton/ha).

On the rangelands of Niger, the biomass production increased from quasi zero kg/ha of dry matter to more than 600 kg/ha. Research by Kessler et al (1998), Hien (1995), Kiema et al (2006) indicates that soil and water conservation measures led to a significant increase in vegetation cover both in terms of quantity as well as in terms of quality. This is reflected by an increase in the diversity of woody species and grasses. Species which had disappeared reappeared spontaneously in the wake of land rehabilitation. Perennial grasses have become more abundant on fields treated with soil and water conservation measures; they are even cultivated because of their economic and social value. This is in particular true for Andropogon gayanu,s often planted along contour stone bunds. They benefit from the water and the sediment retained by the bunds. At the same time they contribute to retain more sediment and to stabilise the bunds. This species is used in handicraft and has considerable commercial value.

Land rehabilitation in Niger led to an increase in Eragrostis tremula, a species with a high fodder value, however, it is also used for human consumption. This makes it a species of great importance in the local economy.

The large-scale farmer-managed natural regeneration analyzed in the previous chapter, has led to a considerable growth of fodder. The pods of Faidherbia albida and of Piliostigma reticulatum have a high nutritive value. In some parts of Niger, livestock now survives on tree fodder for six months per year.

Investments in NRM have reduced conflicts between herders and farmers. One reason is the fact that the natural resource cake has increased and there is more to be shared. Another reason is the rehabilitation of unproductive land specifically for grazing. This means that livestock can stay longer outside the cultivated lands and wait for the end of the harvest. In some regions, livestock corridors are now clearly demarcated and respected (Aguié department, Niger), which also helps reduce conflicts.

Quantitative data on how investments in NRM have influenced livestock productivity (increases in milk production, higher calving rates, lower livestock mortality, etc.) are not available. However, livestock owners who were interviewed, unanimously state that productivity has increased. Local groundwater recharge means that livestock does not have to walk long distances, which means that they burn less energy and lose less weight. The increased availability of fodder has a positive impact on livestock health during the dry season.

The trade in fodder has been booming in regions with a lot of farmer-managed natural regeneration and in regions with a lot of soil and water conservation. Some producers have become specialized fodder traders. Livestock fattening has become a very important economic activity in which also women and young men are playing an important role.

In Niger, women have considerably invested in livestock. For instance, in the Keita region many women were involved in the construction of conservation infrastructure. They were paid with food-for-work. Part of this food was consumed, and part was sold on the market. The proceeds of this sale were often invested in buying sheep and goats. In this way they built a small livestock capital for themselves.

All changes mentioned in this chapter are positive. Have any negative changes been observed? One negative change that should be mentioned though, is related to the emergence of a fodder market. Fodder is being increasingly marketed and its monetary value has increased. In some parts of Niger, farmers are tempted to harvest all crop residues for their own livestock or for sale. This exposes their denuded fields to the forces of sun and wind.

7. Impact of NRM technologies on the improvement of food security in the Sahel

The Sahel countries face a chronic food insecurity resulting from the conjugation of many factors. Occasionally at the beginning, the crises tend to become structural. To illustrate the extent of food security problems in the Sahel, the following statistics are revealing: about 30% of Sahelians are still undergoing the pangs of hunger and 20% of children under five are suffering from malnutrition. In rural areas where the majority of the poor live, this situation is largely explained by the insufficiency of household food production. In urban areas, the extent of unemployment and under-employment does not provide households with sufficient resources to allow them adequate access to food markets, especially when the price of cereals is high.

Several factors determine the level of food security. The analysis in this report looks at whether investments in natural resource management have led to increases in crop yields and in food production.

Investing in soil and water conservation techniques: a key to a new "Green Revolution" in the Sahel?

The study found that investments in soil and water conservation techniques usually have a positive impact on cereal yields. Simple water harvesting techniques used to rehabilitate strongly degraded land has increased cereal yields from 0 kg per hectare to 400 to 1500 kg per hectare. The increase depends on rainfall and the quality of fertility management (Hassane et al. 2000).
Surveys carried out in 2005-2006 in Niger, showed that 70% of the persons interviewed in villages with NRM investment perceived an improvement in food security. In villages without such investments, only 1% perceived such an improvement.

Table 4 summarizes research by Hamado (2008), which shows that in 2007 yields on fields treated with improved traditional planting pits (zaï) were 214 to 428 kg per hectare higher than on control plots. Where different techniques were combined (stone bunds + zaï or stone bunds + grass strips) yield increases ranged from 494 to 546 kg per hectare. On Burkina's Central Plateau, at leasqt 200,000 ha of land have been rehabilitated. Using a net average gain in cereal production of 400 kg per hectare, which is conservative from a farmer's perspective, this implies an additional harvest of 80,000 tons/year (Reij, Tapppan and Smale, 2009). Based on an average per capita cereal consumption of 200 kg/year, this additional harvest annually feeds about 400,000 people.

Considering these yield data, it should be borne in mind that 2007 was a year of high, but poorly distributed rainfall. The data are also hiding that farmers who used at least 5 tons of manure per hectare harvested 1,000 to 1,250 kg/ha of grain (Sawadogo, 2008).

One of the lessons which can be drawn from experience is that yield differences between fields with and without soil and water conservation techniques are higher in years of low rainfall than in good years of good rainfall. This is not surprising. In years of good rainfall, all fields produce a crop, but in years of low or erratic rainfall, the soil and water conservation techniques make a bigger difference. They store more water in the top soil, which helps crops tide over dry spells.

Tableau 4 : Impact of soil and water conservation techniques on cereal yields in four groups of villages in 2007 (kg/ha)

Village	Without Situation	Zaï	Yield iIncrease	Contour stone bunds	Yield increase	Stone bunds + zaï* or grass strips**	Yield increase
Ziga	434	772	+ 346	574	+ 130	956*	+ 522
Ranawa	376	804	+ 428	531	+ 155	922*	+ 546
Noh	486	700	+ 214	706	+ 220	980**	+ 494
Rissiam	468	716	+ 248	649	+ 181	992**	+ 524

The increase in cereal production improves levels of household food security. This perception is general in villages of Niger where NRM interventions have taken place. The study in Burkina Faso shows that farmers in villages with significant investments in soil and water conservation bought almost the same quantity of cereals at the market as the farmers of villages with little investment. The quantities of cereals purchased varied from an average of 26 kg per person in villages with high investment in soil and water conservation to 38 kg per person in villages with low investment in soil and water conservation. How to explain that considerable increases in cereal yields (on average + 400 kg/ha) apparently did not result in more food security? An explanation can be that the study in Burkina Faso was carried out in 2007, a year of poor harvests. In years of poor harvests every farmer buys cereals at the market, even those who have an important security stock [7].

