

**EVALUATION OF THE RESTORATION OF DEGRADED LANDS BY
THE TECHNICS OF SOIL WATER CONSERVATION AND SOIL
DEFENSE AND RESTORATION (CES/DRS) IN THE VILLAGE OF
BADOKO (DOSSO, SOUTH-WEST NIGER).**

*Moussa Hassane and Amadou Djouedou

Institute National de Recherche Agronomique du Niger (INRAN) Niamey - Niger.

*Corresponding author: Ph.D, researcher at the forest CERRA - Niamey- National Institute of Agronomic Research of Niger (INRAN). BP: 429 - Niger.

ABSTRACT

This study on the restoration of land degraded by Soil Conservation and Soil Defense and Restoration (CES/DRS) technics was conducted in the rural community of Loga (Niger), at the village of Badoko. The study assessed some land restoration actions carried out to evaluate assess the level of their contributions to the resilience of agricultural land to climate change.

The methodology used is based on socio-economic surveys, measurements of the technical standards of run off cashment structure (Bench) and the dendrometric survey of planted trees in naturally regenerated in Benches structures.

The results showed (1) that communities are aware of the degradation of natural resources that has been restored using the benches appreciated and accepted by the populations; (2) that the money obtained by the beneficiaries has enabled households to eat well; (3) that the vegetation at the site was markedly improved by a high floristic richness (woody and herbaceous) with 0.63 bits of diversity and 0.59 bits of Piélou's equitability. This reflects an instability of the species in the environment whereas the Piélou equitability index follows the opposite trend; (4) that the species *Acacia senegal* and *Bauhinia rufescens* recorded the highest survival rates and the largest increases in diameters and heights; (5) that the high mortality of the species *Ziziphus mauritiana* is related to the eccentric position of this species which is found on the last rows of the Benches structures with a small supply of runoff water and the presence of the rodents which damaged the young Plants during their development.

Keywords: Evaluation of land restoration, CES/DRS, agricultural land resilience, climate change, *Acacia senegal*, *Bauhinia rufescens*, *Ziziphus mauritiana*, Loga, Badoko, Niger.

INTRODUCTION

Niger, a Sahelian country, located in the heart of West Africa in the margin of the southern Sahara, covers an area of 1,267,000 km². The austere natural environment is marked by a climatic regime characterized by low rainfall, variable in time and space, and high temperatures that accentuate its aridity [1]. In this country, the socio-economic activities of the populations are mainly based on agriculture and the exploitation of spontaneous plant resources [2] and each year 80,000 to 100,000 ha of land are degraded [3]. This degradation remains a global concern due to the threat of desertification which has the environmental consequences of the gradual disappearance of vegetation cover and wildlife. It also has negative effects such as declining agricultural production, declining population incomes, food insecurity, and rural-to-urban migration. The situation was exacerbated mainly by droughts of 1972/73 and 1984/85, with the consequences of accelerating the phenomenon of desertification [4].

These repeated droughts and chronic food shortages cause the population to exploit the forest resources in an abnormal way in order to meet their energy needs, which results in a decrease in vegetation cover and an acceleration of runoff that promotes water and wind erosion on all the territory [5]. Globally, it is estimated that 75 billion tons of soil are eroded per year [6].

Fuelwood and service sampling as well as animal fodder are mainly located on the plateaus (high land) causing a disturbance of natural ecosystems by reducing the potential productivity of the soil, the loss of biodiversity, the virtual disappearance of certain ecological and cultural valuable species. In Niger, nearly 130,000 tons of timber are harvested and transported to urban centers each year [7]. In order to maintain sustainable socio-economic activities, production systems must therefore be regenerated. Faced with these problems, several mechanical and / or biological technics are used to restore the degraded lands of the plateaus (high land).

