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Changing land management practices and vegetation on the Central Plateau of Burkina Faso (1968–2002)

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Abstract

In the early 1980s, the situation on the northern part of the Central Plateau of Burkina Faso was characterized by expanding cultivation on lands marginal to agriculture, declining rainfall, low and declining cereal yields, disappearing and impoverishing vegetation, falling ground-water levels and strong outmigration. This crisis situation provoked two reactions. Farmers, as well as technicians working for non-governmental organizations, started to experiment in improving soil and water conservation (SWC) techniques. When these experiments proved successful, donor agencies rapidly designed SWC projects based on simple, effective techniques acceptable to farmers. A study looked at the impact of SWC investments in nine villages and identified a number of major impacts, including: significant increases in millet and sorghum yields since the mid-1980s, cultivated fields treated with SWC techniques have more trees than 10–15 years ago, but the vegetation on most of the non-cultivated areas continues to degrade, greater availability of forage for livestock, increased investment in livestock by men and women and a beginning change in livestock management from extensive to semi-intensive methods, improved soil fertility management by farmers, locally rising ground-water tables, a decrease in outmigration and a significant reduction in

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rural poverty. Finally, data are presented on the evolution of land use in three villages between 1968 and 2002.

Keywords: Soil and water conservation; Environmental degradation; Land rehabilitation; Land use change; Burkina Faso; Poverty reduction

1. Introduction

In the early 1970s Burkina Faso and other countries in the West African Sahel were struck by a series of drought years, which had devastating consequences for the entire region. Monimart (1989) analysed the consequences of drought and desertification for women in the Sahel in terms of the additional labor required for fetching water and firewood, and the social disruption caused by the massive departure of their husbands in search of income. The drought years compelled many farm families to leave their villages and to settle in regions of higher rainfall elsewhere in Burkina Faso (McMillan et al., 1990) or in coastal countries, particularly the Ivory Coast. Others were attracted to urban centers. Faced with this situation, governments, donor agencies, non-governmental organizations, and the villagers took initiatives to fight against drought and environmental degradation to improve rural living conditions (Rochette, 1989).

Several major soil and water conservation (SWC) projects were initiated in 1980s.[1] Their major objective was rehabilitation of the productive capacity of the land through better control of rainfall and runoff, as well as through improved soil fertility management and reforestation. These types of projects have been implemented during the last 20 years in the northern part of the Central Plateau, which is considered one of the regions most affected by drought. This region is also characterized by high population densities, which can reach 100 people/km^2. Fig. 1 shows the location of the Central Plateau in Burkina as well as the 12 study villages.

Despite all the investments in SWC, the general consensus among researchers and policy makers is that the environment on the Central Plateau continues to degrade. For example, the National Action Plan to Combat Desertification (CONAGESE, 1999), indicates that the current situation is characterized by:

- continuing deterioration of climatic conditions: decreasing rainfall and endemic drought;
- the degradation of natural resources, which is evidenced by the destruction of vegetation cover, depletion of soil fertility and intense erosion (CONAGESE, 1999, p. 12).

[1]They include the OXFAM funded Agoforestry project (PAF), which introduced contour stone bunds in the Yatenga region in the early 1980s; the Dutch-funded PEDI project in the Sanmatenga region, which became operational in 1982; the IFAD-funded soil and water conservation and agroforestry project in the Sanmatenga, Bam and Yatenga regions and the German-funded PATECORE project in the Bam region.

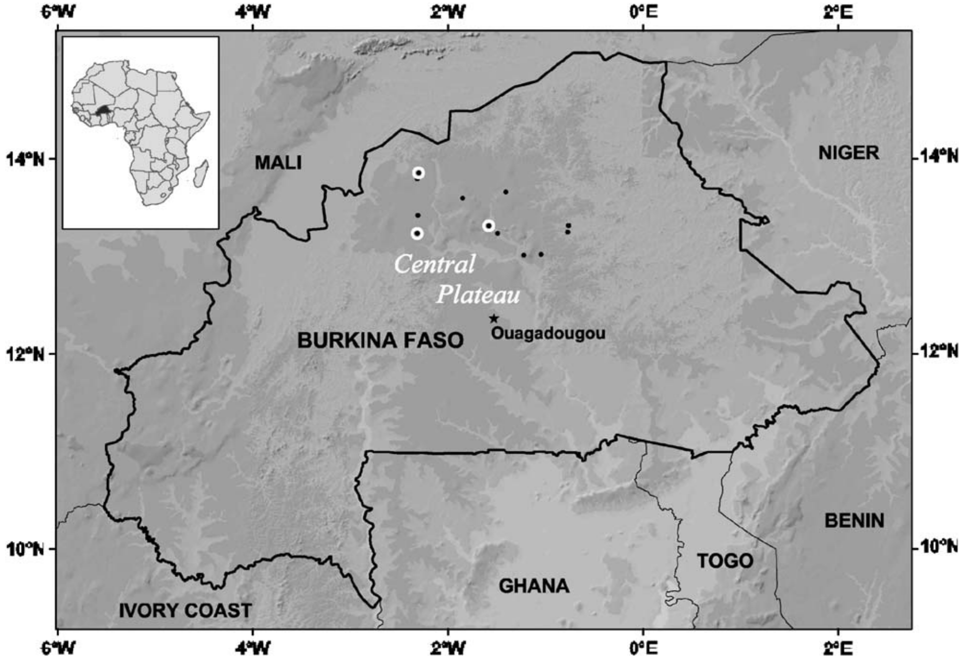

Fig. 1.

