IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 16, Issue 12 Ser. I (December 2022), PP 16-31
www.iosrjournals.org

Economic analysis of the ecosystem services rendered by the realization of plants of recovery for degraded lands in the rural commune of Badaguichiri (Region of Tahoua-Niger).

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Abstract
Niger, a West African country, has an arid climate marked by a lack of rainfall, high evapotranspiration and chronic drought. This combination of circumstances exposes the country to land degradation, the main environmental problem facing the country. As a result of this problem, several techniques for restoring degraded land have emerged in all regions of the country. This study was conducted in the rural commune of Badaguichiri in the department of Illéla (Tahoua region), with the aim of demonstrating the importance of ecosystem services and the economics of land reclamation works carried out in this commune. The sites selected for this study, according to the type of work, namely Nagaroa (agricultural bench), Tambass (agricultural stone cordon), Lalamna (sylvopastoral bench) and Kiré-Kafada (sylvopastoral half-moon), were the subject of socio-economic surveys based on random sampling. On the basis of the investments made, the estimation of the financial and economic profitability of the works was planned on two horizons (4 and 8 years). The calculation of NPV and IRR remains positive for all the facilities at a discount rate of 10%, implying that the facilities are viable regardless of the income of the population. This indicates that the facilities are viable from the point of view of the land users. The NPV increases when "Cash for Work" is added, indicating that without "Cash for Work", the development remains viable even if the income of the producers is lower.
Keywords: *Benching, Stone cordon, half moon, Cash for Work, net present value (NPV), internal rate of return (IRR), Cost-benefit analysis.*

Date of Submission: 02-12-2022 Date of Acceptance: 14-12-2022

I. Introduction

Land degradation negatively affects the condition and management of natural resources (water, soil, plants, and animals) and leads to decreased agricultural production (UNCCD, 2012). Reviews on global land degradation state that Africa is particularly vulnerable to land degradation and desertification, and is the most severely affected region (ELD, 2015). Indeed, the drylands of West Africa in general and Niger in particular especially in the Tahoua region, people already endure poverty, food insecurity, caused by land degradation which often leads to impoverishment, migration and conflict. In Tahoua, due to desertification and land degradation, soils are losing their structure and fertility, and this is affecting crop yields and vegetation used for livestock production, and consequently local livelihoods and the regional economy. This has led to soil disintegration and erosion with the formation of impermeable lateritic crust preventing water infiltration and plant root penetration (Balarabé, 2012). From then on, it was necessary to act to try to reverse the trend or at least stabilize the situation for the benefit of future generations because the risks of disappearance of the production potential in the Sahel area were real (Angel and Elsa, 2012). By 2030, Niger is committed to achieving neutrality of land degradation, reducing degraded areas from 9% to 5% and increasing vegetation cover from 17% to 19% in order to sustainably improve the living conditions of populations throughout the national territory in general and in the Tahoua region in particular. Thus, for decades, the government and NGOs have intervened in the area to stop this land degradation that constitutes the main constraint for sustainable agricultural production and therefore a real threat to food security (Mariama M., 2013). However, in order to deal with the pronounced degradation of soils, techniques for reclaiming degraded land are seen as an adequate solution and concern mainly highly degraded areas with low production potential. Several sustainable land management techniques have been installed by these projects and programs throughout the Tahoua region in general and in the commune of Badaguichiri in particular. Many studies have been conducted nationally and in Tahoua in particular to determine the impact of investments in natural resource management. Nevertheless, few of these studies provide information on the socio-economic importance of land reclamation techniques, whereas their applications aim not only to combat soil degradation for better land productivity, but also to improve human socio-economic and cultural well-being. Human well-being depends on the functioning of ecosystems and their ability to provide ecological goods and services, such as food and drinking water supplies (Vanja et al., 2017). Indeed, humans benefit from the many non-timber forest products and services of plant origin (leaves, flowers, fruits, seeds, bark, sap, fiber, rhizomes, etc.) that multipurpose woody plants abound (Mavsar et al., 2017).

The purpose of this study is therefore to provide additional information with the central question: what is the ecological impact and economic profitability of the anti-erosion techniques used to restore degraded land in the rural commune of Badaguichiri? The theme "Plant diversity and economic analysis of services rendered by techniques for the recovery of degraded lands in the rural commune of Badaguichiri (Tahoua Region)" is thus proposed to provide elements of an answer to this question.

In order to assess the potential benefits of adopting sustainable land management practices, and the economic consequences of land degradation, this study is part of the overall "Economics of Land Degradation" (ELD) initiative and approach.