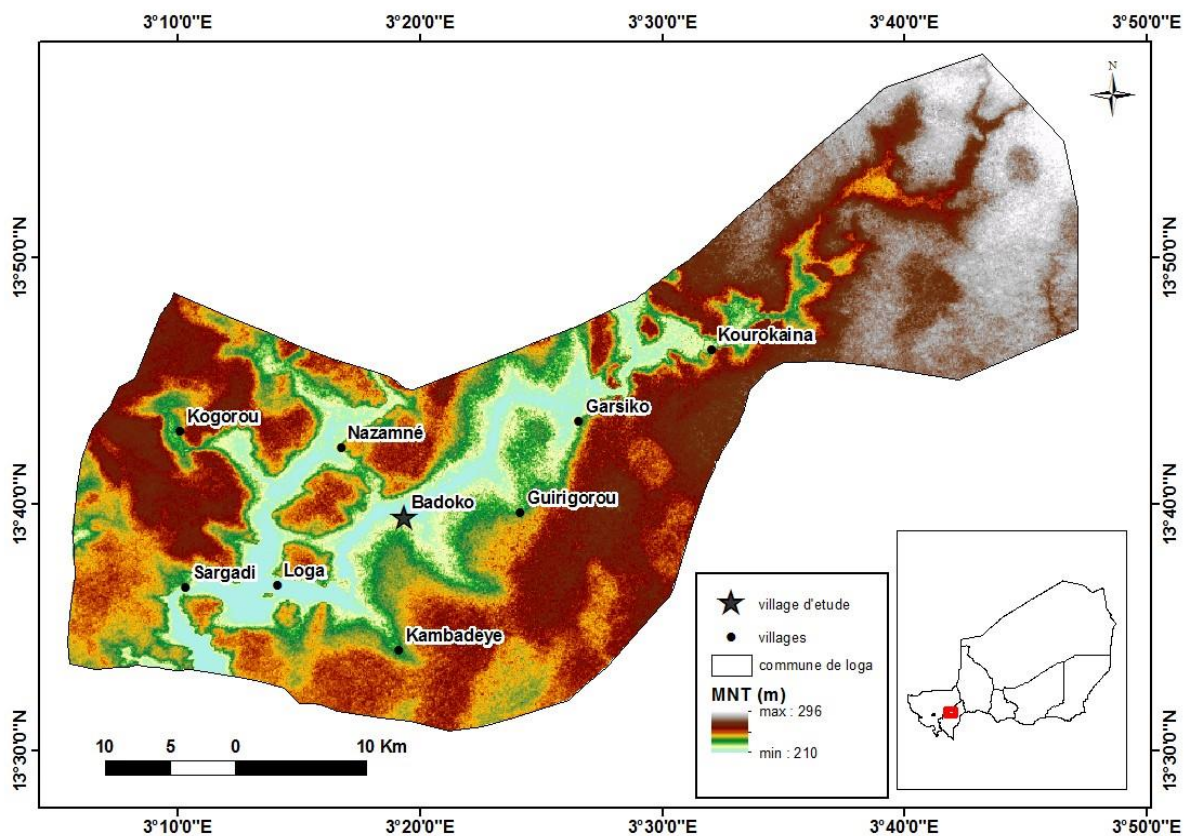
The CES/DRS technics are used to collect and control runoff from surface water, thus ensuring the infiltration of much of the rainwater, a collection of sediment transported by runoff. The CES/DRS techniques include several structures, including benches, which are very often used in the treatment of degraded land in the plateaus.

This study aims to: (1) Evaluate the socio-economic impact of actions to restore degraded lands on the lives of the populations concerned; (2) Assess the level of degradation of the benches after four years of implementation; (3) Appreciate the growth and development of trees planted in benches.

The present study provides an update on the sustainability, socio-economic aspects of the cash for work used in making the benches, the impact and the level of growth of plantations made in the benches.

PRESENTATION OF THE STUDY AREA

The village of Badoko is located 12 km north-east of Loga. It is located between the longitudes: $3^{\circ} 33-3^{\circ} 19'59''$ East and the latitudes: $13^{\circ} 66-13^{\circ} 40'0''$ North. It is bounded on the east by the villages of Bakitombo Gorou and Guirigorou, on the west by the villages of Tombo Bana and Sargadi, on the north by the village of Nazamn , on the south by the villages of Guid mario, Bouhoum and Kambadeye.



Source: (Djibril, 2015).

Figure 1: Location map of the study area

Theoretically, the benches are designed as shown in figure 2 below with the different parts and their dimensions.

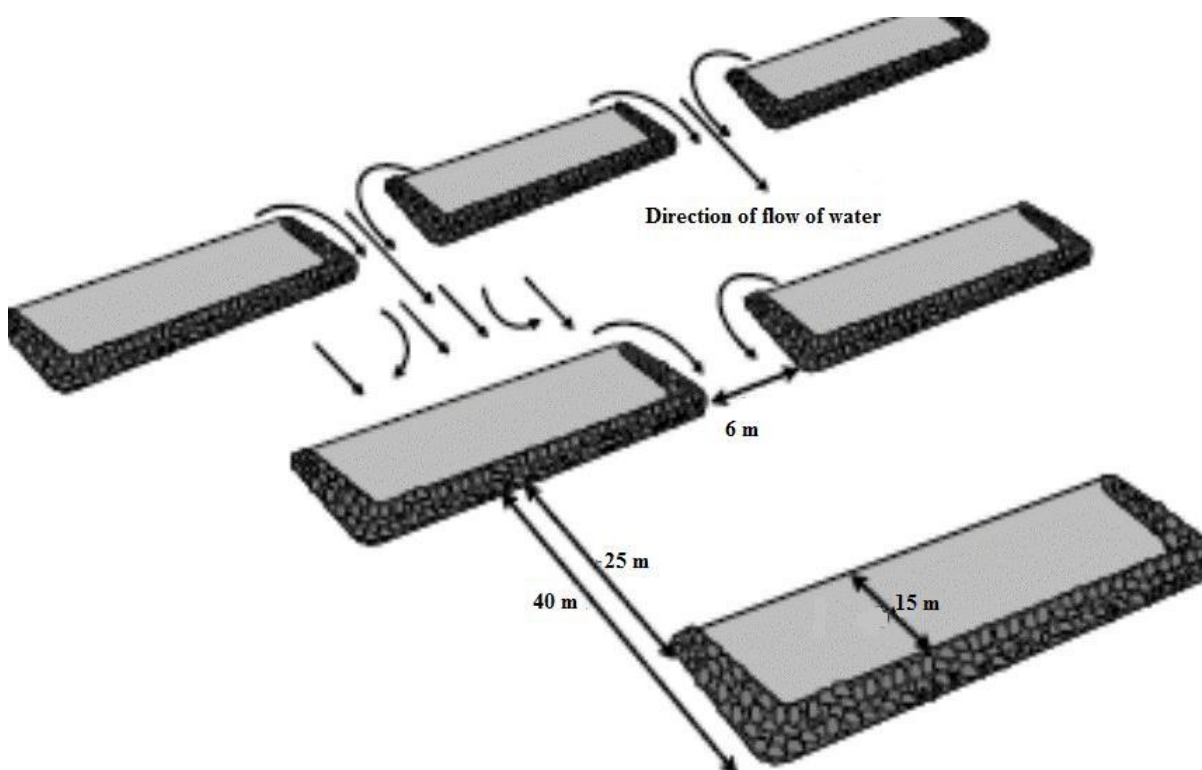


Figure 2: Device and dimensioning of the benches (Salouhou, 2013).

MATERIALS AND METHODS

Study site

Meetings with the authorities in particular, the Mayor, the project representative and the village chiefs were carried out initially. The technical services concerned were then consulted in order to share the content of the research protocol and its feasibility. These include the Department of the Environment and the Department of Agriculture.

The geographical coordinates of the site were determined using a Garmin GPS. Stakes have been placed for the delimitation of bands (transects) and rectangular plots. The measurements of the dimensions of the benches (length, width, spacing) were carried out using a tape measuring 50 meters. The dendrometry was carried out using a tape measuring 3 meters and a graduated pole of 5 meters. In addition, the lexicon of Niger plants, trees, shrubs and shrubs of the Sahel were used for the identification of floristic species [8; 9]. Photographs were taken using the Fujifilm digital camera (14 mega pixels).

The woody stand is composed of 5 plots of one hectare with 6 benches each. An exhaustive enumeration of woody individuals (planted and / or natural regeneration) was carried out in each plot.

The floristic composition of the planted trees is established by the exhaustive inventory of woody vegetation carried out between April and May 2015. The survival rate was increased and expressed as a percentage.

Socio-Economic Surveys

Individual surveys have been carried out. These involved fifteen (15) people out of a hundred and fifty (150) who participated in the recovery of the land, and were chosen randomly.

Measurement of the dendrometric parameters

The measurements of the dendrometric parameters are evaluated by the determination of the average density, the mean height, and the average diameter at the collar.

Alpha diversity is the species richness within a local ecosystem. It is obtained from the calculation of two indices which are:

- **The Shannon Diversity Index:** This index expressed in bits is based on the theory of information. It varies between 0 (zero diversity) and 5 bits (very high diversity) [10]. It is calculated using the following formula:

$$H' = - \sum_{i=1}^S \frac{n_i}{n} \log_2 \frac{n_i}{n}; n = \text{total workforce}; n_i = \text{number of individuals of a species } i.$$

- **The Pielou equality index** which varies between 0 and 1. It tends towards 0 when there is a phenomenon of dominance and towards 1 when the distribution of the individuals between the species is regular (no phenomenon of dominance).

It is defined by the formula:

$$E = \frac{H'}{\log_2 S}; H' = \text{observed diversity}; \log_2 S = \text{maximum theoretical diversity}$$

H' = Observed diversity, Log₂S = Theoric maximal diversity Analysis and Data Processing

The tabulation was initially manual before being coded and processed using the EXCEL spreadsheet to output useful information in the form of tables or figures.

RESULTS

Socio-economic impact of bench-making activities.

- **Forms of use of the financial resources received in cash for work by the populations concerned.**

Figure 3 below shows the distribution of financial resources received by the beneficiaries in cash for work.

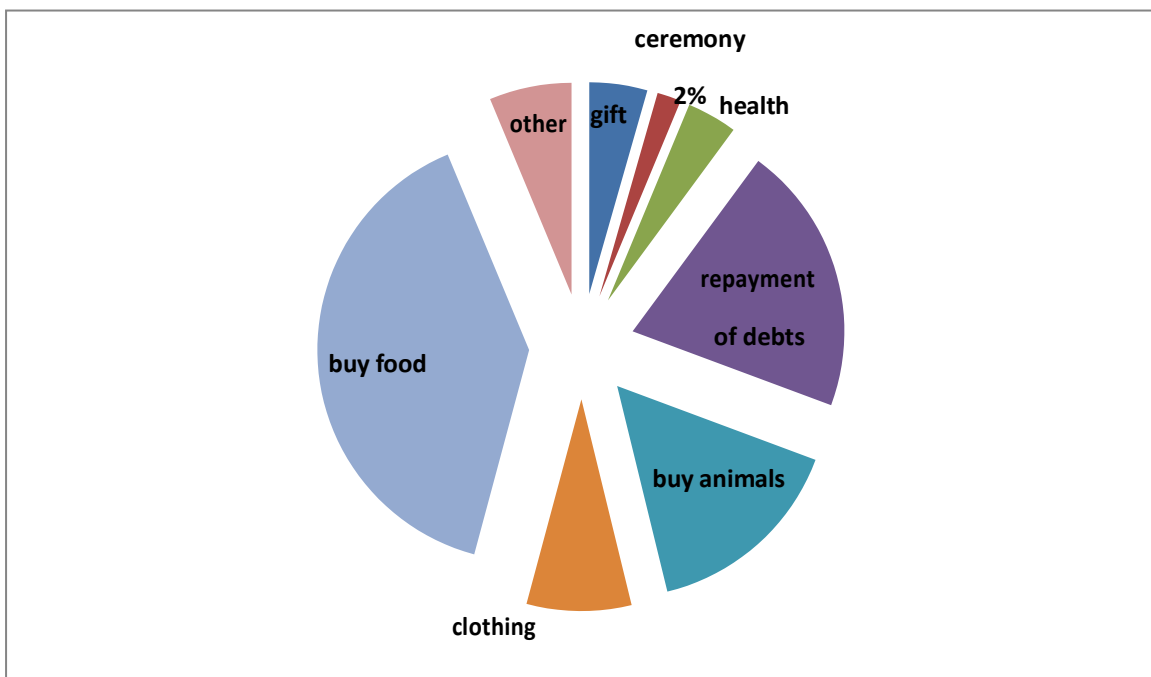


Figure 3: Distribution of sums received in cash for work by the beneficiary populations.

Survey results show that (1) 40% of the amounts earned are used to purchase food to better feed, (2) 21% to debt repayments, (3) 15% to purchases of animals, (4) 8% for clothing, and 16 % for gifts, health, ceremony and other.

Current status of works

Table 1 below shows the variation in the dimensions of the benches at the Badoko site.

Table 1: Dimensions of the benches of the Badoko site

THEORETICAL STANDARDS		Average field *	Standard deviation	CV(%)
Dimension of the seat element				
- width :	10m	10.8	0.79	7.33
- spacing :	25m	24.62	2.42	9.84
- length :	60m	59.30	2.11	3.57
Dimension of the bundle (bead)				
Width at base :	1.5	1.65	0.31	18.95
Height :	0.50 - 0,70m	0.66	0.31	46.89
Width at the top :	0.5 - 1m	1.55	0.52	33.90
Dimensions of the channel				
Channel width :	2m	2.30	0.33	14.39
Depth of channel :	20cm	18.48	5.74	31.06
Distance between 2 aligned benches :	6m	6.20	0.92	14.94

*: The average of the 30 benches measured on the ground.

The analysis of the measurements of the dimensions of the benches shows that the technical standards have been respected in general, however the width at the top and the depth of the gutter have undergone a slight modification. Indeed, the width at the top has increased by more than 0.55m and the depth of the trench decreased by 1.12cm. This can be explained by runoff and silting at the level of the benches designed 4 years ago. These effects of erosion combined with the non-respect of the dimensions (the norms of the tilting, the staggered aspect) can damage the benches. This can lead to new gullies that cause gully formation (see photo 1 below).



Photo 1: Broken bench and sanded bench.

Current status of site vegetation

The survival rate of plantations is shown in Table 2 below.

Table 2: Survival rates of local woody species planted.

Species	Situation of seedlings planted on the site		
	Number of seedlings planted	Number of planted seedlings alive	Survival rate (%)
<i>Acacia senegal</i>	300	203	67.66%
<i>Bauhinia rufescens</i>	100	63	63%
<i>Ziziphus mauritiana</i>	80	31	38.75%
Total	480	297	61.87%

Analysis of survival rates shows differences between species. These rates are 67.66%; 63% and 38.75% respectively for *Acacia senegal*, *Bauhinia rufescens* and *Ziziphus mauritiana*. The low survival rate for *Ziziphus mauritiana* can be explained by the fact that it is found on the last rows of benches in addition to the effect of rodents on seedlings after planting.

Composition of the current woody flora of the site

Table 3 below shows the composition of local woody species divided into families, genera and species.

Table 3: Composition of local woody flora divided into families, genera and species.

FAMILY	BOTANICAL NAME	LOCAL NAME		NUMBER OF GENDER	NUMBER OF SPECIES
		Zarma	Haoussa		
Mimosaceae	<i>Acacia senegal</i> (L.) Willd *	deligna	akwara	1	3
	<i>Acacia nilotica</i> (L) WILLD. Ex Del.	baani	bagaruwa		
	<i>Acacia albida</i>	gao	gao		
Combretaceae	<i>Combretum micranthum</i> G. DON.	kubu	giéza	2	2
	<i>Guiera senegalensis</i> (lam.) j.f. gmel.	sabara	sabara		
Caesalpiaceae	<i>Bauhinia rufescens</i> LAM. *	namary	dirga	1	1
Rhamnaceae	<i>Ziziphus mauritiana</i> LAM. *	darey	magaria	1	1
Cesalpiniaceae	<i>Pilotigma reticulatum</i> (DC) HOCHST.	kossai	kalgo	1	1
Capparidaceae	<i>Boscia angustifolia</i> a. RICH.	hassou	agahini	1	1
Anacardiaceae	<i>Sclerocarya birrea</i> (A. RICH.) HOCHST.	diney	daniya	1	1
Euphorbiaceae	<i>Chrozophora brocchiana</i> VIS et c. <i>senegalensis</i> (lam.) A. C.	dorey	damaigi	1	1
Myrtaceae	<i>Eucalyptus camaldulensis</i> debnhadt	farkahanga	touraré	1	1
TOTAL				10	12

*: Species planted in the benches.