In early 2001, an impact assessment indicated that investments in SWC, agroforestry and agricultural intensification on the northern part of the Central Plateau resulted in significant improvements. These included increased cereal yields, improved household food security, more trees on fields treated with SWC and increased availability of water at village level (Reij et al., 2001). These findings contradicted the gloomy picture presented in the National Action Plan to Combat Desertification (CONAGESE, 1999).

The disparity between the pessimistic view of the current situation on the Central Plateau and field observations led to a study on the long-term trends in agriculture and environment on the northern part of the Central Plateau between 1968 and 2002. This study was undertaken in 2002 (Reij and Thiombiano, 2003).

2. Study methods

Considering the findings of the rapid impact assessment of SWC, agroforestry and agricultural intensification (Reij et al., 2001), we assumed that investments in SWC were driving changes in agriculture and environment. On the northern part of the Central Plateau, SWC projects have intervened in hundreds of villages. Twelve villages were selected for the study, nine with significant project investments in SWC and three without such investments. Of the nine villages with investments in SWC, several began adopting SWC practices around 1985 while others started about 10 years later. Those with a long history in SWC had 25–50 percent of all cultivated area treated with one or more techniques, usually contour stone bunds, improved traditional planting pits or rock dams for gully rehabilitation. Two of the three control villages without project investments in SWC are located adjacent to study villages with such investments.

The first step was to carry out a participatory rural appraisal (PRA) study in every village to quickly identify trends perceived by villagers (Ouedraogo and Reij, 2003). One of the tasks was to stratify the households into wealth categories: rich, average, and poor. On the basis of the PRA exercise, 249 farm households were selected and data were collected using questionnaires. Furthermore, available agricultural statistics and population census data were analysed. Parallel to this, a vegetation transect was made in every village and a remote sensing team analysed time-series imagery, including high-resolution Corona satellite photographs made in 1968, aerial photographs taken in the period from 1981 to 1984, and aerial photographs taken for this study in June 2002. These visual data made it possible to document and map changes in vegetation, land use, and the spread of SWC. In addition, a vegetation transect was undertaken in each of the 12 sites. A broader survey carried out in 59 villages identified local perspectives on the availability of water before and after SWC activities had been initiated (Reij and Thiombiano, 2003).

The emphasis in this article will be on changes in land use and vegetation between 1968 and 2002.[2] To put the current situation into perspective, agricultural and environmental conditions on the northern part of the Central Plateau will be briefly presented.

3. Conditions on the northern part of the Central Plateau around 1980

In the early 1980s, the situation on the northern part of the Central Plateau was one of crisis and despair. The following trends could be observed:

3.1. Expanding cultivation onto lands marginal for agriculture

A strong expansion of cultivation onto lands not suited for agriculture contributed to a rapid destruction of vegetation and accelerated erosion processes (Reij, 1983). To quote the French geographer, Jean-Yves Marchal (1977), who studied the

[2]A more detailed analysis of agricultural change will be the subject of another article. Here we will just mention some general trends in agriculture and environment to create a context for a more detailed analysis of changes in land use and vegetation in two villages with SWC and in one without. Nor does this article present a comparative analysis of land use change in Burkina Faso based, e.g. on work by Mazzucato and Niemeijer (2000) and by Reenberg and Lund (1998) in eastern Burkina Faso, by Reenberg et al. (1998) or by Rasmussen et al. (2001) in northern Burkina Faso. This will also be the subject of a separate article.

Yatenga region in detail, "in the Yatenga the last remaining major forests were cut about 30 years ago and what is left is nothing more than bushes on stony hillocks, which are used as forage by herds of goats and sheep as well as by people for firewood purposes. Everywhere else the land is cultivated and 50–75 percent of the cultivated land is prone to erosion."

3.2. Declining rainfall and growing food deficits

During the 1960s, average rainfall in the study region was around 700 mm, but, due to recurrent drought years, average rainfall declined in the 1970s, and particularly in the 1980s, to about 550 mm. Average rainfall for the 1982–1985 period was only 381 mm (Dugue, 1989). The years of recurrent drought provoked structural food shortages and hunger. In the early 1980s, 14 out of 18 households studied by Broekhuyse (1983) in the village of Oualaga (Sanmatenga province) had a food deficit of more than 50 percent.

3.3. Low and declining cereal yields

A study by the International Crops Research Institute for the Semi-Arid Tropics (quoted by Brons et al., 2000), carried out between 1981 and 1985 (a period of low rainfall), indicated yields of sorghum (*Sorghum bicolor*) and millet (*Panicum* sp.), which averaged 293 and 232 kg/ha, respectively. Normally yields of these grains would be in the range of 400–600 kg/ha. These low and declining cereal yields explain why the majority of farm households had structural food deficits.

3.4. Disappearing and impoverishing vegetation

In and immediately around villages, agricultural parklands composed of useful tree species, including *Faidherbia albida*, were still maintained, but little or no natural regeneration could be observed. Expansion of cultivated land and pressure from firewood collection resulted in much reduction of adjacent bushland (Winterbottom, 1980). The impoverishing vegetation increased the burden of women, whose responsibility it is to collect firewood to cover household energy needs.

3.5. Falling ground-water levels

In 1980, villagers and well diggers agreed that ground-water levels were falling rapidly. According to a 1981 evaluation report of a World Bank-funded wells and boreholes programme (Dutour, 1981), 87 percent of 450 modern wells dug during the 1977–1980 period had water during the dry season in the year of construction. By 1984, this number had dropped to 39 percent. In 1980, all wells in the village of Rissiam fell dry by the end of the rainy season and women had to walk about 8 km to fetch water. Some could not cope with this burden and left their families.

3.6. Out migration

Because many farm families could no longer cope with drought and hunger, they moved to areas in the south of Burkina Faso, which were free of river blindness, or to the Ivory Coast. The total population of the 12 study villages remained stable between 1975 and 1985, but the population of 5 of the 12 villages decreased (Reij and Thiombiano, 2003).

3.7. Conclusion

The situation in the period from 1970 to 1985 was extremely difficult for the majority of farm households on the northern part of the Central Plateau. They had to cope with declining rainfall, low cereal yields and substantial food deficits, shortages of drinking water and diminishing vegetation. In those days, the trend ran counter to the Boserup hypothesis, which contends that population growth is a major determinant of technological change in agriculture, leading to innovation, improved land care and thus intensification (Boserup, 1965). With local population densities of up to 100 people/km^2 a transition to intensification could have been expected, but instead extensification continued. Ramaswamy and Sanders (1989) remarked that the Central Plateau was one of the last regional holdouts for exponents of Mathusian theories. Efforts to modernize agriculture during the 1950–1980 period, in particular the promotion of cash crops such as cotton and peanuts, animal traction, and sowing on straight lines to facilitate mechanical weeding, did not succeed. For example, animal-drawn ploughs were used to rapidly expand the cultivated area rather than being used as a tool for intensification.

4. Reactions to the agricultural and environmental crisis

The crisis situation provoked two reactions. Farmers, as well as technicians working for non-governmental organizations, started to experiment in improving SWC techniques. When these experiments proved successful, donor agencies quickly designed SWC projects based on simple, effective techniques acceptable to farmers. Effectiveness in this context means that they conserve rainfall by decreasing runoff and increasing infiltration, thus reducing erosion and resulting in significant increases in plant production.

4.1. Improvements in SWC techniques

Three SWC techniques were improved in the first half of the 1980s and these technological changes were subsequently considered to be key in triggering a process of agricultural intensification and environmental rehabilitation.

First, around 1980, several farmers close to Ouahigouya, the capital of the Yatenga, started to experiment with traditional planting pits or *zaï* and improved them by increasing their dimensions and by adding organic matter to them during the dry season (Ouedraogo and Sawadogo, 2001; Kabore and Reij, 2003). These farmers started innovating out of despair. They were confronted with decreasing yields and an expansion of barren denuded land, but they preferred to stay and find solutions rather than leave and settle elsewhere. The improved *zaï* were used to rehabilitate barren and highly degraded land, locally called *zipélé*. Secondly, stone lines or bunds constructed on contour lines were the outcome of a process of experimentation led by the OXFAM-funded Agroforestry Project in the Yatenga (Fig. 2). This project started in 1979 with a research phase of four years. Its main objective was to develop water harvesting techniques capable of stabilizing the degradation of the environment while increasing the productivity of the soil (Wright, 1985).

Level permeable rock dams, which are long, low dams of loose stone constructed without a spillway, are used to rehabilitate gullies. They represent the third technical breakthrough in SWC. In 1981–1982 the first such dam was tested by a French volunteer in a gully in the village of Rissiam (Bam province). It became a success and, in the years that followed, hundreds of such dams were built in the region to control and rehabilitate gullies (Reij, 1983; Vlaar and Wesselink, 1990).

Fig. 2. Farmers weeding the land between contour stone bunds.

4.2. Increased investment in SWC

At the request of the government of Burkina Faso, many NGOs intervened on the northern part of the Central Plateau, because this was one of the poorest regions in the country. In the 1980s, they all initiated SWC activities based on the above-mentioned three simple and effective techniques. Several bilateral and multi-lateral agencies started major SWC projects in the second half of the 1980s (cf. footnote 4). Most of them paid for the use of trucks to transport stones, while all labor involved in collection of stones and the construction of stone bunds and rock dams was the responsibility of village organizations. On the northern part of the Central Plateau, thousands of hectares of severely degraded land have been reclaimed with *zaï* or a combination of *zaï* and contour stone bunds. Since the mid-1980s, at least 100,000 ha in the study region have been treated with contour stone bunds (Reij and Thiombiano, 2003). At an estimated average cost of 200 US $/ha for labor, transport and technical support, the total investment in SWC during this period has been about 200 million US $. The costs of the recent construction of a major dam to improve the water supply of the capital Ouagadougou are of the same magnitude.