1. Presentation of the study area

The present study was conducted in the commune of Badaguichiri covering an area of 1360 km² and located in the eastern part of the department of Illéla (Tahoua region) between latitudes 14°25'10" and 14°34'00" North and longitudes 5°16'45" and 5°26'10" East (Figure 1). It is bounded to the east by the rural commune of Alakayé, to the west by the urban commune of Illéla, to the south by the rural commune of Tajayé; and by the rural communes of Garhanga, Kalfou, Bambaye and Tamaské to the north (Figure 1).

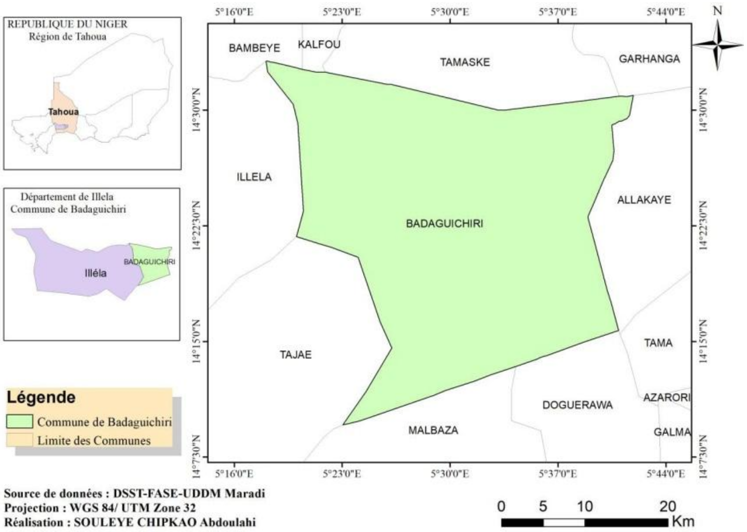

Figure 1 Map ofthe rural commune of Badaguichiri.

II. Material And Methods

1Sampling

1.1.Selection of study sites

Fieldwork was conducted at four sites. The choice of these sites is guided by two criteria. The first is related to the geomorphological units and the second to the type of land reclamation techniques carried out on the site. These criteria were chosen taking into account the development of the different landscape units (plateaus, slopes, glacis). Thus, a sub-basin approach was applied according to the types of techniques called CES (Water and Soil Conservation) and DRS (Soil Defense and Restoration). This approach consists in delimiting the portion of one of the tributaries that feed the basin of the rural commune of Badaguichiri. For this purpose, four sites (Figure) were selected from south to north according to the variation and according to the topographic sequences. These are the Nagaroa agricultural bench site, the Lalamna sylvopastoral bench site, the Kiré-Kafada sylvopastoral half-moon site and the Tambass stony cordon site.