The plateau of Badoko contains many vegetable potentialities. Indeed, in all the surveys of natural and planted species (Table 3), 10 genera grouped into 9 families were inventoried for a total of 12 species, 3 of which were planted in the benches. Mimosaceae with 3 species (31.43%) followed by Combretaceae with 2 species (46.57%) and other families (Caesalpiaceae, Rhamnaceae, Cesalpiniaceae, Capparidaceae, Anacardiaceae, Euphorbiaceae, Myrtaceae) are represented by a species with low frequencies (22%).

Herbaceous seeds

During this study, 4 families of herbaceous plants seeded on the site were inventoried. These families are grouped into 8 species and 7 genera. Indeed, these herbaceous seeds are highly appreciated by the breeders for the feeding of the animals.

The photos below show the growth rate of the planted trees and the condition of the herbaceous plants planted on the site.



Photo 2: Shows the state of the regenerated site.

Stand structure parameter

The site structure parameters are shown in Table 4.

Table 4: Site structure parameters

Diversity Parameter	Value
Shannon Diversity Index (H')	0.63729526
Pielou Equity Index (E)	0.59053589
Specific wealth (S)	12
Number of individuals	693

At the site level, the Shannon index (H') is relatively low with a value of 0.63 bits indicating an instability of the species in the medium. On the other hand, the Pielou equality index follows the opposite trend to that of Shannon. It is on average 0.59 bits. This explains why there is a phenomenon of dominance between species.

Growth in diameter of trees and shrubs

The distribution by size (cm) of the individuals of trees and shrubs allowed to appreciate the growth of the different species. Thus, the structure of the stand is represented by figure 4.

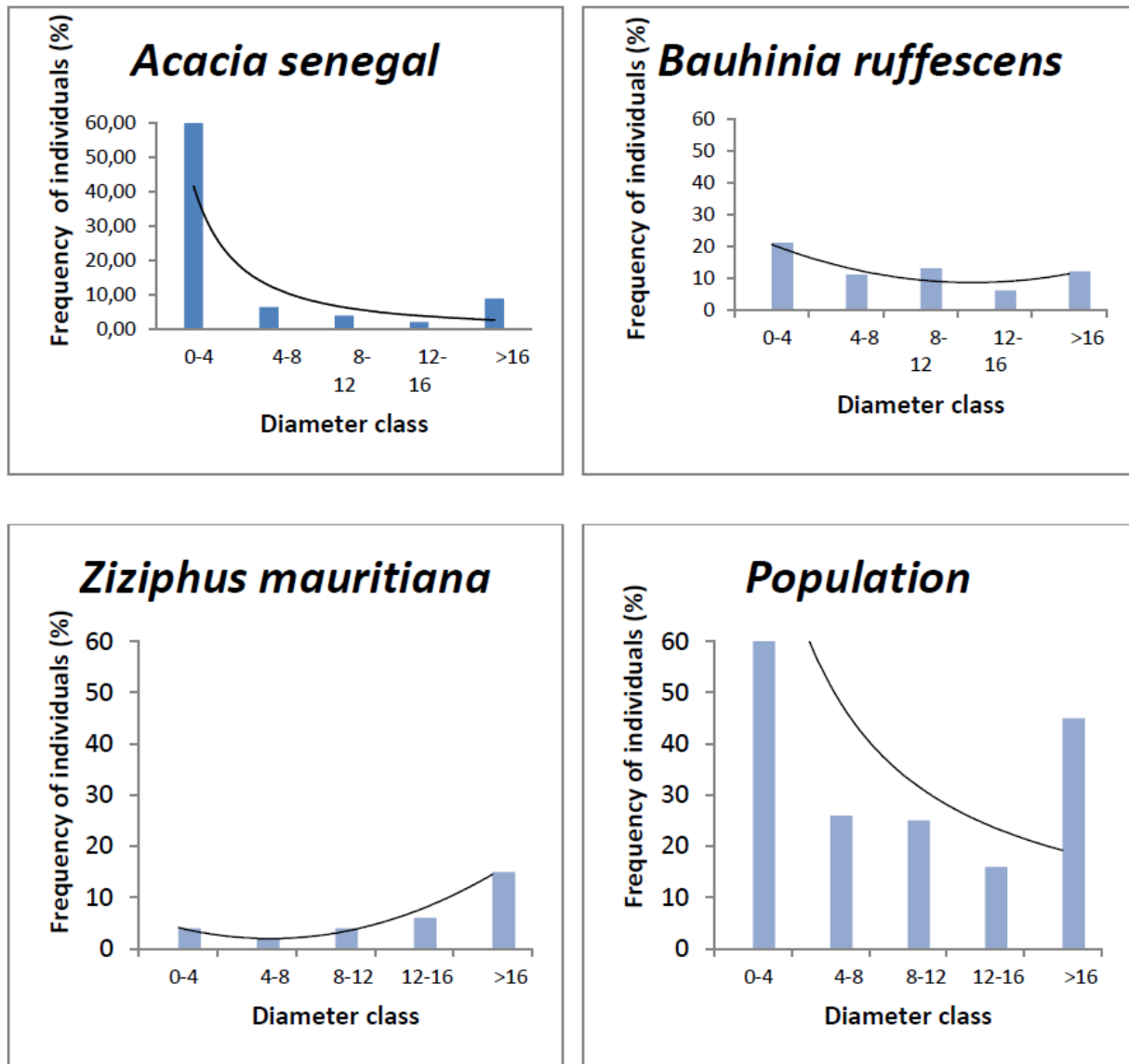


Figure 4: Structure by diameter class of trees and shrubs

The distribution of the individuals by class of diameters of the three species and the stand made it possible to make an analysis of the population structure of the different populations.

Examination of this figure makes it possible to say that *Acacia senegal* presents an "L" structure characterized by a decreasing distribution of individuals from large classes of diameter to small classes. Indeed, 78.8% of the individuals surveyed are concentrated in the small diameter class (0 to 4 cm).

Bauhinia ruffescens has an erratic or irregular distribution of individuals with moderately high growth rates of 33.3% in the 0 to 4 cm diameter class and 20.6% in the 8 to 12 cm diameter class. On the other hand, individuals of class 4 to 8 cm, 12 to 16 cm and > 16 cm are weakly represented respectively 17.4%, 9.5% and 19%.

As for the species *Ziziphus mauritiana*, it has a "J" structure characterized by an increasing distribution of individuals from small diameter classes to large classes. Indeed, 67.7% of the individuals enumerated are concentrated in the classes of large diameters (> 16 cm and 12 to 16 cm).

Growth in height of trees and shrubs

Figure 5 shows the distribution of trees and shrubs as a function of height.

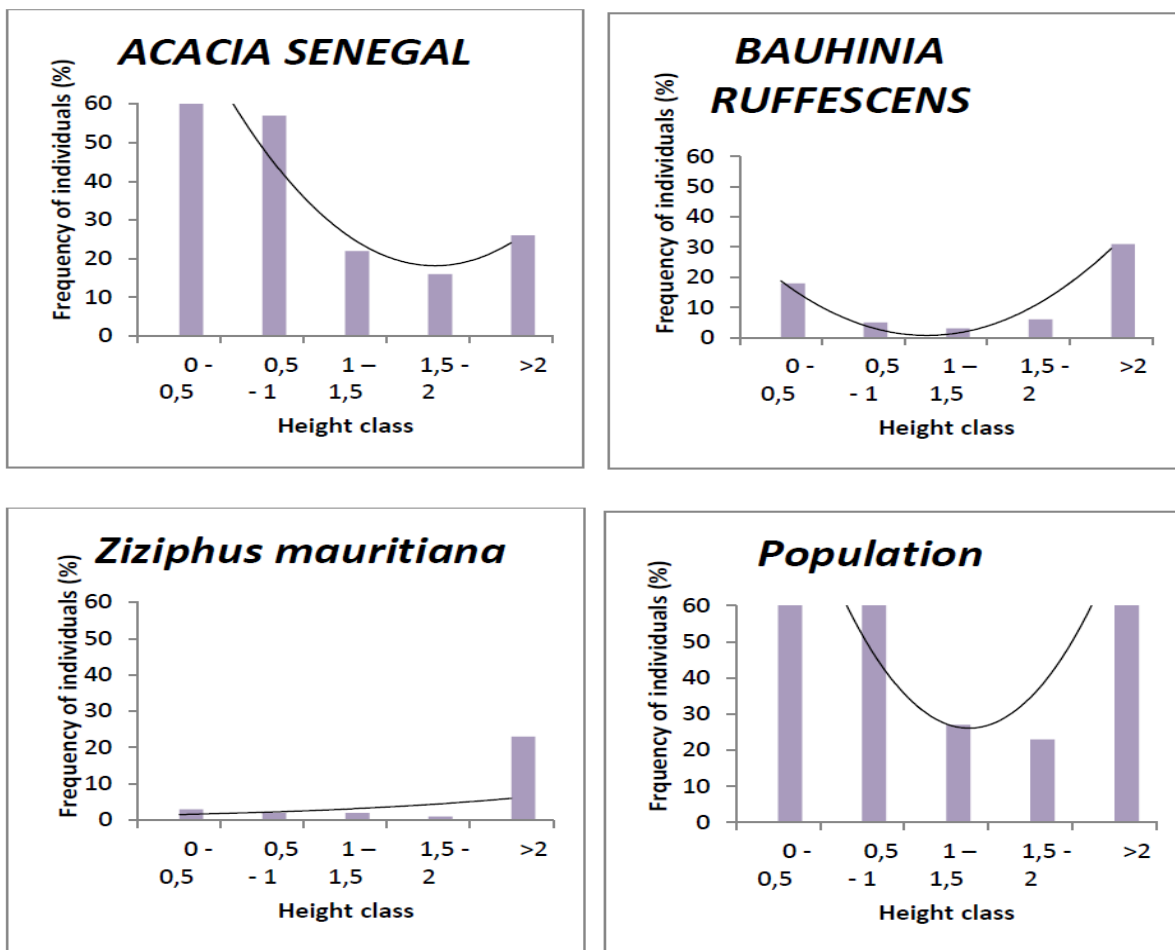


Figure 5: Structure by height class of trees and shrubs

The distribution of individuals by height class of the three species and their population makes it possible to comment on the population structure of the different populations (Figure 5).

Examination of this figure shows that *Acacia Senegal* presents an "L" structure characterized by a decreasing distribution of individuals from large classes of height to small classes. Indeed, 68% of the individuals enumerated are concentrated in the classes of small heights (0 to 0.5 m and 0.5 to 1 m). There was also an approximately low presence of individuals in the high heights classes (1 to 1.5 m, 1.5 to 2 m and > 2 m) with 10.8%, 7.8% and 12%, respectively.

The curve of the population of *Bauhinia ruffescens* is characterized by a strong number in the height classes > 2 m with 49.2%, then class 0 to 0.5 m with 28.5% then the other classes present with Small numbers 0.5 to 1 m; 1 to 1.5 m and 1.5 to 2 m, of which 7.9%, 4.7% and 9.5%, respectively.

The species *Ziziphus mauritiana* presents an erratic distribution which translates an irregularity of individuals with the high rates of 74% in the class > 2 m and weakly in the other classes.

Classes of trees and shrubs according to the number of branches at the collar

The distribution of individuals by branching class of the three planted species (*Acacia senegal*, *Bauhinia ruffescens*, *Ziziphus mauritiana*) is recorded only in the class from 0 to 2, ie the number of stem at the collar does not exceed 2.

DISCUSSIONS

The results of socio-economic surveys have enabled the populations to acquire financial means to meet their needs. After four years of realization of the benches, the gullying tends to decrease, the presence of the animals on the plateau (high land) for the grazing, the return of the forest and the runoff which is less important than before. These results are similar to those found in the village of Kobi in the rural commune of Tondikandia [11] and in the Badaguichiri watershed [12].

The cash for work allowed the beneficiary populations to have money that enabled them to buy food, repay their debts, buy animals, and get dressed.

The anti-erosion benches allowed the plantations to cross the periods of lack of rain during their growth. This has been observed in the Conservation and management of water and soils in Niger and in the Rehabilitation of fallow land degraded by CES/DRS technics in the Sahel [13; 14].

The diversity of the medium has a low Shannon index (H') with a value of 0.63 bits, indicating a high heterogeneity in the distribution of species at the site indicating the instability of the

medium. This has already been observed in ferlo in Senegal [15] and in the decommissioned area of the Tamou wildlife reserve [16]. On the other hand, the Pielou fairness index follows the opposite trend as that of Shannon. It is 0.59 bits. This reflects a dominance of species in the environment. The *Acacia senegal* and *Guiera senegalensis* species are in ecological balance compared to the other species because they undergo less pressure. These two species represent 76.76% of the vegetation cover, mainly 46.75% for rapidly propagating *Guiera senegalensis*, thus contributing to the regeneration of vegetation cover. This result is in line with that found in the declassified zone of the total Tamu fauna reserve [16] with 78.30% of the vegetal cover constituted by *Guiera senegalensis*.

The survival rates of planted species were 67.66, 63 and 38.75% respectively for *Acacia senegal*, *Bauhinia rufescens* and *Ziziphus mauritiana*. These results follow the same trend as those found in the Restoration of bare beaches of a spotted bush in Niger [17] for the same species (96, 89 and 65%).

The high mortality of the species *Ziziphus mauritiana* could be due to its eccentric position at the device (last rows of the structure). This situation was observed for the same species in the Restoration of bare beaches of a spotted bush in Niger [17].

CONCLUSION AND RECOMMENDATIONS

Land degradation is the main factor in the loss of biodiversity and the food insecurity of rural populations. This study made it possible to understand that the financial resources received in each for work contributed to the improvement of the lifestyles of the population. The dimensions of the benches have changed over time (silting and sagging). The floristic composition of the trees is determined through an inventory of 10 genera grouped into 9 families for a total of 12 species of which 3 planted in the benches. Mimosaceae include 31.43% species, Combretaceae 46.57% species and the other families only one species with low frequencies (22%) including Caesalpiniaceae, Rhamnaceae, Cesalpiniaceae, Capparidaceae, Anacardiaceae, Euphorbiaceae, and Myrtaceae.

The spiked herbs are summarized in 4 families grouped into 8 species and 7 genera.