8. Impacts of NRM on biodiversity

In the regions studied in Niger (Tillabéri, Tahoua, Maradi and Zinder), the last remnants of natural vegetation disappeared in the 1970s and the 1980s. The combination of strong population growth and drought forced villagers to expand their cultivated fields and this often meant that natural vegetation had to be cut. This observation was also made in the three other countries studied(Burkina Faso, Mali and Senegal). Only useful species such as nêrê (Parkia biglobosa), shea (Butyrospermum parkii), and tamarind (Tamarindus indica) were spared. Not only the number of trees, but also the diversity of woody species strongly decreased in the 1970s and the 1980s. But in parts of Niger, the number of on-farm trees started to increase again in the mid 1980s. This phenomenon cannot possibly be attributed to one cause only, but it is obvious that the rural population had very little choice. Since natural vegetation, which provides energy and many other services had become scarce, another source of energy had to be created. The only feasible option was to increase the number of on-farm trees. The process of on-farm re- greening was often induced by external intervention (e.g. promotion of natural regeneration by NGOs, but also by donor and government investments in soil and water conservation), but later farmers spontaneously protected and managed woody species regenerating naturally on their farms.

The number of on-farm trees is increasing and is also followed by a change in the composition of species in the new agroforestry parklands. In Niger's Zinder region,a significant part of the parklands are dominated by Faidherbia albida. This species not only improves soil fertility, it is also an important source of fodder. Also in other regions of the Sahel, Faidherbida albida is systematically protected. This is the case, for instance, in the study villages in the peanut basin of Senegal, where the research team detected signs of a beginning rejuvenation of ageing agroforestry parkland.

There have also been farmers' initiatives to increase biodiversity. In the village of Dan Saga (Maradi Region, Niger), the villagers have begun to re-introduce species which disappeared in 1970s.

In 6 villages studied in 2007 in the regions of Maradi and Zinder (Niger), the average tree density varied from 60 to 360 trees/ha. One of the findings is that the density of trees increases with increasing distance from the village. Although situated in an area with slightly lower rainfall, the villages of Dan Saga and Dogarawa (North of Aguié) have higher tree densities (an average of 82 trees/ha) than (of) the villages of Elguéza and Yadagamo, located South of Aguié (60 trees/ha). This paradox could result from differences in tree management or in local organisation, but also from the number of years of experience with tree management. The farmers of Dan Saga have explained that they were the first in the region of Aguié to start protecting and managing spontaneous natural regeneration on their farms to increase tree densities. They had no choice as they had very few trees left 25 years ago. Also in the Magaria depertment (Zinder) high tree densities can be found (up to 458 trees/ha in Gaounawa and up to 428 trees/ha in Ara Sofoua). This is explained not only by slightly higher rainfall in this region, but also by the population's interest in preserving trees on their farms.

[7] Il y a des cas d'agriculteurs qui ont un stock de sécurité de 1 à 3 ans, qui achètent de céréales au marché en année de mauvaise récolte, afin de ne pas se distinguer d'autres agriculteurs.

Tableau 5 : Average density of woody species in four villages.

Villages	Average density of ligneous (feet/ha)				Dominating species in descending order of density
	1st ring	2nd ring	3rd ring	Average density	
Dan Saga Nord Aguié	50	68	103	74	Combretum glutinosum ; Piliostigma reticulatum ; Guiera senegalensis et Faidherbia albida
Dogarawa Nord Aguié	55	78	113	82	Combretum glutinosum ; Piliostigma reticulatum ; Guiera senegalensis et Faidherbia albida
Elguéza Sud Aguié	33	72	73	60	Hyphaene thebaïca ; Prosopis africana ; Piliostigma reticulatum et Faidherbia albida
Yadagamo Sud Aguié	42	91	99	78	Prosopis africana ; Piliostigma reticulatum et Faidherbia albida
Gaounawa Magaria	233	222	458	304	Faidherbia albida ; Annona senegalensis; Piliostigma reticulatum
Ara Sofoua Magaria	206	445	428	360	Faidherbia albida ; Piliostigma reticulatum ; Hyphaene thebaïca

Source : Larwanou and Toudou (2008)

Generally, the average density of trees is very high: from 74 to 360 trees per hectare. The number of Faidherbia albida trees per hectare can easily reach more than 100 trees per hectare (all age classes included). The on-farm re-greening is not only about increasing tree densities, it is also about improvements in biodiversity. In villages which had few trees and low diversity 25 years ago, one now finds 15 to 27 species according to villages. The most frequent species in the region are: Faidherbia albida, Piliostigma reticulatum, Hyphane thebaïca followed by Annona senegalensis, Prosopis africana, Phoenix dactylifera, Prosopis africana and Guiera senegalensis.

The comparison of current tree densities with those of 1975 shows a significantly positive evolution. Reij, Tappan and Smale (2009) have analyzed tree cover for the triangle of the Mirriah-Magaria and Matameye area (Southern Zinder, Niger) for 1957, 1975 and 2005. Tree cover in 2005 is higher than in 1957 and the percentage tree cover is likely to increase as there is a high density of young trees in the current agroforestry parkland. The increase in tree cover is due to farmers who protect and manage on-farm natural regeneration.

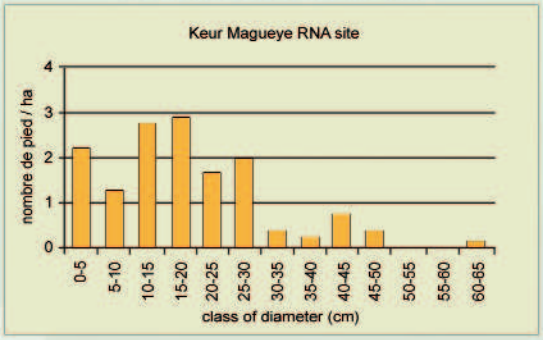
It has also been noticed that tree densities are higher on fields cultivated by poor farm families compared to those on fields of medium-rich or rich farm families. A possible explanation is the weak income of very vulnerable farmers, which induces them to protect and manage trees, not only to improve soil fertility but also and above all, to sell firewood and non-timber products generated by trees. In drought years, many poor literally survive on their trees (Larwanou et Toudou, 2008).

On the Central Plateau of Burkina Faso, the areas treated with soil and water conservation techniques exert a positive impact on the reconstitution of the lwoody vegetation and on biodiversity: 60 species were counted on fields with soil and water conservation techniques and 41species on fields without such investments (Belemvire, 2003). The volume of wood is higher in fields with soil and water conservation than in fields without: 26 m3/ha) compared to 14.5m3/ha.

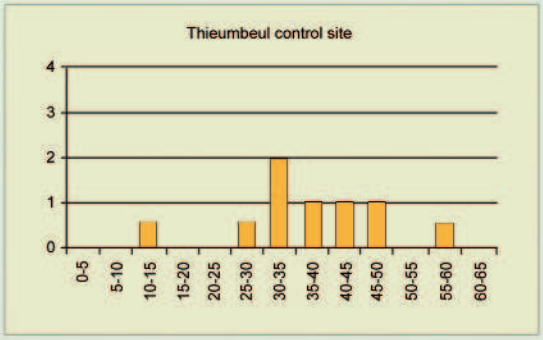
The practice of planting perennial grasses, such as Andopogon gayanus, not only stabilizes the stone bunds, but it also adds to income. Andropogon gayanus is not only a good source of fodder, it is also used for handicraft. It is good to note here that in the 1970s this species had largely disappeared from parts of the Yatenga region (Burkina Faso) and it was re-introduced in some villages in the second half of the 1980s using seeds collected in the South. Nowadays farmers from the South come to the Yatenga region to collect Andropogon gayanus.

Figure 3 shows that there is an important difference in the number of species as well as in tree densities between sites with farmer-managed natural regeneration and sites without in the villages studied in the peanut basin of Senegal.

Figure 3 : Density and diversity of trees in a village with and without intervention in the northern part of the peanut zone (Senegal)



Number of specis : 23
Density : 31 individus / ha
Rejuvenation of Kad Park



Number of specis : 5
Density : 5 individus / ha
Degradation of Kad Park

Source: report Sahel study Senegal

9. Water harvesting techniques and groundwater recharge

Within the framework of the study, the impacts of water harvesting techniques (zaï, contour stone bunds, half moons and others) on the behaviour of the groundwater table were not analyzed systematically. However, one thing became obvious during the field visits; in many cases villagers perceived a positive impact of water harvesting techniques on water levels in their wells. Anecdotes are not hard evidence, but the number of anecdotes points at a significant relationship between water harvesting techniques, increased infiltration of rainfall and runoff and local recharge of groundwater.

For example, in the village of Batodi (Department of Illéla, Niger) the level of water in the wells was at - 18 m in 1994 (after a good rainfall) and at – 4 m in November 2004 (after a very bad rainfall). At first, the villagers attributed this rise of the water table to Allah (God), and then after discussion, they recognised that since the introduction of water harvesting techniques in the early 1990s, more water infiltrated into their soils and that surface runoff had decreased significantly.

In the northern part of the Central Plateau of Burkina Faso, many examples are found of positive impacts of soil and water conservation on groundwater recharge (Reij and Thiombiano, 2003). For instance, in the villages of Ranawa, Ouattinoma and Rissiam, all the wells dried up at the beginning of the dry season (February – March), but since the introduction of water harvesting techniques in the beginning of the 1980s, all wells in these villages have had water all year long. In the department of Oula (Yatenga province), 21 out of 23 villages have noticed a rise in water levels in wells.

Is this local rise of the water table attributable to an increase in rainfall or to improved land management? There are some indications that this rise is mainly related to the introduction of water harvesting techniques,, because the rise is above all noticed in wells which are inside or immediately downstream of areas treated with contour stone bunds, zaï or half moons and not in wells which are upstream of the areas treated with these techniques. Another example: in the village of Rissiam, the water table started to rise immediately after the construction of a long and level rock dam in a gully in 1981. This was well before any increase in rainfall occurred in the Sahel. The construction of permeable rock dams in this village and in surrounding villages, continued after 1981 and also during the drought years of 1984 and 1985 Rissiam and other villages had water in all their wells during the whole year.

Some preliminary conclusions

1. The many anecdotes make us believe that NRM techniques have contributed to local groundwater recharge. However, it has not happened everywhere and it can't always be predicted. The encouraging aspect is that despite a strong increase in human and animal population, the availability of water has improved and in some cases the rise in water levels is so important that the villagers were able to create small irrigated plots around the wells.

2. It would be useful to carry out a study on the impacts of NRM techniques on local recharge of groundwater. As long as this information is not available, economists can't express the range of impacts of investments in NRM in monetary terms, which means that the economic impact of investments in the NRM will be underestimated.

10. NRM and adaptation to climate change

More and more workshops and conferences are being organised in the Sahel about climate change. But it is important to take into account the fact that farmers and herders in the Sahel faced a dramatic decrease in rainfall at the beginning of the 1970s. This decrease was in the order of 30% and lan users had to adapt to it. The search for solutions began around 1980 and the beginning of the 1980s was characterised by innovations in water harvesting techniques and by a strong increase of investments in the rehabilitation of degraded land by financial partners and farmers. If the forecasts for the Sahel are a temperature increase of 3°C, a decrease of rainfall of 20% and a decrease of agricultural yield of up to 50% by 2050, it is important to build adaptation strategies on what has already been achieved by NRM rather than re-invent the wheel again.

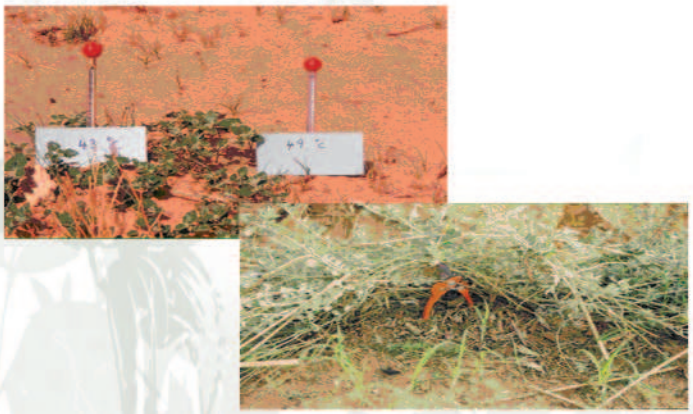
What are these achievements in the Sahel which would permit its people to better adapt to climate change? In other words, which NRM techniques used in the Sahel permit: (i) to reduce the effects of an increase in temperature; (ii) to increase or improve water availability for people, crops and livestock; (iii) to improve soil fertility by sequestering carbon to mitigate global warming. As already mentioned in the previous chapters, there is no ambiguity about the answer to these questions. Research shows that innovations in NRM have transformed agriculture as well as environment in some regions. Some examples will be presented to illustrate this.

1. The development of agroforestry systems at small and large scale. This process occurred mainly in regions with high population densities (More People, More Trees). The on-farm re-greening is not due to tree planting, but as mentioned before, it is mainly due to the protection and management of spontaneous natural regeneration by farmers. This increase in on-farm tree densities has created more shade and reduced temperatures by several degrees Celsius. It also created more complex production systems less vulnerable to drought years. The conclusion is that trees constitute an important pillar in the adaptation to climate change in semi-arid areas and it is important to do everything to increase the number of trees in farming systems.

The farmers of the Regions of Zinder and Maradi (Niger) have noticed that 20 years ago the strong winds at the beginning of the rainy season destroyed the crops on their farms so that they had to sow again three or four times before succeeding. There were hardly any trees left on their farms to reduce the strong winds and these were,often moving sand and cutting the crops like a razorblade, or burying the crops under sand. A study in the North of Burkina Faso has shown that the presence of 6 trees/ha already starts to influence the speed of the wind (Leenders, 2006). The development of agroforestry systems with high tree densities (20 to 80 trees/ha or even more) has decreased the speed and force of the wind. Now many farmers proudly declare that they sow only once instead of three or four times twenty years ago. This has increased the length of the growing season.

The trees, but also the shrubs and the permanent grass, do not only break the speed of the wind. They moreover permit the fixation of the sand and also reduce the temperature of the soil by limiting evaporation and water loss. The decrease of the temperature and the protection of crops against winds are well illustrated by the images below.

Photo 14 : The vegetation decreases the temperature and protects crops against the wind and the sand



2. The development of several water harvesting techniques has permitted farmers to harvest even in years of low or erratic rainfall.

In extreme climatic conditions, of course there is no miracle! In the village of Batodi (Tahoua Region Niger) the rainfall in 2004 was between 200 and 250 mm only and despite the water harvesting techniques used at a significant scale in this village, little or nothing was harvested that year.. However, water harvesting techniques had made the water levels in their wells rise by about 14 m between 1994 and 2004. This permitted several farmers as well as a group of women to cultivate vegetables around wells during the dry season of 2004 – 2005.

Photo 15 : Picture taken in November 2004 after an annual rainfall of only about 200 mm

3. Since the beginning of the 1980s, the farmers have made every (a great) effort to improve soil fertility management by increasing the quantity of fertilizers and by improving the quality. Many projects promoted and supported the construction of compost pits. Almost all farmers who invested in soil and water conservation also improved soil fertility management in order to benefit optimally from their investments. The growing number of on-farm trees produce litter which helps increase the organic matter content of the soils.
We have already noticed the importance farmers attach to the regeneration of Faidherbia albida. According to the farmers « one Gao equals a cow in terms of contribution to fertility». It has been shown in Dosso (Niger), that the annual biomass of a Faidherbia albida parkland of 40 to 50 trees/ha restores to the soil 100 kg of nitrogen, 18 kg of calcium, 20 kg of manganese and 2 kg of potassium (Bailliez et al., quoted by Ountêni., 1993).

To adapt to the impacts of climate change, it is imperative to increase the number of trees in the production systems, which is a low-cost and efficient approach to agricultural intensification. It is also important to continue to invest in water harvesting techniques, which will accelerate local groundwater recharge and will always increase the quantity of water available to crops. Fortunately, there are some important achievements in these domains in the Sahel upon which it is possible to build future activities.

11. NRM and rural poverty reduction

A study by Irz et al. (2001), showed that in Africa an increase in agricultural production of 10% decreases rural poverty by 6% to 9%. In Burkina Faso and Niger, increases in cereal yields from 20% to 100% have been reported in areas treated with soil and water conservation techniques. The implication is that rural poverty in villages which have benefited from NRM interventions must have been reduced since the beginning of the investments. The results of the Sahel study in Burkina Faso and Niger confirm that tendency.

In 8 of the 12 villages with NRM interventions studied in Niger, the villagers perceive a reduction in rural poverty. This is the case in only 2 out of 4 control villages without intervention.

It seems useful to present the data of Burkina Faso here. The team of researchers classified farm households according to their level of prosperity. They based their classification on criteria used by the villagers to characterise three levels of prosperity: rich, medium and poor. These criteria are presented in table 3 below.

Tableau 6 : Main common used by villagers for wealth ranking

ZONDOMA/YATENGA		
Rich	Medium	Poor
1. Has got a good agricultural production (surplus) 2. Possesses important livestock (big and small ruminants) 3. Has a good habitat (permanent with metal roof) 4. Possesses a motorcycle or, a bicycle	1. Succeeds in feeding household for 6 to 7 months after the harvest 2. Possesses some small ruminants 3. Habitat with wooden roof (« mako ») 4. Possesses a good bicycle	1. Succeeds in feeding household up to 2 months after the harvest 2. Does not have big or small livestock 3. Habitat with thatched roof 4. Does not have any means of transportation
BAM		
Rich	Medium	Poor
1. Important livestock (big and small ruminants) 2. Surplus harvests 3. Possesses a motorcycle and a bicycle 4. Possesses a permanent habitat with metal roof 5.Has agricultural equipment	1. Possesses some small ruminants 2. Succeeds in feeding household for 12 months 3. Possesses a bicycle 4. Has a house with metal roof 5.Has some equipment (donkey plough)	1. Succeeds in feeding household up to 3months after the harvest 2. Does not have small or big ruminants 3. No means of transportation 4. Habitat in bad state 5. No agricultural equipment

When looking at the classification of households according to levels of wealth in tables 4, 5 and 6, it is striking that the percentages for the study villages in the Yatenga, Zondoma and Bam provinces show considerable variability between the villages.

In the villages with a long history in soil and water conservation and with 50% or more of their cultivated fields treated with soil and water conservation techniques (Ziga in the Yatenga province and Ranawa inZondoma province), the households seem more prosperous than in surrounding villages with a shorter history and less land treated.

The village of Ranawa in the province of Zondama has the longest history in soil and water conservation. The figures for this village show that during the researchers' survey in 2007, 39% of the households were considered as poor. This percentage was 32% in 2001(Reij and Thiombiano, 2003), but it is good to recall that 2007 was a year of bad harvest, which has certainly made a number of households slide into poverty. For the village of Ziga these percentages are respectively 27 % in 2001 and 38.6 % in 2007.

According to a report of the National Institute of Statistics and Demography (INSD) published in 2003, 46.4% of the Burkinabe population lives below the poverty threshold (www.ruralpovertyportal.org). This report indicates that the poorest regions are situated in the Northern part of the country where 68.8% of the population is classified as poor. Although it is the same criteria which are used for the survey of 2001 and 2007, we can try a comparison. It is obvious that the poverty levels in the villages of Ranawa and Ziga in 2003 (32%) were way below the regional average for Northern Burkina Faso (almost 67%).

Tableau 7 : Classification of households according to level of wealth (Zondoma province)

	Ranawa		Solgomnoré		Tangaye		Douré		Salaga		Kiblo	
	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%
Rich	24	14,9	6	13,0	38	18,0	15	9,1	8	17,8	25	8,6
Middle	74	46,0	8	17,4	31	14,7	62	37,6	9	20,0	26	8,9
Poor	63	39,1	32	69,6	142	67,3	88	53,3	28	62,2	241	82,5
Total	161	100	46	100	211	100	165	100	45	100	292	100

Tableau 8 : Classification of households according to level of wealth (Yatenga province)

	Ziga		Kirê		Fili		Wagandé		Bilalga		Sonh	
	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%
Rich	33	19,3	3	8,1	4	6,8	17	21,0	5	7	7,5	7
Middle	72	42,1	16	43,2	6	10,2	30	37,0	2	27	29,0	27
Poor	66	38,6	18	48,6	49	83,1	34	42,0	127	59	63,4	59
Total	171	100	37	100	59	100	81	100	134	93	100	93

Tableau 9 : Classification of households according to level of wealth (Bam province)

	Rissiam		Boalin		Sankondé		Gonsé		Noh		Tensobodogo		Loungo		Safi	
	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%
Rich	10	11,6	2	1,5	5	14,7	4	23,5	26	22,4	4	16,7	17	22,1	16	44,4
Middle	34	39,5	78	60,0	16	47,1	6	35,3	28	24,1	9	37,5	30	39,0	14	38,9
Poor	42	48,8	50	38	13	38,2	7	41,2	62	53,45	11	45,8	30	39,0	6	16,7
Total	86	100	130	100	34	100	17	100	116	100	24	100,0	77	100	36	100

Poverty seems to be more prevalent in some study villages in the Yatenga and Zondoma provinces than in Bam province. The percentage of poor households varies from 42% to83% in the first two provinces and from 38% to 48% in the latter province. A partial explanation may be that Bam province not only has a long history of interventions in soil and water conservation, but it also has relatively more fertile soils (valley bottoms) than the other two provinces. An indicator of better soils is that cotton cultivation never disappeared in Bam province, whereas it did in the other two.

Relatively high rural poverty levels in the study villages of Rissiam (48.8) and Noh (53.5%) in Bam province may be related to the presence of Fulani herders, who are more numerous than in other villages. The profile of poverty made by the earlier mentioned report of INSD (2003) shows that farmers and agro-pastoralists in the Sahel region of Burkina Faso, who practise subsistence farming and livestock breeding, experience living conditions which are precarious in terms of income, opportunity and capacity.

One aspect not taken into account in data on rural poverty is the distinction between the poor with development perspectives (young families) and the poor without any perspective. The last case concerns especially the old women who work for themselves. In some villages this latter category is important and influences overall poverty data.

A partial conclusion

The development of agroforestry systems and the rehabilitation of strongly degraded land using water harvesting techniques constitute forms of natural resource recapitalisation (asset building). The scale of this recapitalisation is considerable in the Sahel and external interventions have significantly contributed to it. The level of wealth in villages which have benefited from NRM investments shows that the fight against rural poverty in the Sahel is for a large part determined by better management of existing natural resources. Sustainably increasing agricultural production is an important key to rural poverty alleviation.

12. NRM and institutional and socio-economic dynamics

Three topics will be addressed in this chapter: 1. the impacts of NRM on the demographic dynamics; 2. the impacts of NRM on conflicts between herders and farmers and 3. NRM and local institution building.

Impacts on the demographic dynamics

Two important observations were made. The first is that investments in NRM have an effect on migratory flows. They reduce permanent departures from families as well as temporary labour migration because young men have more opportunities of earning some income, for instance through small-scale irrigation, trade in firewood and non-timber produce.

This appears to have influenced the demographic dynamics in villages. A study carried out in 2002 in 12 villages on the northern part of the Central Plateau (Burkina Faso) showed (with only one exception) population growth rates higher in villages with soil and water conservation than in villages without (Reij and Thiombiano, 2003). The demographic dynamics of the village of Ranawa can be used to illustrate this. According to the national census of 1985, its population had decreased by 25% between 1975 and 1985. Because of recurrent drought, hunger and low yields families decided to leave the village and settle in Southwest Burkina Faso or in Ivory Coast. However, since the beginning of land rehabilitation in 1984/85, not a single family has left the village any more. According to the 1996 census, its population more than doubled between 1985 and 1996.

The second observation is that population growth has led to land saturation in regions with high population densities. In Niger's Zinder Region villagers remarked that they have considerably increased their agricultural production since 1984, but the gains in production have been diluted because they have « many more mouths to feed ». The villagers are aware of the issue, but do not to know what to do. Some families leave the village and move northwards to more drought-prone areas with lower population densities (for instance, around Dakoro in the Maradi region).

The impact of NRM on conflicts between herders and farmers

In the Sahel, conflicts between farmers and herders are triggered by competition over access to natural resources (for instance access to surface water and to wells, encroachment of agriculture upon grazing land, damage caused by livestock to crops and trees) The large-scale degradation of natural resources in the 1970s and the 1980s aggravated those conflicts. The Sahel study in Niger noticed a strong decrease in the number of conflicts in villages which had invested in NRM. In some areas the quantity of biomass has strongly increased, which means that more fodder is available to livestock. Where water harvesting techniques have led to local recharge of groundwater, more water is available for use by human and livestock populations. To put it simply: in some regions the "resource cake" has grown, which means that there is more to share. Certainly, conflicts have not disappeared and may be more frequent in drought years, but they have become less numerous (Baoua, 2006).

NRM and local institutions

In the 4 countries studied, the investments in NRM were accompanied by local institution building. Everywhere, there was either revitalization of traditional organisations or the creation of new types of village organisations. For instance, in the Bankass area (Mali), the Barahogon, a traditional institution of natural resource management, was revitalized. In 1994, the decentralisation policy and the new forest legislation created new opportunities for the population to involve themselves actively in the management of natural resources. In this case, an NGO supported the revitalization of the Barahogon. In Niger's Aguié department a project funded by a multilateral organisation supported the creation of new village as well as inter-village institutions to manage on-farm trees.

Everywhere, groups were created and put in charge of implementing and managing soil and water conservation activities, management of on-farm trees or remaining natural forests, management of pumps and boreholes, schools and primary health care centres.

The conclusion can be drawn that the organisational and technical capacities have been strengthened of hundreds of thousands of villagers across the Sahel. This process began in the early 1980s and investments in NRM have contributed to it.

13. Which impacts on women?

The public and private investments in NRM have got positive impacts on rural women's living conditions. A few examples below will illustrate this observation.

Photo 16 : The time required for the collection of firewood has decreased in areas with higher on-farm tree densities

As mentioned before, villages where water harvesting techniques were used to rehabilitate degraded land, have experienced a considerable increase in water levels in wells. This increase was often 5 meters or more. It is obvious that women benefitted, because the time required to fetch water got considerably shorter. Time saving has often permitted women to develop other income generating activities (petty trade).

Women have often played a key role in the construction of soil and water conservation infrastructure. This aggravated their workload. They invested their time and energy, but they are primary beneficiaries of these NRM investments. Sometimes women benefitted directly through the provision of food-for-work or temporary access to rehabilitated land, and sometimes they benefitted indirectly, through an increase in cereal production and in biomass). On other occasions women benefitted, because their plots were included in the fields treated with conservation techniques. Agricultural production of women's fields is important, because they are responsible for feeding the children for a part of the year.

Both farmer-managed natural regeneration and soil and water conservation have increased the availability of leaves and fruits which improves diets and can be marketed by women. How much it increases their income does not only depend on quantities, but also on their proximity to urban centres. Furthermore, there are indications that women in parts of Niger own about 80% of small ruminants (Baoua, 2006). It is impossible to compare this percentage with earlier years, but those interviewed are unanimous in claiming that the number of animals held by women has increased.

The ecological change brought about by development projects has improved women's access to natural resources, however, it has not influenced the social control they can exert on these resources. They still have the right to use the natural resources. With regard to access to land, women's marginalisation due to demographic pressure has slightly disappeared in areas where land rehabilitation has led to a considerable expansion of cultivated land..

The NRM activities have led to a significant improvement of women's participation in development actions while giving them the opportunity to (also) participate in decision-making structures. This is a considerable change in a traditional setting in which women do not always have right of speech.

Economic activities allow women to invest in livestock, to finance or pre-finance young people's migration, but rarely to invest in land. The income generating activities first serve to assure food security. This increases household food security by several months. Usually, women are not allowed to sell themselves the livestock they own as they do not have the right to go to the livestock market.

The economic evolution brought about by development programs and projects is very important. The situation today would have been a catastrophic fall in/the living conditions of households, if the projects had never intervened. This is the perception of many villagers interviewed by the different Sahel study research teams. The projects have improved and stabilized the livelihoods of rural households (Diarra, 2006).

The conclusion is justified that environmental rehabilitation in the Sahel has had positive impacts on agriculture, livestock and agroforestry. All three activities are increasingly integrated and by doing so more productive farming systems have been developed by farmers. This has improved livelihood and women have benefitted from it. Rural poverty has decreased in villages which have invested in NRM. The role of women has evolved and their capacity has been strengthened in those cases where they benefitted from training. However, this evolution has not fundamentally changed gender relations. The social norms protecting and guaranteeing this order are not influenced by development actions. These norms will continue to preserve the status quo as long as actions specifically oriented towards promoting equity in access to and control of natural resources, including land, will not be undertaken (Diarra, 2006).

14. Is it economically cost-effective to invest in NRM?

An under estimation of the impact of investments in the NRM

Our work hypothesis is that we systematically underestimate the impact of investments in NRM. Impact studies carried out have very often been reductionist, focussing only on one or two direct impacts./ Impact/ studies of NRM interventions have seldom expressed indirect impacts (or externalities) in monetary terms. For example, impact evaluations of stone bunds, zaï, and half moons often focus on the impacts of these techniques on cereal yields, but rarely take into account other types of impacts such as:

- groundwater recharge, which decreases the time women spend on supplying their families with water and which sometimes allows men and women to practise small market gardening around wells;
- the accelerated growth of trees and an increase in a growth of the production of fruit and other tree products;
- goods and services such as nitrogen fixation and carbon sequestration.

The economic evaluation of natural regeneration is often limited to the value of firewood production However, it ignores the value of fodder, pharmacopoeia, time saved for planting crops and seeds saved because farmers plant crops only once instead of three or four times.

Consequences of underestimating the impacts of NRM investments

One of the consequences of underestimating the impacts of investments in NRM is the general belief that investments in agriculture in the 1980s and the 1990s had little or no positive impact. It is therefore not surprising that governments and financial partners diminished their investments in this sector in favour of investments in education and health. In most national poverty reduction strategies, agriculture and environment hardly played a role and agriculture barely gets 5% of the national budgets, besides, not much more is offered from donor budgets. Investments in agriculture plummeted in the 1990s. They are increasing again, but due to the economic and the food crisis, more than one billion people are suffering from starvation each day.

The economic and financial cost effectiveness of NRM investments

The Sahel study in the four countries has attempted to analyse the economic and financial cost effectiveness of some NRM technologies. The indications are that internal rates of return to investments are high. Table 7 presents some data for different NRM techniques used in Niger.

The internal rates of return of investments in NRM techniques vary from 31¨% to 82%. For zaï two cases have been distinguished. In the first case the farmer restores degraded land which he already owns and in the second case he buys a plot of degraded land to rehabilitate it. This increases his investments and decreases the internal rate of return from 82% to 39%. Nevertheless, even the investment in the purchase of degraded land is quickly earned back and an internal rate of return of 39% is highly satisfactory.

Tableau 10 : Net Present Value and Internal Rate of Return of some NRM techniques

Work	Planning horizon (years)	Net Present Value (FCFA)			Internal rate of return (%)
		10%	25%	50%	
Zaï or Tassa 1	6	124 000	69 600	25 600	82
Zaï or Tassa 2	6	84 000	29 600	-14 400	39
Agricultural half moons	5	77 800	26 100	-18 500	37
Protection of natural regeneration	20	83 800	8 400	-12 700	31
Tree plantation	20	17 200	-36 900	-53 200	13 [9]

Source: Abdoulaye and Ibro (2006)

The internal rate of return of the protection of natural regeneration is 31%. The initial investment is limited to the time required to protect young trees against livestock and to prune them. This is estimated to be 24 person days/ha at an average cost of CFA 1000/day, which means an initial investment of CFA 24000 only. The calculation of benefits is more complex. This calculation is based on an estimation of wood production over a period of 20 years and an increase in millet yields and crop residues of 5% during the first 4 years. Other benefits like the fodder value of leaves and pods and impact on soil fertility (fixation of nitrogen by some species and restitution of organic matter to soils) have not been included in the calculation.

The internal rate of return for tree planting is 13%. Its Present Net Value, which is CFA 17,200 FCFA (at a discount rate of 10 %) becomes negative at a discount rate of 25%. This is due to the length of the planning horizon and to the choice of species whose benefits are just limited to the value of wood. The plantation can also have other benefits not valued here, such as shade and fodder from trees (depending on species).

On the Central Plateau of Burkina Faso, the economic impacts soil and water conservation investments are also highly variable as shown by the internal rates of return (IRR), which as table 8 shows, vary from 27% for stone bunds only to 145% for half moons.

Tableau 11 : Cereal yield and internal rate of return of different soil and water conservation techniques

SWC technique	Internal rate of return
Stone bunds only	27%
Stone bunds + zaï	à 95%
Half moons	145%
Zaï	93%
Farmer-managed natural regeneration	24%

Source: Etude Sahel Burkina Faso (2008)

The impacts of the coastal dune fixation in Senegal

Before the fixation of the coastal dunes, the "Niayes", were a hostile environment for developing economic activities. The sand dunes threatened the valleys in which small irrigated gardens allowed the production of vegetables for urban markets, in particular for Dakar. Only 20% of the area was used for agriculture. As described in chapter 3, sand dunes were fixed by planting filao (Casuarina equisetifolia). This helped remove the threat of sand dune encroachment and it even allowed the population to expand irrigated areas. The average income per household and per market gardening campaign varies from one area to another. The average per household varies from CFA 270,000 to CFA 500,000. In addition to this, the sale of filao wood generated a net income to village organisations ranging in 2004 from CFA 600,000 to CFA 10,000,000.

The annual incomes from the sale of filao on the carbon market are estimated to be $ 1,225,000 (URCE price: Certified Unit of Emission Reduction) for $ 10 per ton of CO2.

[9] Ce taux de rentabilité interne est basé sur un taux de survie de 100 % des arbres plantés. Il est important de noter ici que le taux de survie des arbres plantés au Niger se situe autour de 20% seulement.

15. The sustainability of impacts

It is necessary to explore the issue of the sustainability of impacts of investments in NRM.

Farmer Managed Natural Regeneration (FMNR)

FMNR started in Niger around 1985, this led to an increase in on-farm trees on about 5 million hectares. Is it possible that this large-scale transformation will be destroyed, for instance if a succession of drought years occurs, or because of a doubling of the population in the next 20 years, or because farmers change behaviour? It is obvious that a sequence of back-to-back drought years will cause damage, at least temporarily, and reduce the stock of trees. Indeed, in 2005 many farmers, and especially the poor ones, had to cut trees to survive, but it did not have a visible impact on the total stock of trees. The rampant demographic growth may however present a threat and it is not possible to predict exactly what will happen in areas with already a high population density. In general increasing demographic pressure induces agricultural intensification and increasing the number of on-farm trees is a low-cost and efficient way to intensify agriculture. The question remains if there is a maximum level of population density, which if reached, will lead to a decline in tree densities? Considering the age of trees in the agroforestry parklands, for instance, in Southern Niger and around Bankass (Mali), it is obvious that if farmers continue to protect and manage trees, these regions will be a lot greener in 10 to 20 years.

Would it be possible for farmers who now protect and manage natural regeneration and develop agroforestry systems, to change their attitudes and suddenly adopt a destructive behaviour? This is unlikely to happen, because farmers clearly perceive the multiple benefits of growing on-farm trees.

The re-greening of some densely populated parts of Niger and other countries of the Sahel has not reached its limits yet. National policies and forest legislation which encourage farmers to invest in trees could reinforce the process of re-greening.

Simple water harvesting techniques

Farmers in Burkina Faso (Central Plateau), Niger (Tahoua) and Mali (between Djenné and Sévaré) started using zaï, half moons and stone bunds in the 1980s.The field visits during the Sahel study showed that farmers continue to maintain their investments and even to expand them in some cases. The expansion of the area under stone bunds by farmers, is often difficult as stones are not always or no longer available at a short distance from their fields. The construction of contour stone bunds on one hectare requires about 40 tons of stone. The transport of large quantities of stone often requires external support. The expansion of the area under zaï or half moons, depends on the availability of labour at household level, but also on farmers' motivation. Digging zaï on one hectare requires a labour investment of up to 300 hours /hectare (Barro et al, 2005).

Collective and individual land rehabilitation

Considerable efforts have been made to rehabilitate degraded plateaus in the Tahoua region of Niger. This helped to restore the productive capacity of the land. Many plateaus were rehabilitated collectively, using machinery and food-for-work. Although there were impressive results, the sustainability cannot always be guaranteed, because in several areas land tenure conflicts emerged. After the rehabilitation of degraded land and their distribution to families who had participated in the effort, others claimed their right to the land. In other cases, herders had grazing rights to the land that was rehabilitated.

In general, land tenure conflicts do not emerge on land which is rehabilitated by individual farmers as they only rehabilitate land on which they have a permanent right. As individual farmers reap the benefits of their investments, they maintain stone bunds and re-dig zaï or half moons if necessary.

16. General conclusion and recommendations

The general perception of the Sahel is that this region is in a permanent crisis: its natural resources continue to degrade, drought and famine regularly hit the region, if it is not drought, it is floods, and poverty is increasing. Of course, there are regions in the Sahel where the situation is now worse than 20 years ago, but as this study shows without ambiguity, positive trends can be observed in several regions of the Sahel. These positive trends have often flown under the radar, they have not been observed,they even show a considerable capacity of farmers to adapt to changing environmental, socioeconomic and market conditions. This chapter will present some conclusions of the Sahel study and will draw some lessons for African initiatives like the "Alliance for a Green Revolution in Africa" (AGRA) and for the "Great Green Wall for the Sahara and the Sahel."

Several conclusions

In many regions of the Sahel, farmers have developed more intensive production systems. This process began in the 1980s and sometimes later. Farmers reacted to the ecological crisis, but also to demographic changes (urbanisation, population growth) and to changes in the market (reduction of transport costs due to road construction, and also the demand exerted by urban centres for certain crops). It is remarkable that these transformations have not always been noticed. For example, the scale of agroforestry development in Niger (5 million of hectares) escaped attention.

Water harvesting techniques and the rehabilitation of degraded land

The development of water harvesting techniques (especially zaï, contour stone bunds and half moons) at the beginning of the 1980s, enabled farmers to succesfully rehabilitate strongly degraded land. The increase of public and private investments in land rehabilitation has transformed regions like the Yatenga in Burkina Faso and the plateaus of the Ader Doutchi Maggia in the region of Tahoua in Niger. Both regions were strongly degraded in the early 1980s. However, the rehabilitation of tens of thousands of hectares of degraded land (= recapitalisation of land) in each region has produced numerous impacts: expansion of cultivated land, improvement of food security, local recharge of groundwater, expansion irrigation, reduction of vulnerability to drought, etc.

The development of agroforestry systems constitutes an important pillar in a process of intensification

In many regions of the Sahel, farmers have invested on a small and on a large scale in the development of agroforestry systems. This mainly happened in regions with a high population density ("more people, more trees") and with sandy soils. In parts of Niger, 15 to 20 times more trees were found on farmland in 2005 than in 1975. These trees were not planted but are the result of the protection and the management of the spontaneous regeneration by the farmers. The latter acknowledge without ambiguity the numerous impacts of re-greening: "trees are for us like millet", "trees serve as windbreak", "without trees our animal wouldn't have anything to eat"... Trees are part of the production system and have allowed a strong integration of agriculture, breeding and forestry. The development of agroforestry systems is a clear example of asset building. The number of new trees in Niger is estimated to be in the order of 200 million (Reij, Tappan and Smale). If each tree produces an annual production value (firewood, fodder, soil fertility, etc.) of only one euro per tree, then the total annual production value will be in the order of 200 million euros or 130 billion CFA .

Adaptation to climatic changes

Farmers in the Sahel have a long experience with adaptation to climate change. The major droughts of the 1970s and 1980s, forced farmers to adapt to low and irregular rainfall (water harvesting techniques and small-scale irrigation), to fight dust winds and temperature increase (agroforestry systems and windbreaks). In the debates about adaptation to climate change in the Sahel, it is important not to" re-invent the wheel" and to build on the existing rich experience and the many achievements.

Fight against rural poverty

In villages which have invested in NRM, the majority of villagers perceive a reduction of poverty. This is not surprising as a 10% increase in agricultural production in Africa leads to a reduction in rural poverty of 6% to 9% (Irz, et al. 2001)

Economic cost-effectiveness of investments

The impacts of investments in NRM are often underestimated, since impact evaluations do not take into account the multiple indirect impacts of these investments. For instance, investments in soil and water conservation do not only lead to an increase in agricultural yields, but can contribute locally to groundwater recharge, which reduces the necessary time for water collection and sometimes allows the development of vegetable gardening. As long as these indirect impacts such as the rise of the level of water in wells are not expressed in monetary terms, it is obvious that the impacts of such investments will continue to be underestimated.

The internal rates of return of NRM techniques are high, despite the fact that indirect impacts are usually not included in the stream of benefits. For most techniques the internal rate of return is higher than 30%, which shows that these investments are economically attractive.

Institutional and socioeconomic dynamics

Investments in NRM were often accompanied by the development of social capital in villages. Many villagers acquired new knowledge (planning, organisation, management) and new technical capacities (for example composting, management of trees, determination of contour lines).

Women have benefited from investments in NRM. In areas where on-farm tree densities have increased, they no longer have to walk far to collect firewood. In villages where groundwater levels have improved, women do not have to wait many hours anymore at wells and other water points. Moreover, the increase in agricultural production and reduced vulnerability to drought shelters them a little more from food insecurity.

Demographic dynamics

There has been a demographic explosion in the Sahel. Since 1960 its population has multiplied by almost 5. The population in the Sahel doubles on average every 20 years. For example, Niger had 3.2 million inhabitants in 1960 but will have about 15 million inhabitants in 2010. This makes it very difficult for governments and their partners to reduce poverty and improve livelihoods

On the other hand, an increasing population pressure on natural resources has induced a beginning of intensification of production systems ("more people more trees"). Although the process of intensification has in most places not reached its ceiling, there are limits. In regions with a high population density (for example in Maradi and Zinder in Niger) a class of landless or almost landless farmers is emerging.

Investments in NRM have changed the demographic dynamics in the villages concerned. Fewer young people are leaving their villages and even the number of families abandoning their villages has dropped.

A few lessons for the implementation of some African initiatives

Alliance for a Green Revolution in Africa (AGRA)

The Alliance for a Green revolution in Africa intends to accelerate agricultural development in Africa to break the cycles of hunger and poverty, and improve the life of hundreds of millions of small farmers. To reach this goal, the Alliance wants to promote a package including an increased use of chemical fertilisers, improved seed varieties, expansion of irrigation, improved access to markets and improved storage to reduce post-harvest losses.

All these measures are important and it is obvious that improving soil fertility is the key to increasing agricultural yields significantly. However, the use of chemical fertilizers in the Sahel should be preceded or accompanied by improved soil management or by soil and water conservation in order to make the use of fertilizers rational. It is doubtful whether agriculture in the Sahel on soils which are fully exposed to the scorching sun and strong winds, can be sustainable. The implication is that a large-scale initiative is required to develop tree-based farming systems, which, as experience shows, will produce multiple benefits to farmers. Trees are like Green factories; some species fix nitrogen from the air on their roots and produce fodder, others produce firewood or construction wood, medicinal products, or fruits and leaves, which improve nutrition. Besides this, trees also constitute the backbone in efforts to adapt and to mitigate climate change. Promoting farmer-managed natural regeneration is a low-cost and efficient approach to agricultural intensification, which produces win-win situations.

The Great Green Wall

The original idea was planting a 7000 km long tree barrier across the Sahel and Sahara, from Dakar to Djibouti, to stop desertification. Although tree planting remains an important component, the current thinking seems to focus on the development of a wide range of natural resource management activities. One of the lessons that can be drawn from the Sahel study is the fact that farmers in the Sahel invest in trees when they have clear rights to their on-farm trees. Since 1985 farmers in Niger's Maradi and Zinder regions have already created their version of a Great Green Wall at low investment cost, without any recurrent costs for government and its financial partners. By recognising in forestry legislation an exclusive right of the farmers to their on-farm trees, governments will encourage millions of farmers to invest in trees.

Another lesson drawn from the experience of Niger and Mali is that in terms of costs and benefits, it is often more rational to protect and manage spontaneous natural regeneration than to plant trees. There are of course conditions in which tree planting is preferable, but it must be recognised that the number of trees surviving after 2 or 3 years is often very low. When facing problems of desertification and environmental degradation, the standard reaction of governments and development partners (NGOs, bi-and multilateral agencies) is "let's plant trees". The Sahel study shows that this reaction is not necessarily the best and other alternatives such as protecting and managing natural regeneration produce better results, more quickly and at lower costs.

Some final recommendations

Continue and increase investments in NRM to reduce rural poverty and reduce vulnerability to drought years

Despite the numerous successes recorded, the agro-ecological and socioeconomic situation in the Sahel remains precarious for a significant part of the rural population. There is still much work to be done, but what should encourage all partners is that much has already been achieved and it is possible to build on existing successes. The years of drought, but also the food crisis of 2007 and 2008, show the necessity of increasing investments in NRM to sustainably increase yields, reduce vulnerability to drought, to reduce rural poverty and to adapt to climate changes.

Develop and intensify agro forestry systems to adapt to increasing climate variability

During years of drought and food shortages, poor families depend on trees for their survival. No trees, no life. A better integration of trees, crops and livestock will allow the intensification of production systems and will help farmers and herders to adapt to increasing climate variability.. In many regions of the Sahel, this process is already ongoing, however, there are possibilities to /more quickly/ expand the scale of this process more quickly by developing participatory approaches to extension and by systematically using mass media (like rural radio) to inform land users.

Change the demographic dynamics

A moderate population growth rate is likely to stimulate development, but the current demographic growth rates are very high and make it very difficult, if not impossible, for governments to reduce poverty and to provide a significant part of the population with access to education and health. Niger has the highest demographic growth rate in the world. Even if it were possible to increase food production sufficiently to keep pace with demographic growth, it would still be very difficult to create developing perspectives for the large number of young people in the Sahel.

Not through agriculture alone: develop other sectors of the economy

The agricultural sector constitutes an important engine for economic growth and a better management of natural resources will allow an increase in production. However, it is obvious that agriculture on its own cannot meet the demand for work and income of millions of young people in the Sahel who are added each year to the labour force. It is therefore vital to develop other sectors of the economy. This could, for instance, be achieved by a reduction to a minimum of barriers to the creation of small-scale enterprises and by the reduction of obstacles to trade within each country and between countries. This will help reduce transaction costs and lower consumer prices.

Final remarks

Does not this study paint a too positive picture of the impacts of investments in agriculture and environment in the Sahel and of the dynamics in production systems?

Our answer to this question is as follows: it is obvious that the Sahel is still facing many economic and environmental problems, but the picture painted in this report is not too positive. Our view is that the transformation that has occurred since the 1980s continues to be underestimated. One reason is that it remains difficult to adequately express impacts of NRM investments in monetary terms, another reason is the fact that we continue to underestimate the capacity of farmers and herders to adapt to changes as well as their capacity to innovate. There are many small-scale and even large-scale development successes in the Sahel, but these are often ignored or overlooked.. If this report helps to create a more balanced view of the Sahel, then it has served its purpose. The prevailing sense of doom and gloom does not do justice to its people, who have shown enormous resilience in adverse conditions.

Is it possible that a report with positive news about the Sahel will tempt financial partners to reduce their financial support?

First of all, it is important that people in the Sahel should be aware and proud of the successes they have achieved under adverse agro-ecological and socioeconomic conditions. We are convinced that the successes obtained are important assets. Despite these achievements there is still a long way to go: "if we cross a river by swimming and we get to the middle, it is important not to stop but to keep swimming". It is urgent to increase public and private investments in the Sahel to improve livelihoods, to improve household food security and to adapt to climate change. The discourse must change from one emphasizing doom and gloom: so help us...to one emphasizing the current achievements. There are many successes upon which it is possible to build...let us all work together to increase their scale.



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