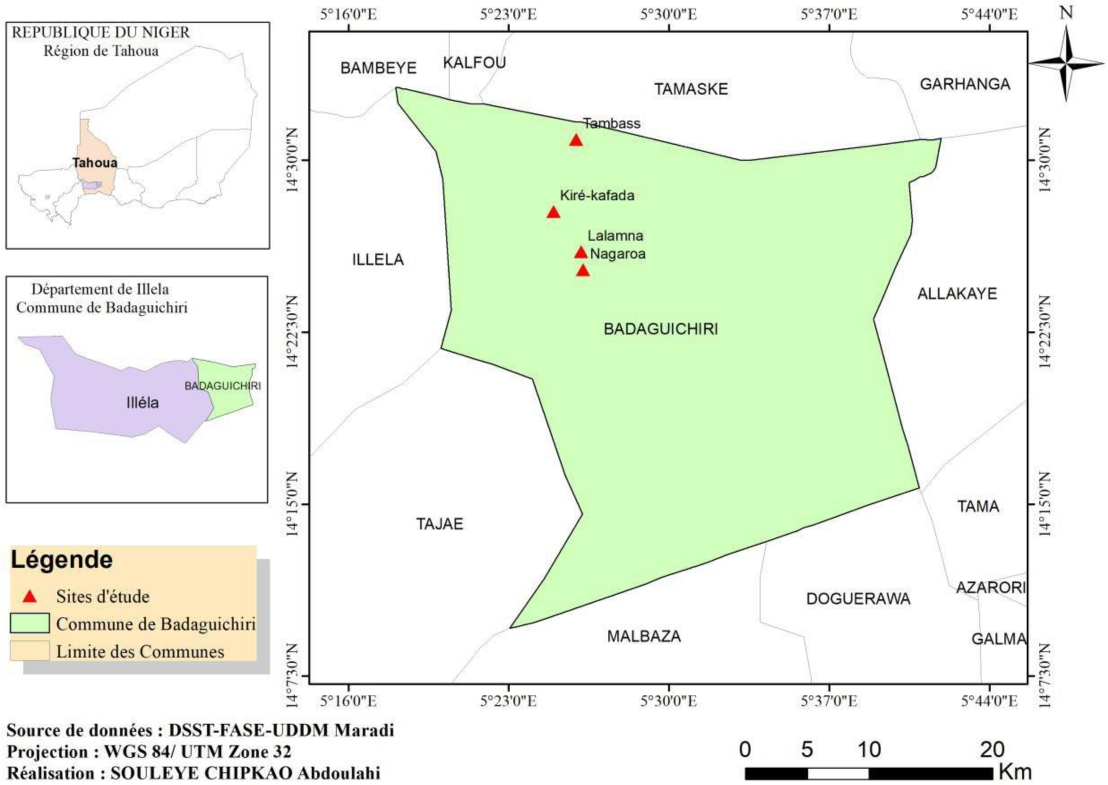

Figure 2: Map of the location of the sites studied in the commune.

1.2.Description of the sites

1.2.1.Nagaroa Agricultural Bench Site

This is a plateau reclaimed using the bench technique for agricultural purposes, where the main species cultivated in the rainy season are millet, sorghum, groundnuts and cowpeas. The populations also exploit on this site wood for domestic and commercial use (Figure 3).


Figure 3: Views of the Nagaroa Farm Bench Site.

1.2.2.Site of sylvopastoral benches of Lalamna

This site is located on a plateau reclaimed and grazed by the Peulhs (herders) of the village of Lalamna. It is a site of silvopastoral benches made in 2006 and rehabilitated in 2010 (Figure 4).

Figure 4: Views of the Lalamna silvopastoral bench site.

1.2.3.Site of sylvopastoral half-moons of Kiré-Kafada

The half-moon site of Kiré-Kafada is characterized in the south by a gently sloping plateau surrounded by rainfed fields. The site begins on a plateau and ends on the glacis from the west to the east of the village, reclaimed by the half-moons seeded with two herbaceous species (*Cenchrus biflorus* Roxb, *Pennisetum pedicellatum* Trin) and planted with *Acacia senegal* (L.) Willd. and fencing (Figure 5). This site was completed in 2006 by the Badaguichiri Watershed Project.

Figure 5: Views of the Kiré-Kafada half-moon site.

1.2.4.Tambass stone cordon site

The Tambass stone cordon site was completed in 2014 by the NGO (LWR/Nazari) and is located on a steeply sloping glacis with the objective of decreasing the velocity of runoff water that threatens the fields and people of the village. Part of this site is seeded with a herbaceous species (*Pennisetum pedicellatum* Trin) and the other part has been cultivated.

Figure6: Views of the Tambass rocky outcrop site.

1.3.Selection of respondents

The sampling of respondents was done according to the status (pastoral and agricultural) of the sites. In the villages of Kiré-Kafada and Lalamna, whose sites are sylvopastoral, a sample of 10% of all households was surveyed at random (Table 1). In Nagaroa and Tambass, on the other hand, since the sites are agricultural, the sample of respondents was based on the site's farmers. A sample of 50% of all farmers was surveyed according to the layout of our survey plots on the sites. For the focus group, in each village, people meet without distinction of gender and the number varies from one village to another.

Table 1: Distribution of the population and respondents in the study villages

Villages	Number of operators	Number of farmers surveyed	
		Male	Woman
Nagaroa	72	20	15
Tambass	63	18	14
Total	**904**	**38**	**29**
Villages	Number of households	Number of households surveyed	People surveyed
Kiré-Kafada	145	15	30
Lalamna	320	32	64
Total	**465**	**47**	**94**

2.Estimating ecosystem service values

Two methods were used in estimating the economic values of the services provided by the land reclamation techniques taken in this study: the market price method and the contingent valuation method.

2.1.Marketprice method

The market price method has been used to estimate the economic value of ecosystem goods or services that are sold or purchased in markets. The market price method can be used to estimate qualitative and quantitative changes in a good or service. It uses standard economic techniques to measure the economic benefits provided by goods and services available in markets. The measures are based on the quantities of goods or services purchased at different prices, as well as the quantities supplied at different prices (Mavsar, 2013).

2.2.Contingent valuation method

The contingent valuation method is a questionnaire-based technique that seeks to determine individual preferences for environmental change. The contingent valuation method is based on the basic assumption that individuals are sensitive to a given environmental change, and their preferences can be measured in terms of willingness to pay (WTP) to experience that change, or willingness to receive (WTA) compensation to avoid it (Voltaire, 2011). WTP is the maximum amount of money an individual is willing to pay rather than forego an improvement in the service provided by a natural asset. It is the amount of money the consumer is willing to pay to avoid losses in environmental quality. The RAC or willingness to accept (WTA) is the minimum amount of money that an individual would require to voluntarily forego an improvement in the quality of service provided by a natural asset. In other words, it is a monetary compensation that the consumer is willing to receive for a welfare loss. In the case where individuals are not willing to give up their willingness to pay because they do not desire the good. In this case, WTP is not an accurate measure of the overall benefit to the community. On the other hand, some individuals may be willing to pay more than the market price. The expenditure incurred in purchasing the good thus represents the willingness to pay.

Results

1.Quantified ecosystem services

The main ecosystem services quantified by the yield square method for agricultural and pastoral products (biomass) and others by the socio-economic survey considered in the sites of this study are grouped into three (3) categories that are provisioning services, regulating services, and supporting services. Cultural services were not taken into account in this study.

In fact, this study was only interested in sites with a primarily agricultural vocation and not recreational, aesthetic, educational or religious purposes.

1.1.Procurement Services

These are products for consumption, construction or commercial use by farmers such as wood, construction materials, cash crop products (groundnuts, cowpeas) and subsistence crops (millet, sorghum), fodder (crop residues). The stock of these products from the treated sites quantified especially at the agricultural sites (Nagaroa and Tambass); fodder for animals (Table 2) and genetic resources for medicines is higher than that of the control sites.

Table 2: Stocks of Major Procurement Services

Home villages	Stocks of products	Test sites	Treated sites
Nagaroa (agricultural benches)	Millet (kg/ha)	178,08	212,02
	Sorghum (kg/ha)	51,95	104,5
	Cowpea (kg/ha)	65,5	90,62
	Peanut (kg/ha)	96,75	267,97
	Wood (stere)	0,6	8,31
Tambass (agricultural stone cordons)	Millet (kg/ha)	156	210
	Wood (stere)	0,54	3
	Straw (kg/ha)	95,55	180
Kiré-Kafada (sylvopastoral half-moons)	Straw (kg/ha)	119,95	11760
	Wood (stere)	0,96	4
Lalamna (silvopastoral benches)	Straw (kg/ha)	73	140
	Wood (bundle)	8	18

In terms of wood production, the silvopastoral bench site has a higher production (12.05 steres of wood/ha) followed by the agricultural bench site (8.31 steres/ha). The results show that the stony cordon (1.96 steres/ha) and sylvopastoral half-moon (2 steres/ha) sites produce almost the same amount of wood stere/ha (Table 3).

Table 3: Results of processing wood production/ha data from sites

Types of works	Wood volume (sample)	Volume (m^3) wood/site	Stere/ha wood/site	economic value (FCFA)
Agricultural bench	1,75	5,82	**8,31**	16622,99
Witness	0,13	0,42	0,60	1209,14
Stone cordon	0,41	1,35	1,96	3865,71
Witness	0,06	0,19	0,27	542,25
Silvopastoral bench	2,53	8,43	**12,05**	24091,43
Witness	0,22	0,74	1,06	2125,77
Half-moon sylvopastoral	0,42	1,40	2,00	4000,00
Witness	0,14	0,48	0,68	1361,90

Given that a bundle of dry matter weighs 7.35 kg, the results for biomass production per hectare (Table), show that the site with sylvopastoral half-moons has more biomass (375.51 kg/ha). Next is the site with agricultural benches (281.63 kg/ha), ahead of the sites with stony strips (85.71 kg/ha) and the site with sylvopastoral benches, which has a very low production (19.05 kg/ha). These results indicate that the biomass of the control sites is very low compared to that of the treated sites.

Table 4: Treatment results for biomass production/ha of sites

Type of work	Tms/ha	Total portion (t)	Total portion (Kg)	Number of boots	Economic value (FCFA)
Agricultural benches	2,07	2,07	**2070**	281,63	98571,43
Witness	0,11	0,11	110	14,97	5238,10
Stone cordon	0,63	0,63	**630**	85,71	30000,00
Witness	0,1	0,1	100	13,61	4761,90
Silvopastoral benches	0,14	0,14	140	19,05	6666,67
Witness	0,01	0,01	10	1,36	476,19
Half-moons for sylvopastoral purposes	2,76	2,76	**2760**	375,51	131428,57
Witness	0,12	0,12	120	16,33	5714,29

1.2.Regulatory Services

The types of these services quantified in this study are carbon storage and sequestration (Table), flood and wind reduction, and soil erosion. The carbon stock was essentially taken into account at the Kiré-Kafada silvopastoral site, the only site that benefited from the planting of *A. senegal trees*. Thus, the quantity of carbon was calculated according to the Thiam allometric equation model. A quantity of 10498.67 kg/ha was obtained, i.e. 10.50 tons/ha.

Table 5: Total amount of carbon (silvopastoral half-moon)

Coefficient	DHP^3		DHP^2		DHP	Constant	Carbon (kg)
0,032	0,00001654	1,0160	0,00064911	10,87	0,02547771	7,429	7,71
0,032	0,00001654	1,0160	0,00064911	10,87	0,02547771	7,429	7,71
0,032	0,00001108	1,0160	0,00049698	10,87	0,02229299	7,429	7,67
0,032	0,00003230	1,0160	0,00101424	10,87	0,03184713	7,429	7,77
0,032	0,00015869	1,0160	0,00293115	10,87	0,05414013	7,429	8,01
0,032	0,00010901	1,0160	0,00228204	10,87	0,0477707	7,429	7,95
0,032	0,00004299	1,0160	0,00122723	10,87	0,03503185	7,429	7,81
0,032	0,00003230	1,0160	0,00101424	10,87	0,03184713	7,429	7,77
0,032	0,00004299	1,0160	0,00122723	10,87	0,03503185	7,429	7,81
0,032	0,00003230	1,0160	0,00101424	10,87	0,03184713	7,429	7,77
0,032	0,00005582	1,0160	0,00146051	10,87	0,03821656	7,429	7,84
0,032	0,00008863	1,0160	0,00198791	10,87	0,04458599	7,429	7,91
0,032	0,00007096	1,0160	0,00171407	10,87	0,04140127	7,429	7,88
Total							**101,61**
Total carbon (kg)				10498,67			
Carbon/ton				**10,50**			

1.3.Support Services

These services mainly concern biomass, soil formation and nutrient cycling. Except for runoff protection and flood control quantified by the willingness-to-pay method, most of the economic values of these services have therefore not been quantified.

2.Uses of priority woodyspecies

A total of 15 of the 28 woody species identified are the most used by the inhabitants according to the results obtained during the survey: *Acacia nilotica (L.)* Willd. ex Del., *Acacia senegal* (L.) Willd., *Acacia tortilis* (forsk.) Hayne, *Balanites aegyptiaca* (L.) Del., *Bauhinia rufescens*, *Cadaba farinosa* Auct., *Combretum glutinosum* Perr ex DC, *Combretum micrantum* G.Don., *Faidherbia albida* (Del.) Chev, *Guiera senegalensis* J.F Gmel, *Leptadenia hastata* (Pers.) Decne, *Piliostigma reticulatum* (DC.) Hochst, *Prosopis juliflora* (Sw.) DC, *Sclerocarya birrea* (A. Rich.) Hochst and *Ziziphus mauritiana* Lam.

2.1.Useof organs of woody species

The different parts of the above-mentioned woody species are used by the local populations to satisfy different needs (Table and Table).

In the four villages studied, people use either leaves, fruits, stems (branches), bark and roots in their daily needs in different proportions. However, the plant organs do not have the same degree of importance for the population. In Nagaroa and Tambass, the leaves and fruits of *Faidherbia albida* (Del.) Chev are used for animal feed, while those of *Balanites aegyptiaca* (L.) Del. and *Leptadenia hastata* (Pers.) Decne are used mainly for human consumption.

Combretum micrantum G.Don. *Guiera senegalensis* J.F Gmel and *Combretum glutinosum* Perr ex DC are more used for their wood.

Table 6: Frequency of use of different organs of woody species used by the populations of Nagaroa and Tambass

Scientific names	Sheet	Fruits	Root	bark/gum	Branch
F. albida	**54,29**	**51,43**	-	25,71	**38,57**
A. tortilis	4,29	**45,71**	3,93	-	20,02
P. reticulatum	-	**45,71**	-	-	**32,86**
B. aegyptiaca	**65,71**	**32,86**	-	6,79	26,43
G. senegalensis	1,43	-	15,71	-	**54,29**
L. hastata	**77,14**	**32,50**	-	-	-
A. senegal	-	4,29	-	20,07	14,29
S. birrea	**30,02**	10,01	7,14	10,71	22,86
B. rufescens	**34,29**	5,71	-	4,29	20,01
Z. mauritiana	-	**65,71**	7,14	1,43	18,57
A. nilotica	-	**37,14**	4,29	11,43	22,86
P. juliflora	-	5,71	-	5,71	20,07
C. micranthum	-	-	-	-	**44,29**
C. farinosa	**58,57**	2,86	-	**51,43**	32,86
C. glutinosum	8,57	-	8,21	-	**42,86**
Total % of total	**334,29**	**339,64**	**47,86**	**136,79**	**410,71**

In Kiré-Kafada and Lalamna, the leaves of *Leptadenia hastata* (76.79%), *Balanites aegyptiaca* (63.93%) and *Cadaba farinosa* (55.71%) are the most appreciated by the population. These leaves are all used in human food as well as the fruits of *Ziziphus mauritiana* (68.21%).

Table 7: Frequency of use of different organs of woody species used by the populations of Kiré-Kafada and Lalamna

Scientific names	Sheet	Fruits	root	bark/gum	Branch
A. nilotica	-	**33,93**	6,79	11,07	19,64
A. senegal	-	5,36	-	**40,10**	11,07
A. tortilis	10,12	**40,02**	5,36	11,07	13,93
B. aegyptiaca	**63,93**	25,36	-	5,36	21,07
B. rufescens	**35,36**	5,36	3,93	6,79	19,64
C. farinosa	**55,71**	6,79	-	**52,86**	**35,36**
C. glutinosum	11,07	-	5,36	-	**40,71**
C. micrantum	5,36	-	-	-	**40,31**
F. albida	**42,86**	**51,07**	-	25,71	**34,29**
G. senegalensis	19,64	-	11,07	-	**48,21**
L. hastata	**76,79**	**33,93**	6,79	-	-
P. reticulatum	3,93	**35,36**	-	-	28,21
P. juliflora	-	6,79	-	5,36	13,93
S. birrea	28,21	15,36	4,29	5,36	13,93
Z. mauritiana	-	**68,21**	13,93	5,36	15,36
Total (%)	**352,86**	**327,50**	**57,50**	**168,93**	**355,36**

2.2.Ethnobotanical use values ofplantspecies

Priority plants (most used) are used for livestock feed (Ab), human food (Ah), fuelwood (Bc), service wood (Bs), timber (Bo), pharmacopoeia (Ph), and income (Sr). In the case of agricultural sites (Table) for example, in Nagaroa, *Faidherbia albida* and *Acacia tortilis* are the most used species with total VUT values of 3.86 and 3.21; followed by *Balanites aegyptiaca* (2.67). While in Tambass, *Balanites aegyptiaca* (3.40) is the most used species followed by *Ziziphus mauritiana* (2.56) and *Cadaba farinosa* (2.52).

Table 8: List of major species used, total use values (TUVs) and service categories in Nagaroa and Tambass

Nagaroa			Tambass		
Species	**Uses**	**VU_T**	**Species**	**Uses**	**VU_T**
F. albida	Ab, Bc, Bs, Ph, Sr	3,86	*B. aegyptiaca*	Ab, Ah, Bc, Bo, Bs	3,40
A. tortilis	Ab, Bc, Bs, Ph, Sr	3,21	*Z. mauritiana*	Ah, Bc, Ph, Sr	2,56
B. aegyptiaca	Ab, Ah, Bc, Bo, Bs	2,67	*C. farinosa*	Ab, Ah, Ph, Sr	2,52
P. reticulatum	Ab, Ah, Bc, Bo, Bs, sr	1,88	*G. senegalensis*	Ab, Bc, Bs, Ph	1,44
G. senegalensis	Ab, Bc, Bs, Sr	1,46	*A. senegal*	Ab, Ah, Ph	1,14
L. hastata	Ab, Ah, Ph	1,36	*F. albida*	Ab, Bc, Bs, Ph, Sr	1,07
A. senegal	Ab, ph, Sr	1,11	*P. reticulatum*	Ab, Ah, Bc, Bo, Bs, sr	0,98
S. birrea	Ab, Ah, Ph	0,96	*A. tortilis*	Ab, