<u>Short Research Article</u>

Management of climatic degraded embankment of the River Nakanbé (Burkina Faso) by participatory reforestation

ABSTRACT

The reforestation of the river banks is a form of resilience of populations facing climate change, soils erosion, silting and sedimentation of rivers. In its participatory form, the reforestation highlights the primordial role of the riverside populations in the management of water resources. The present study made it possible.

This paper evaluates the soil and vegetation parameters indicating the stabilization of the rivers banks. The methodology is based field description and characterization of vegetation and soils depending the oldness of reforestation.

This study shows that the participatory reforestation approach for the reconstruction of degraded vegetation and soils, reduce silting of the banks and contributing to fix the banks. However, the participatory approach remains limited by the lack of plants and their accessibility in the villages for reforestation ; in addition there is a still incomplete mastery of the technique of river banks' reforestation.

Keywords: banks' degradation; reforestation; water resources management, participatory approach, Nakanbé Basin, Burkina Faso

1. INTRODUCTION

Since a few decades, precarious climatic conditions have forced farmers to exploit the shallow soils in a context of increasing land pressure, which makes an unsuitable agriculture still largely dominant [1]; [2]. The strong anthropogenic pressure, without respect for the statutory texts, has its corollary, the degradation of the rivers banks by (1) the occupation of rivers banks along the watercourse for agricultural and pastoral farming; (2) the anarchic wood harvesting which contributes to the degradation of the vegetation cover of the banks; (3) the lack of woody plants cover in the banks contributes to water and wind erosion are the fundamental causes of the silting up of water reservoirs and water courses. The silting of water courses gradually and slowly fills the reservoirs and reduces its potential for uses and survival of ecosystems [3] ;(4) pollution by fertilizers (NPK and urea) and pesticides used in agriculture have a negative impact on water and soil quality [4]; [5].
This situation is worrying in some places, particularly at Bam, Dem lakes (Figure 1) , where farmers are seeing the progressive reduction of water disponibility and at the same time, the emergence of invasive plants indicative of polluted water [6].
In order to ensure better banks' protection for sustainable management of water resources, project such as "The Project for Sustainable Management of Forest Resources and the Water Governance Improvement Project in the Volta Basin", have included their program of interventions as part of a concerted and participatory action plan for the protection of banks by riverside populations [7]; [8].
This study was carried out through a project entitled "Agro-sylvo-pastoral practices for adaptation to climate change in the Nakanbé basin : effects and impacts on soils and water resources in a context of Integrated Water Resources Management ". The main objective of this study was to evaluate the impact of the participatory approach of stabilization and reforestation of degraded banks in the context of climate change. In order to achieve the objectives, we hypothesized that the reforestation of the banks allowed to improve and fix the banks by regeneration of vegetation.

2. MATERIALS AND METHODS

2.1 Study framework

The area of this study is located in the village of Sampéma (Boulgou province) at the latitude 11°17' N and the longitude 0°33' W(Figure 1). The climate is of North-Sudanese type. The average annual rainfall is 900 mm. The winter period is between July and October. This period is followed by a dry season from November to June ([9]).

The average minimum temperature is 15°C (from December to February) while the average maximum temperature is 34.9°C (April, May). The soils along the banks are hydromorphic soils.

According to the division of [9], the vegetation and agricultural practice, Sampema belongs to the northern Sudanian phytogeographical zone. The Wooded Savannah is the bank vegetation species due to the process of degradation along the rivers. Some gallery forests species grow along the main rivers and are composed of *Borassus aethiopium*, *Terminalia sp, Anogeissus leocarpus, Khaya senegalensis, Daniella oliveri, Anogeissus leiocarpus, Diospyros mespiliformis, Pterocarpus erinaceus, Parkia biglobosa, Tamarindus indica*. The grass carpet is quite large and composed of species such as *Andropogon gayanus, Schoenefeldia gracilis and Cymbopogon schoenanthus.*

2.2. Collection of data

2.2.1 Placement of plots

For the placement of the plots, we first delimited the plots according to their age using man hand GPS. Using the "Mapsource" software, we then realized the plots and the sampling plots on the computer. We initially limited blocks of 75mx30m surface along the water course. Three reforested blocks of 6; 4 and 3 years old were selected. Within each block, we made three plots along the slope. For each block, the first plot (top of the slope) of 10mx30m is reforested with *Azadirachta indica* or *Senna siamea*, the second (mean of the slope) of 30mx30m in *Mangifera indica* and the last (down of slope) of 35mx30m in *Sarcocephalus latifolia* (Figure 1).

Figure 1: Location of Sampéma site

2.2.2 Soil sampling

In order to analyze the fertility of the reforested banks, four samples were taken using an auger according to the diagonal of each plot and according to the depths 0-10, 10-20, and 20-30cm. From the four samples of the same depth along the diagonal, we mixed to obtain a composite sample, including three composite samples per plot. The samples were dried in the shade for 14 days.

2.2.3 Inventory of vegetation

The woody plants inventory has consisted of identifying the different species and their numbers, measuring the diameter of the trunk at the base and the total height of the plant.

2.2.4 Participatory approach

A field survey was possible to know that this protection of the banks by reforestation was possible with a participatory approach.

2.3 Data processing

The data collected was entered using the Excel spreadsheet. The analysis of the variance was made using the GenStat 4 software. The comparison of the averages was made with the Student Newman Keuls test at the error threshold of 5%.

3. RESULTS AND DISCUSSION

3.1. Wood density of reforested banks

The analysis of the number of woody species by age of reforestation (Figure 2), in high and medium slope, the number of plants show non-significant growth with the age of reforestation ; at the bottom of the slope, the 4-year-old reforested bank has the most significant tree population (0.075 individuals/m²).

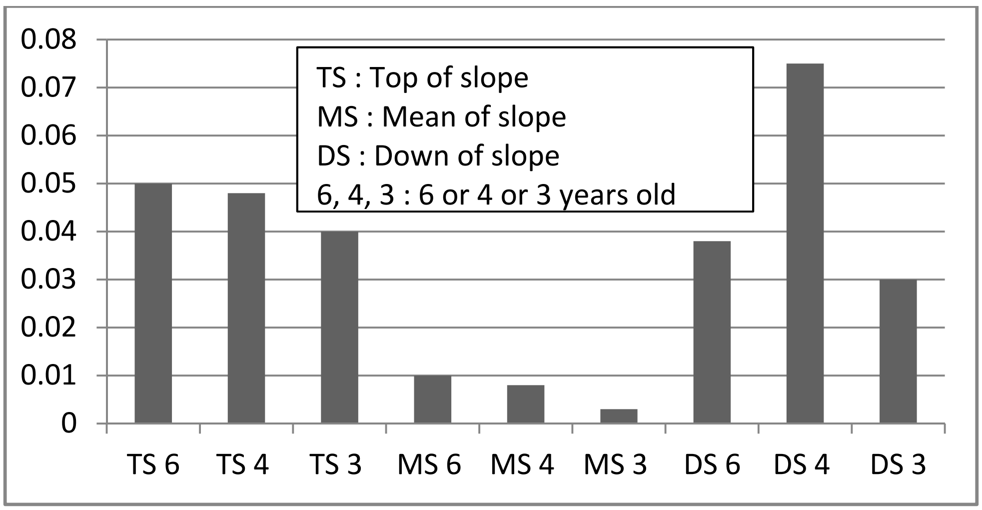

Figure 2: Ratio of woody species according to the oldness of reforested banks
TS = top of slope; MS = mean of slope and DS= down of slope

The analysis of the number of woody species by age of reforestation (Figure 2) show, in high and medium slope, non-significant growth with the age of reforestation ; at the bottom of the slope, the 4-year-old reforested bank have the most significant tree population (0.075 individuals/m²).

3.2. Richness and specific contribution of the woody species of the reforested river banks

The analysis of the richness and specific contribution of the woody species in reforested river banks (Table 1) shows that :
- the 3-year-old reforested banks have the most number of species, six (6), with significantly more *Sarcocephalus latifolia* (22 plants) followed by *Senna siamea* (12 plants) and Mimosa pigra (10 plants). The 4-year-old reforested banks have 5 species with significant numbers of *Mimosa pigra* (49 plants) and *Sarcocephalus latifolia* (29 plants).
- the 6-year-old banks have four (4) species with *Sarcocephalus latifolia* (26 plants), which is significantly larger followed by *Azadirachta indica* and *Mimosa pigra* (15 plants each). *Senna siamea, Ficus gnaphalocarpa* and *Eucalyptus camaldulensis* are present only in 3-year old reforested banks while *Vitellaria paradoxa* is only present on the 4-year-old banks.
- the analysis of the vegetation distribution shows that *Sarcocephalus latifolia* is the dominant species followed by *Mimosa pigra* and *Azadirachta indica*.

Table 1: Frequency of woody species by age of reforested banks

	6 years old bank	4 years old bank	3 years old bank	Probability
Eucalyptus c.	0	0	0. 67	0,079
Ficus g.	0	0	0. 33	0,42
Manguifera I.	9a	6b	0c	<,001
Mimosa pigra	15b	49a	10b	<,001
Sarcocephalus l.	26a	29a	22b	0,007
Senna siamea	0b	0b	12a	<,001
Azadirachta i.	15a	13.67b	1c	<,001
Vitellaria p.	0	0. 33	0	0,422

Student-Newman-Keuls test; Threshold 5%; values are averages of 3 repetitions;
Values followed by the same letter in the same line do not differ significantly at the 5% probability threshold
Eucalyptus c.: *Eucalyptus camaldulensis*; *Ficus g .*: *Ficus gnaphalocarpa*; *Manguifera I.*: Manguifera indica ; *Sarcocephalus l.* : *Sarcocephalus latifolia* ; *Azadirachta i.* : *Azadirachta indica*; *Vitellaria p.* : *Vitellaria paradoxa*.

3.3. Distribution of wood plants by height and circumference

The analysis of the distribution of woody plants by height and circumference (Table 2) show that the differences are significant. The reforested 4-year-old banks show the plants with the greatest circumference and height. The plants of the reforested banks of 6 years old and those of 3 years old do not show a significant difference between them despite the dimensions of the plants higher in the level of the replanted banks of 6 years old.

Table 2 : Height and circumference of woody plants according to the age of reforested banks

	6 years old	4 years old	3 years old	Probability
Circumference (cm)	21. 67ab	33. 33a	15. 67b	0, 030
Height (m)	13b	20a	9. 47b	0, 002

Student-Newman-Keuls test; Threshold 5%; Values are averages of 3 repetitions; values followed by the same letter in the same line do not differ significantly at the 5% probability threshold

3.4. Sieve analysis

The results of the Sieve analysis are reported on Table 3. We can show a significant difference between fine and coarse elements.

- At the bottom of the slope, the silt contents show a significant increase and go from 24.84% (reforested banks of 3 years) to 37.25% (reforested banks of 6 years old). At the top of the slope, the silt content decreases from 43.79% (reforested banks of 3 years old) to 37.90% (reforested banks of 6 years old). However, at the top of the slope, the difference is not significant between the reforested banks of 6 years and 4 years old. On medium slope, no significant differences are observed. The bottoms of slope are less silty than high and medium slopes.
- The sand contents decrease from the bottom to the top of the slope, although there are no significant differences, apart from the reforested bottoms of slopes of 4 and 3 years old. At the bottom of the slopes, the sand content decreases with time and goes from 63.40% (reforested banks of 3 years old) to 49.02% (reforested banks of 6 years old). In high and medium slopes, the sand contents do not show any significant differences.
- The clay contents increase significantly with the age of the development. This increase can also be seen in low and top and medium slopes.

Table 3: Granulometric composition of the soils of the reforested banks

	Clay (%)	Silts (%)	Sands (%)
TS 6 years	17.00a	37.90c	45.10c
MS 6 years	17.00a	37.90c	45.10c
DS6 years	13.73c	37.25c	49.02c
TS 4 years	14.38bc	38.56b	47.06c
MS4 years	15.04bc	38.56b	46.41c
DS4 years	12.42cd	31.37d	56.21b
TS 3 years	12.42cd	43.79a	43.79c
MS3 years	15.69b	33.98d	50.33b
DS3 years	11.76d	24.84e	63.40a
Probability	<.001	<.001	<.001

Student-Newman-Keuls test; Threshold 5%; values are averages of 3 repetitions;
Values followed by the same letter in the same column do not differ significantly at the 5% probability threshold ; TS = top of slope; MS = mean of slope and DS= down of slope

3.5. Chemical parameters of soils

The statistical analysis of the chemical parameters of reforested soils (Table 4) shows significant differences in their chemical composition.

The top of slopes of the reforested banks of 3 years and 6 years have nitrogen levels increased from 0.0283 meq/100g to 0.045 meq/100g. Carbon levels increased from 0.343 mg/g to 0.575 mg/g. The C/N ratio increases from 12 to 13. The available potassium levels increase from 54.12 meq/100g to 68.88 meq/100g. But along medium and low slopes, their evolution are neither function of time nor topography.

On the top of slope (TS), pH values did not differ significantly, except for the 4-year (6.607) and 3-year (6.587). The pH values had a downward trend at the top of the slope. On the mean of slope, there is a small increase in pH value.

In high and low slopes, assimilable phosphorus levels are significantly lower in the reforested banks of 3 years old and higher in those of 4 years old.
The mean slopes have the highest values, while the down of slopes have the lowest ones.

Table 4: Chemical characteristics of reforested soils

	Total Carbon (g/kg)	Total nitrogen (g/kg)	C/N	Total organic matter (g/kg)	Water pH	Available phosphorus (meq/100g)	Available Potassium (meq/100g
TS 6 years	0.575a	0.045a	13.00a	0.992a	6.20b	10.867b	68.88b
MS 6 years	0.575a	0.045a	13.00a	0.992a	6.20b	10.867b	68.88b
DS 6 years	0.337c	0.028cd	12.33bc	0.581c	6.13b	7.473c	53.79bc

TS 4 years	0.405c	0.033c	12.33bc	0.698c	6.61a	12.323a	59..37bc
MS 4 years	0.450c	0.035bc	12.67b	0.776c	6.12b	10.093b	84.62a
DS 4 years	0.,359c	0.028c	12.67b	0.618c	6.03c	8.637c	43.62c
TS 3 years	0.343c	0.028c	12.00c	0.592c	6.59b	4.620d	54.12bc
MS 3 years	0.567b	0.044b	13.00a	0.978b	6.09b	11.253b	84.95a
DS 3 years	0.204d	0.019d	11.00d	0.352d	6.22b	5.710cd	53.46bc
Probability	<.001	<.001	<.001	<.001	<.001	<.001	<.001

Student-Newman-Keuls test; Threshold 5%; values are averages of 3 repetitions; values followed by the same letter in the same column do not differ significantly at the 5% probability threshold ; TS = Top of slope; MS = Mean of slope and DS = Down of slope

4. DISCUSSION

The participatory approach of the reforestation on the banks allowed the revegetation once degraded and deforested. The reconstruction of the vegetation is more important at the level of the riparian formation. Indeed reforestation was initially done with plants of *Sarcocephalus latifolia* but one finds after a strong population of wild *Mimosa pigra*. The authors [10] and [11] reported that riverbank development improves the regeneration of plant species by trapping seeds and seedlings transported by waterflow and runoff.

The analysis of the specific richness showed that the dominant species are *Nauclea latifolia* and *Mimosa pigra*. These species are typical to flood-prone soils. Aquatic plants by the phenomenon of hydrochory, let the flow disseminate their seeds. It is a common strategy in these plants, such as *Sparganium emersum, Nelumbo nucifera, Nymphea alba, Nuphar luteum* or *Mimosa pigra* [12].

In the high and medium slopes there are no species from post-reforestation regeneration despite the large quantities of seeds produced by *Azadirachta indica* and *Senna siamea*. Similarly, there is no regeneration of species other than those reforested or already present on the site before reforestation. This finding shows that assisted natural regeneration is not practiced in high and medium slopes unlike low slopes.

The small number observed on medium slope of the banks of 4 years (Picture 1, appendix) is due to the 2007 flood which destroyed almost all the plantations of 2006 (Picture 2, appendix). Flooding could also be the cause of the growth retardation observed in the plants of the 6-year-old reforested banks compared to those of the 4-year-old reforested banks. Indeed, the excess of water creates anaerobic conditions that alter the root metabolic functions, lead to poisoning and cause the deterioration of the physical properties of the soil and make them more vulnerable to degradation. The oxygen required for root breathing, circulates in the interstices of the ground. In case of flooding, water occupies all these pores and the roots are placed in an asphyxic condition, which inhibits their growth. Plants can survive short periods of anaerobic condition (up to 0.5% oxygen). Roots require 6-8% oxygen to grow normally. Under these values the leaves become chlorotic, the growth is interrupted, the formation of new roots stop, the stems become dry and the plant dies. Flooding can also reduce sweating by almost 90%, limiting the absorption of water and nutrients and reducing photosynthesis. These anaerobic conditions at the soil level are combined during insufficient drainage of heavy soils during heavy rains and flooding [13].

The mean slopes of the reforested 3-year-old banks are a fallow not replanted by lack of mango trees (Picture 3, appendix), hence the number of plants very low compared to other parts of the banks.

The decline in silt content in soils at the top of the slope, as well as their increases at the bottom of the slope, show that there is leaching of the silts from the top to the bottom of the slope. The higher grades of sand at the bottom of the slope reflect a silting phenomenon (Picture 4, appendix). The slope intervenes in the degradation of the land by its declivity, length and form. The soil erosion increase exponentially with the slope [14]. The increase in the degree of slope lead to increasing of runoff [15].

The low slope plots are in the flood plain of the Nakanbé, where the phenomenon of sandy alluvial deposits is more important (Picture 4, Annex). However, the sand content decline at the bottom of the slope showing that reforestation allowed the retreat of silting. Similarly, the increase in clay contents over time indicates that reforestation increase the fine texture of soil content. Clay minerals make the soils heavier and therefore improves the stability of the banks.

The other aspect of this study is the participatory approach that brought together all stakeholders from the beginning to agree on the terms of action so that it is mutually beneficial for all stakeholders. Thus, land owners benefit from the fruit plants offered by the project and firewood that will constitute *Nauclea latifolia*. The project and the Nakanbé water agency benefit from the protection of the bank by fixing species. This approach is a real innovation that makes it a consensus for the protection of the banks.

5. CONCLUSION

At the end of this study, we can draw the following conclusions:

• The reforestation of the rivers banks initiated in recent years in Sahelian country of Burkina Faso have proved their efficiency in the restoration of degraded banks. It accelerates the regeneration of vegetation, the restoration of soil fertility and texture.

• The reforestation of the river banks remain however limited by the availability of the plants for reforestation in the areas and internal villages who need it.
• Reforestation of the banks also causes a decrease in pH value in water and have negative effect on quality of soil.

• These techniques of reforestation would not have any positive impact on regeneration of vegetation without the practice of the assisted natural regeneration.

RECOMMENDATIONS AND PERSPECTIVES

Based on the findings of this study, we propose the following recommendations and perspectives for better optimization of participatory reforestation and better management of water, soil and mitigation of the effects of climate change in the Nakanbé watershed :
• Extend the reforestation of the banks in the entire Nakanbé watershed,
• Associate stony barriers and / or grass strips with the reforestation of the banks to increase their durability and efficiency,
• Promote and prioritize participatory environmental management approaches,
• Sensitize people on the practice of the natural assisted regeneration.

Picture 1: Area destroyed by the 2007 flood, 4 years after

Picture 3: Average slope of banks of 3 years old

Picture 2: Result of the flooding of the river bank in 2007 [15]

Picture 4: Sandy bank

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