The growth of the trees and shrubs of the 3 planted species (*Acacia Senegal*, *Bauhinia ruffescens*, *Ziziphus mauritiana*) has an average diameter of 28.01 cm and an average height of 5.49 m. For the number of branches per tree, only in class 0 to 2 for all species planted.

The benches had a positive impact on the woody vegetation of the Badoko site plateaus through:

- The rapid growth of the species *Bauhinia ruffescens* planted in the benches;

- The gradual return of vegetation to the site, which is appreciated by breeders;
- Soil fertilization due to the presence of trees and herbaceous cover;
- The feasibility of species planted after these four years of planting;
- The return of certain extinct species (*Monechma ciliatum*, *Commelina forskoalei*, *Sida ovate*).

For such studies potential recommendations may be summarized as follows:

- Recruit permanent custodians to protect sites against animal wandering and bush fires for at least 4 to 5 years so that plantations escape the tooth of animals and bush fires;
- Evaluate the impact of land reclamation operations on groundwater recharge;
- Intensify the awareness and training of local populations on the recovery of degraded lands and the management of biodiversity in general;
- Desensitize the benches and pour the sand on the impluvium to improve its fertility and maintain the standard of the depth of the bench after these four years.

BIBLIOGRAPHICAL REFERENCES

[1] ICRISAT Niger, 1994. Annual Activity Report, Niamey, Niger. 87 p.

[2] Moussa MS, Amadou B., 2011. Local governance and control of space in a context of degradation of natural resources: Games and stakes of actors around the village territory of Tulwarey (periphery of Niger's W Park) Kara sani, 15: 76-103.

[3] Issaka A. S., 2009. Climate Change and Environmental Assessment: Issues and Tools for Impact Assessment and Development of Adaptation Plans. 14th International Colloquium on Environmental Assessment, Niamey, Niger. 31 p.

[4] Larwanou. M., 2005. Dynamics of vegetation in the Sahelian domain of western Niger following a gradient of aridity: ecological, social and economic roles, Doctoral thesis, FS / UAM of Niamey, Niger. 186 p.

[5] Anderson et al., 2000. Null Hypothesis Testing: Problems, Prevalence, and an Alternative Author(s): David R. Anderson, Kenneth P. Burnham, William L. Thompson Source: The Journal of Wildlife Management, Vol. 64, No. 4 (Oct., 2000), pp. 912-923 Published by: Allen Press Stable URL: <http://www.jstor.org/stable/3803199> Accessed: 14/10/2008 12:35. 13 p.

[6] Volebele. H., 2011. State of play and analysis of erosion in the Lèze valley. Toulouse France: Internship report. SMIVAL, INP-ENSAT: 78 p.

- [7] Karim S., 2001. Contribution to the study of natural regeneration through vegetative propagation of two Combretaceae in western Niger (*Combretum micranthum* G. Don and *Guiera senegalensis* J.F. Gmel) consequences for pastoral forestry management. Univ., Ouagadougou.
- [8] ARBONNIER M., 2009. Trees, shrubs and vines of the dry zones of West Africa, QUAE, Paris, France 3rd edition.
- [9] MAYDELL (von) H.J., 1983- Trees and shrubs of the Sahel. Their characteristics and uses. GTZ, Niamey – Niger. 530 P.
- [10] Frontier S., Pichoud-Viale D., 1993. Ecosystems: Structures, functioning, evolution. Paris: Masson, 1993.
- [11] Mana K. I., 2013. Study of socio-economic and environmental impacts of land recovery operations degraded in the Rural Municipality of Tondikandia: Final dissertation, FA / UAM, Niamey, Niger. 81 p.
- [12] Elhadji A. I., 2014. Impact of land restoration on the vegetation dynamics of the Badaguichiri watershed. Final dissertation in the AGRHYMET Regional Center, Niamey, Niger. 69 p.
- [13] Michel E., and Guero Y., 2000. Conservation and management of water and soil in Niger: Ecological sustainability of the Nord-Sahelian agricultural production system. 119 p.
- [14] Ambouta, Moussa, and Daouda, 2000. Rehabilitation of fallow land degraded by CES / DRS techniques in the Sahel. In «fallow in tropical Africa: roles, adjustments, alternatives». Proceedings of the international seminar, Dakar, 13-16 April 1999. Volume1. Pp.751-759.
- [15] Akpo et al., 2003. Floristic diversity of the woody stands of Ferlo, Senegal. Vertigo-the e-journal in Environmental Sciences [Online], Volume 13 Issue 3 / December 2013 Posted on January 24, 2014, accessed on September 10, 2015. URL: <http://vertigo.revues.org/14352> ; DOI: 10.4000 / vertigo.14352
- [16] Douma S., Idrissa S., Morou B., Mamoudou H., Saley K., Ali M and Saadou M. 2012. Diversity of the ligneous stand of the agroforestry parks of the Tamou Wildlife Reserve. (Niger). N ° 18-2012-ISSN: 1028-6535. 191-210
- [17] Douma S., Ali M., Saadou M., Ambouta K., Ichaou A and Gandou Z. 2011. Restoration of bare beaches in a spotted bush in Niger. Africa SCIENCE 07 (1) (2011) 77-92. 16 p.