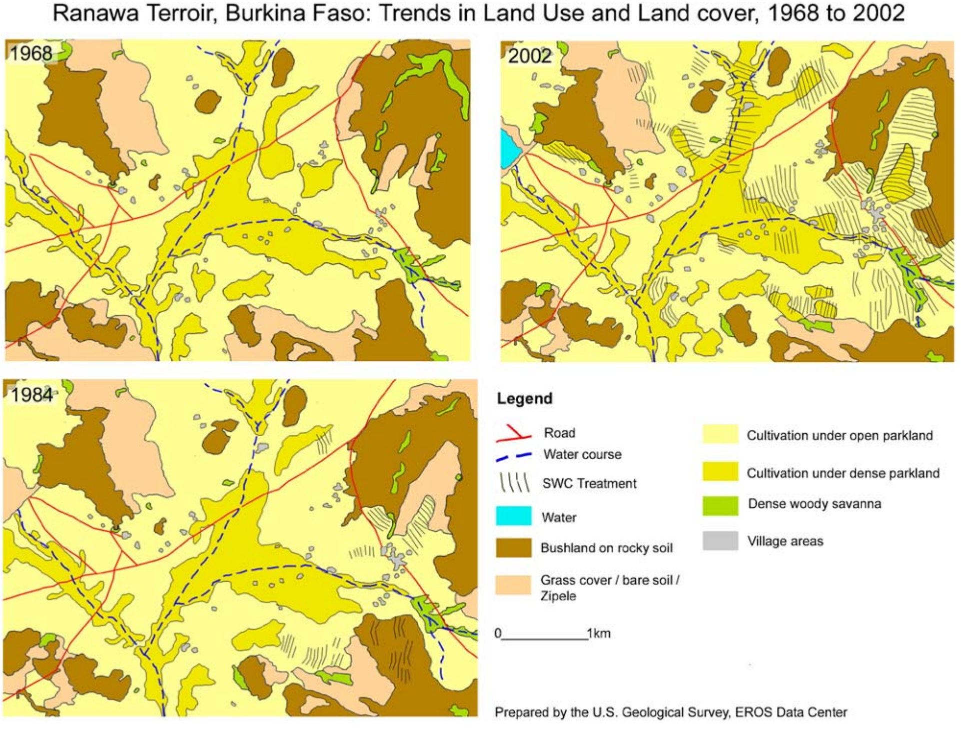

Fig. 3. Time-series comparison of land use and land cover for the Ranawa terroir, showing trends from 1968 to 2002. The maps were produced from photo-interpretation of a Corona satellite photograph (1968), a black and white aerial photograph (1984), and color aerial photographs (2002).

5. Multiple impacts of investment in SWC

An important question to be answered is, what the impacts have been of this significant investment in SWC. Studies on the costs and benefits of SWC have mainly considered the impact of specific techniques on cereal yields (de Graaff, 1996). Other studies looked at yield impacts, but also at soil water balance and at changes in soil fertility (van Driel and Vlaar, 1991) Farmers look at the impact of SWC techniques on crop yields, but they are quick to point out that trees growing on fields treated with stone bunds have much better survival rates, show stronger growth rates, and produce more fruit than trees on untreated fields. They also remark that, one or two years after the treatment of a block of fields with conservation techniques, the water level improves in wells located within or immediately downstream of these fields. Cost–benefit ratios of SWC change considerably when the monetary value of secondary benefits is also included in the calculations.

The study identified several major impacts of investments in SWC, including:

(1) *Average millet and sorghum yields have increased by about 50– 60 percent since the mid-1980s*, but average yields are still low (600–700 kg/ha), which reflects poor soil fertility conditions. These data are based on agro-pastoral statistics at the provincial level and include yields for all cultivated fields, both treated and untreated. Are these increases related to higher rainfall in the 1990s? The rainfall data show that average annual rainfall in the 1990s was, depending on the region, 20 to almost 30 percent higher than in the 1980s. For example, average annual rainfall for the Yatenga was 532 mm for the 1980s, but 682 mm for the 1990s. There can be no doubt that higher rainfall has had a positive impact on yields. However, the increase in average annual rainfall has been accompanied by a growing irregularity in rainfall and by more prolonged drought periods during the rainy season. Both have a depressing effect on yields. Table 1 expresses cereal yields in kg/mm rainfall for the months of September and October. Rainfall during these two months significantly influences yields. Rains before September serve to develop biomass.

In the three provinces cereal yields per mm rainfall for both months have increased and are highest in the period 1996–2001 despite two drought years during this period (1997 and 2000). The most likely explanation for this positive

Table 1
Evolution of cereal yields in kg/mm rainfall for the months of September and October

	Bam		Yatenga		Sanmatenga	
	Sorghum	Millet	Sorghum	Millet	Sorghum	Millet
1984–88	4.1	3.6	5.1	4.1	3.8	3.8
1989–95	4.3	4.1	4.5	4.2	5.7	5.7
1996–01	4.6	4.9	5.3	5.0	6.6	5.8

Source: Reij and Thiombiano (2003).

trend is higher rainfall in combination with better use of rainfall as a result of conservation infrastructure on the land. A shift to early maturing varieties will also have had a positive impact.

The positive impact of SWC on yields is also indicated by the fact that in 2001 average cereal yields in villages with SWC were 793 kg/ha compared to 611 kg/ha in villages without SWC (Sawadogo, 2003).

(2) *The cultivated area has remained stable since the mid 1980s*. The cultivated area varies quite significantly from year to year, which is related to the rainfall characteristics. When the rains arrive late, farmers cultivate less land than when they arrive early. Overall, the average cultivated area has remained stable since the mid-1980s in two of the three provinces. This is an indication of agricultural intensification. Expansion in the third province (the Yatenga) is mainly due to the rehabilitation of highly degraded land.

(3) *Cultivated fields treated with SWC techniques have more trees than 10–15 years ago, but the vegetation on most of the non-cultivated areas continues to degrade*. Increased rainfall must have facilitated natural regeneration, but on-farm protection of natural regeneration is not determined by rainfall, but by the willingness and ability of farmers to effectively protect the trees on their fields. Whereas farmers perceive exclusive rights to the trees on their fields, management rules for non-cultivated fields have, in most cases, broken down.

(4) *Greater availability of forage for livestock is due to local regeneration of vegetation and residues from the production of more crops*. The Peulh of the village of Sam (Bam province) indicated that they no longer move their herds, because of the abundance of crop residues and perennial grasses.

(5) *Women and men are investing more in livestock, and livestock management has changed from extensive to semi-intensive methods.* An increase in cereal yields means improved household food security. The implication is that less cash is spent on the market to make up food deficits and more cash is available, which is now, at least partially, invested in livestock. Before investments in SWC started, Mossi farmers used to entrust their cattle to the Peulh. Since they began to invest in SWC, they have become more interested in soil fertility management and they started to withdraw their cattle from the Peulh at the beginning of the dry season to produce more manure for their own fields. A shift is beginning from extensive to semi-intensive livestock management. This was also stimulated by the currency devaluation in January 1994, which facilitated the export of livestock to Ivory Coast.

(6) *Farmers have improved soil fertility management, but more is needed to sustainably increase yields*. A survey in five villages showed that the percentage of households with a manure pit varied from 10 to 47 percent (Reij et al., 2001). In the Yatenga region, which has the highest population densities in the northern part of the Central Plateau, the large majority of farmers applied organic fertilizers to their fields. On average they use less than a ton of organic fertilizer/ha. In chemical terms the cultivated soils become poorer, but this process is slowed down by SWC as stone bunds trap organic matter. The quantity of nutrients in soils rehabilitated with improved traditional planting pits has increased over time

(Mando, 2003). This is not surprising given the effort to concentrate nutrients and water in these pits. The fertility of soils is not only determined by their nutrient stock, but also by their structure as well as by their flora and fauna. This may explain why cereal yields on the northern part of the Central Plateau have increased rather than diminished, despite a reduction in the nutrient stocks on most fields.

(7) *Although not a general phenomenon, most villages with SWC have seen locally rising ground-water tables (+5 m or more)*. These higher ground-water tables can be attributed to increased infiltration of rainfall and runoff, rather than to higher rainfall in the latter half of the 1990s. In most of the 59 villages surveyed, water levels in wells increased perceptibly one or two years after the start of SWC. This also happened during drought years, which indicates a positive relationship between SWC and local replenishment of ground-water. Despite a substantial increase in water demand generated by more people and more livestock, the village water situation has not deteriorated, but improved. This is not the case in two districts (Pissila and Bourzanga), which is most likely due to specific hydro-geological conditions. More water in wells has not only reduced the labor burden of women, but, in several villages, it has also led to the creation of small irrigated gardens around wells (e.g. in Ranawa).

(8) *Population growth in 12 study villages was 0 percent between 1975 and 1985, and 25 percent between 1985 and 1996*. Whereas labor migration as well as permanent departures were normal phenomena between 1975 and 1985, the average population growth of 25 percent in the study villages between 1985 and 1996 suggests a decrease in departures. The village of Ranawa lost 25 percent of its population between 1975 and 1985, but its population more than doubled between 1975 and 1996. Not a single family left the village since the start of stone bund construction in 1984–1985, which has led to the rehabilitation of an estimated 600 ha. Some families returned from the southwest where they had settled a decade before. They returned mainly because of increasing ethnic tensions in that region, but also because of improved production conditions in Ranawa.

(9) *Based on the villagers' criteria, which are mainly related to the degree of household food security, rural poverty decreased significantly (as much as 50 percent) in villages with SWC*. Rural poverty levels increased in the villages without SWC interventions. Although the data are weak, they do accurately reflect a trend. Investments in SWC have triggered a process of accumulation or asset building. This is well illustrated by Harouna Ouedraogo, a farmer from Ranawa: ''In 1980 only two families had cattle, now all families have cattle. Almost no one had a roof of corrugated iron … just look around you and you'll notice that almost every family has such roofs. All our wells fell dry and for that reason girls from neighboring villages did not want to marry boys from our village. The land where we stand used to be barren, but now it has become productive again and all the trees that you see in these fields have grown since we started to construct bunds''.

A study by Irz et al. (2001) has shown that in Africa an increase in agricultural production of 10 percent leads to a 6–9 percent reduction in rural poverty. The increases in cereal production by 50–60 percent should therefore have led to substantial poverty reduction.

6. A general overview of changes in land use and vegetation

In 1968, highly detailed Corona satellite photos revealed that the vegetation cover was well developed in most of the study villages. Valuable trees were generally scattered throughout agricultural fields. Bushlands and shrub savannas dominated the unfarmed plateaus and terraces beyond the fields. In particular, since the 1968–1973 drought, many on-farm trees were lost, the bushlands thinned out, and the trend continued into the 1980s. In the villages with SWC, the vegetation began to recover. On cultivated fields with SWC one finds an increase in woody species. Many fields were devoid of vegetation until SWC practices were used. Due to selective protection of natural regeneration, in combination with some tree planting, the development of vegetation is impressive. *F. albida* and other useful tree species that were disappearing have now recolonized the fields. *Sclerocarya birrea, Butyrospermum parkii*, *Lannea* sp., and other fruit-bearing species are more vigorous and produce more fruit. On fields with SWC, the dominant species are *Guiera senegalensis* (24 percent) and *Balanites aegyptiaca* (12 percent), whereas on fields without SWC, *Piliostigma thonningii* is the dominant species (30 percent) followed by *G. senegalensis* (17 percent) (Belemviré, 2003).

On cultivated fields without SWC the changes are much less spectacular compared to fields that were rehabilitated with SWC. This is mainly because fields that were selected for SWC were highly degraded; they included barren, crusted land (zipele). The vegetation outside cultivated fields continues to degrade almost unabated due to the combined human and livestock pressures, but in some villages with a long history of SWC (e.g. Ranawa) there is a modest increase in the natural vegetation cover.

6.1. The evolution of land use (1968–2002)

The remote sensing team used the following images for each study village:

- CORONA satellite photographs taken in 1968 (1:10,000 scale);
- Aerial photos taken during the 1981–1984 period (1:50,000 scale);
- Aerial photos taken in June 2002 (1:9000 scale).

In each *terroir* (village territorial lands that constitute the individual study areas), a representative transect was delineated for in-depth analysis and three terroirs were completely studied.

The analysis of the 1968 Corona photos shows that cultivated land already dominated the land use in many of the terroirs. Major tracts of natural vegetation remained intact, varying from open to dense bushlands and shrub savannas. The more northern terroirs of the Central Plateau (particularly Derhogo) exhibited more open vegetation cover, except along drainage channels. The year 1968 marked the end of a long period of relatively abundant rainfall (1950–1968). The aerial photos taken in the early 1980s show a significant reduction of the vegetation cover, which is not surprising because the period since 1968 was characterized by a strong decline in rainfall and a succession of drought years. The strong demographic pressure on the natural resources, in combination with drought, has contributed to an expansion of cultivated areas at the expense of the remaining surrounding bush vegetation. Due to the droughts of the 1980s, the degradation of the vegetation certainly continued well after 1982, while both SWC and tree planting were undertaken at a modest scale in the 1980s. SWC efforts scaled up considerably around 1989.

The focus of the remaining part of this article will be on changes in land use and vegetation in three of the 12 study villages.

7. Changes in land use and vegetation in two villages (Ranawa and Rissiam) with SWC interventions and in one control village (Derhogo) without SWC

Table 2 and Fig. 3 show the evolution of land use in the village of Ranawa between 1968 and 2002 (Reij and Thiombiano, 2003).

The total terroir area analysed is 1841 ha. It is striking that the total cultivated area has expanded modestly since 1984 (66.0 percent in 1984 and 71.6 percent in 2002), whereas according to the population censuses of 1985 and 1996, respectively, the population of Ranawa more than doubled during this period. Another striking feature is that the area under dense cultivated parkland decreased between 1968 and 1981, which is in line with expectations, but then increased between 1981 and 2002 (Table 3).

The area analysed in Rissiam in 1981 and in 2002 is 700 ha. In terms of SWC, very little could be observed in 1981; only some windbreaks and hedges were visible. However, in 2002, 38 percent of the area analysed was treated with stone bunds and rock dams (Table 3). The cultivated area had increased from 66 to 72 percent of the

Table 2
Evolution of land use in the *terroir* of Ranawa between 1968 and 2002

Type of land use (%)	Ranawa 1968	Ranawa 1984	Ranawa 2002
Bushland	21.5	20.6	17.9
Dense woody savanna	2.2	1.6	2.1
Grass savanna/ bare soil during the dry season/zipélé[a]	12.5	11.1	7.7
Cultivation under open parkland	47.6	52.1	54.1
Cultivation under dense parkland	15.9	14.1	17.5
Village areas	0.3	0.5	0.6
Water surface	0	0	0.2
Total	100	100	100
Cultivated land treated with SWC	0	2.1	17.1

[a]In 1968, grass savanna dominated this land use category. In 1984 and in 2002, this same category was dominated by barren and denuded land.

Table 3
Evolution of land use in the *terroir* of Rissiam between 1981 and 2002

Type of land use (%)	Rissiam 1981	Rissiam 2002
Grass and woody savanna	27.4	18.3
Barren soil and *zipélé*	5.1	7.4
Cultivation under open parkland	54.1	56.8
Cultivation under dense parkland	12.3	15.4
Village areas	1.0	1.8
Water surface	0	0.2
Total	99.9	99.9
Cultivated land treated with SWC	0.6	38.0

total surface, which is a 10 percent increase. According to population census data, the village population increased at a much faster rate (+20 percent between 1985 and 1996) than the cultivated area. This indicates a process of agricultural intensification. It is interesting to note that the dense parkland under cultivation increased, rather than decreased, from 12.3 percent to 15.4 percent. Again, this indicates at least a stable, if not an improving environmental situation.

How representative is this development in Ranawa and in Rissiam of villages with investments in SWC? Both are villages with a long history in SWC (15–20 years) and they have achieved more than villages with a shorter history in SWC. Nevertheless in the Yatenga region many villages can be found like Ranawa. A rapid analysis of satellite images and aerial photos of the Southern part of the Yatenga (what is now Zondoma province) shows other villages with a similar evolution. The case of Rissiam is a bit particular in the sense that it is where the construction of level permeable rockdams began in the early 1980s and it has benefited from substantial external support (French volunteers and the PATECORE project). It is difficult to find another village with such a concentration of level permeable rock dams. But also this technique has spread in this area and although numerous other villages in the Bam province may not have rock dams; instead, they have large blocks of land treated with stone bunds.

Table 4 shows that about half the area of Derhogo consists of barren soils with some scattered grasses. The cropland without trees has increased since 1968. Contrary to what was found in the villages of Ranawa and Rissiam, the area covered by parkland declined dramatically from 11.2 percent in 1984 to only 3.8 percent in 2002. The spread of gullies is an indicator of a growing severe erosion problem, related to the degradation of vegetation cover. Derhogo has not seen any major intervention by SWC projects, but a few individual farmers have constructed some stone bunds on their fields. The severe degradation of vegetation in Derhogo is mainly caused by large numbers of livestock in this village, which is situated in an agropastoral zone. The different herds graze most of the year outside the village in an area near the border with Mali, where forage resources are still available.

Table 4
Evolution of land use in the *terroir* of Derhogo between 1968 and 2002

Type of land use (%)	Derhogo 1968	Derhogo 1984	Derhogo 2002
Shrub steppe	1.6	1.4	1.4
Wooded watercourse	1.0	0.2	0
Bare soil/*zipélé*/scattered grass	50.4	41.3	49.4
Cultivation without trees	15.1	22.8	20.7
Cultivation under parkland	30.8	32.1	24.2
Village areas	0.8	1.4	1.9
Gullies	0.2	0.8	2.0
Land treated with SWC	0	0	0.4
Total	99.9	100	100
Percent tree cover in parkland	13.1	11.2	3.8

8. Assisted natural regeneration

During the field studies, the discussions with resource persons in each village also provided insight into the level of regeneration. A distinction was made between *persistent species*, which are species that have never disappeared under the combined pressures of livestock and human needs, and *reappearing species*, which had virtually disappeared, but have now reappeared due to improved conditions at certain sites.

When considering all the species found in the transects, 24 percent are considered persistent and 76 percent had virtually disappeared or had become very rare, but they have reappeared since the last 10 years. The main persistent species are *Combretum glutinosum, G. senegalensis* and *Piliostigma reticulatum*. The main reappearing species are *Diospyros mespiliformis, Anogeissus leiocarpus* and *Acacia dudgeoni*.

Of the persistent species, 61 percent are found on the fields treated with SWC and 39 percent occur on the untreated fields. For the reappearing species these figures are 81 percent and 19 percent, respectively. The reappearing species are significantly more frequent on treated than on untreated fields (Belemviré, 2003).

9. Final remarks

The indications are that technological change in SWC in the early 1980s finally helped trigger a process of agricultural intensification. The decline in cereal yields of the 1970s has been reversed. The cultivated area has remained stable since the middle of the 1980s. Farmers have improved soil fertility management. Increased investment in livestock and higher tree densities on cultivated lands illustrate a process of asset building. The end result is that, in their own perception, many farm families have become less poor and less vulnerable to drought.

Would this process have happened without the substantial support provided by SWC projects? Farmers have invested their labor in improved traditional planting pits and in this way they have rehabilitated severely degraded land, but without massive project support for the transport of stones, they could not have treated large blocks of land in so many villages in such a short time. About 40 tons of stone are required to treat 1 ha of land with stone bunds. In many villages blocks of 50 ha or more have been treated, which requires the transport of at least 2000 tons of stone.

Have poor farm households also benefited from SWC? The indications are that they have, although in most cases less than average and rich farmers. Because most projects opted for treating blocks of land, this meant that fields belonging to poor farm households also benefited from treatment.

Although the introduction of low-cost, risk-reducing, and productivity-enhancing SWC techniques has played a key role in triggering agricultural intensification and environmental improvement, not all the observed improvements can be attributed to changes in such techniques. Other factors have also played a role. Macroeconomic management has been generally sound. The devaluation of the West African franc in January 1994 induced farmers to invest in livestock. The improvement of major roads between the national capital Ouagadougou and two regional capitals (Ouahigouya and Kaya) reduced transportation costs and allowed traders from West Africa to send trucks to the Yatenga to buy cowpeas, sesame and vegetables (Reij and Steeds, 2003).

Despite the positive economic and environmental change, the battle against land degradation and rural poverty on the Central Plateau has not yet been won. The immediate challenges are to promote and accelerate the dissemination of integrated production systems developed by farmer innovators in this region (Taonda et al., 2001; Sawadogo et al., 2001) to further improve soil fertility management on cultivated fields and to address the continuing degradation on sylvo-pastoral lands.

The evolution on the Central Plateau analysed in this article is not unique. Mortimore and Tiffen (2000) have analysed livelihood transformations in Makueni District (Kenya), Maradi Department (Niger), Kano Region (Nigeria), and Diourbel Region (Senegal) (1960–2000). One of their findings is "that farmers in all these semi-arid regions have invested substantially in livestock. The better integration of agriculture and livestock at farm level has largely been a spontaneous process, which has contributed to improved soil fertility management. Higher yields have also led to increased production of crop residues, which means that more fodder is available to livestock. Cumulative public and private investment has led to asset growth—in land value, additional livestock, housing investments, moveable assets—that is clearly visible in many places" Mortimore, pers. communication). This is exactly what happened on the northern part of the Central Plateau during the last 15–20 years.

References

Belemviré, A., 2003. Impact de la Conservation de l'Eau et des Sols sur la Régénération Naturelle Assistée. Etude Plateau Central. Rapport de travail no.1.

Boserup, E., 1965. The Conditions of Agricultural Growth: the Economics of Agrarian Change under Population Pressure. Earthscan Publications Ltd (1993), London.

Broekhuyse, J.Th., 1983. Transformatie van Mossi land. Koninklijk Instituut voor de Tropen, Amsterdam 168p.

Brons, J., Zaal, F., Ruben, R., Kersbergen, L., 2000. Climate Change, Environmental Variability and Risk-Coping Strategies: a Farm and Household Level Analysis in Northern Burkina Faso. Wageningen University and University of Amsterdam.

CONAGESE, 1999. Plan d'Action National de Lutte contre la Désertification. Ouagadougou, Burkina Faso.

van Driel, W.F., Vlaar, J.C.J., 1991. Impact des digues filtrantes sur le bilan hydrique et sur les rendements agricoles dans la région de Rissiam, Burkina Faso. In: Soil Water Balance in the Sudano-Sahelian Zone. Proceedings of the Niamey workshop, February 1991.

Dugue, P., 1989. Possibilités et limites de l'intensification des systèmes de culture vivriers en zone soudano-sahélienne: le cas du Yatenga (Burkina Faso). CIRAD, Collection Documents Systèmes Agraires No. 9.

Dutour, J.C., 1981. Rapport d'evaluation du programme "Puits et forages—FDR III" dans l'ORD du Centre-Nord.

de Graaff, J., 1996. The price of soil erosion: an economic evaluation of soil conservation and watershed development. Ph.D. Thesis, Wageningen University.

Irz, X., Linn, L., Thirtle, C., Wiggins, S., 2001. Agricultural productivity growth and rural poverty alleviation. Development Policy Review 19, 449–466.

Kabore, D., Reij, C., 2003. The emergence and spreading of an improved traditional soil and water conservation practice in Burkina Faso. Washington, IFPRI, EPTD Discussion Paper No. 116, November 2003.

Mando, A., 2003. Gestion des sols et evolution de la fertilite des sols dans le Plateau Central du Burkina Faso. Etude Plateau Central. Rapport de travail no. 16.

Marchal, J.Y., 1977. Evolution des systèmes agraires: l'exemple du Yatenga (Haute Volta). Environnement Africain 2, 75–88.

Mazzucato, V., Niemeijer, D., 2000. Rethinking soil and water conservation in a changing society: a case study in eastern Burkina Faso. Wageningen University. Tropical Resource Management Papers No. 32.

McMillan, D., Nana, J.B., Sawadogo, K., 1990. Settlement and Development in River Basin Control Zones: Case study Burkina Faso. World Bank Technical Paper No.200.

Monimart, M., 1989. Femmes du Sahel: la désertification au quotidien. Editions Karthala, Paris.

Mortimore, M., Tiffen, M., 2000. Livelihood transformations in semi-arid Africa 1960–2000. Drylands Research working paper No. 40.

Ouedraogo, M., Reij, C., 2003. Synthèse des rapports MARP. Etude Plateau Central. Rapport de travail No.7.

Ouedraogo, A., Sawadogo, H., 2001. Three models of extension by farmer innovators in Burkina Faso. In: Reij, C., Waters-Bayer, A. (Eds.), Farmer innovation in Africa: a source of inspiration for agricultural development. Earthscan Publications Ltd., London, pp. 213–217.

Ramaswamy, S., Sanders, J.H., 1989. Population Pressure, New Agricultural Technologies and Sustainability on the Central Plateau of Burkina Faso. Department of Agricultural Economics, Purdue University, West Lafayete, Indiana.

Rasmussen, K., Fog, B., Madsen, J.E., 2001. Desertification in reverse? Observations from northern Burkina Faso. Global Environmental Change 11, 271–282.

Reenberg, A., Lund, C., 1998. Land use and land right dynamics: determinants for resource management options in eastern Burkina Faso. Human Ecology 26, 599–620.

Reenberg, A., Nielsen, T.L., Rasmussen, K., 1998. Field expansion and reallocation in the Sahel: land use pattern dynamics in a fluctuating biophysical and socioeconomic environment. Global Environmental Change 8, 309–327.

Reij, C., 1983. L'évolution de la lutte anti-érosive en Haute Volta: vers une Approche Particpative. Vrije Universiteit, Institute for Environmental Studies, Amsterdam.

Reij, C., Steeds, D., 2003. Success Stories in Africa's Drylands: supporting advocates and answering critics. A paper commissioned by the Global Mechanism of the U.N. Convention to Combat Desertification.

Reij, C., Thiombiano, T., 2003. Développement Rural et Environnement au Burkina Faso: la Réhabilitation de la Capacité Productive des Terroirs sur la Partie nord du Plateau Central entre 1980 et 2001. Rapport de synthèse.

Reij, C., Ouedraogo, M., Ouedraogo, A., Kaboré, D., Belemvire, A., Zida, C., 2001. Etude D'impact des Actions de CES, d'agroforesterie et d'intensification Agricole au Plateau Central, Burkina Faso. IFAD/Vrije Universiteit Amsterdam.

Rochette, R.M., 1989. Le Sahel en Lutte Contre la Désertification: Leçons d'expérience. Josef Margraf Verlag.

Sawadogo, H., 2003. Impact des amenagements sur les systemes de production, les rendements et la securite alimentaire des exploitations agricoles. Etude Plateau Central. Rapport de travail no. 2.

Sawadogo, H., Hien, F., Sohoro, ., Kambou, F., 2001. Pits for trees: how farmers in semi-arid Burkina Faso increase and diversify plant biomass. In: Reij, C., Waters-Bayer, A. (Eds.), Farmer innovation in Africa: a source of inspiration for agricultural development. Earthscan Publications Ltd., London, pp. 35–46.

Taonda, J.-B., Hien, F., Zango, C., 2001. Namwaya Sawadogo: the ecologist of Touroum, Burkina Faso. In: Reij, C., Waters-Bayer, A. (Eds.), Farmer Innovation in Africa: A Source of Inspiration for Agricultural Development. Earthscan Publications Ltd., London, pp. 137–143.

Vlaar, J.C.J., Wesselink, A.J., 1990. Aménagement de Conservation des eaux et des sols par digues Filtrantes: Expérimentations dans la Région de Rissiam, Burkina Faso, 1986–1989. Aspects techniques et agronomiques. Université Agronomique de Wageningen, CIEH, AFVP.

Winterbottom, R.T., 1980. Reforestation in the Sahel: problems and strategies. An analysis of the problem of deforestation, an a review of the results of forestry projects in Upper Volta. Paper presented at the African Studies Association Annual Meeting, Philadelphia, October 15–18, 1980.

Wright, P., 1985. La conservation des eaux et des sols par les paysans. In: Ohm, H.W., Nagy, J.G. (Eds.), Technologies Appropriees Pour les Paysans Des Zones Semi-Arides de L'afrique de l'Ouest. Purdue University, West Lafayette, Indiana.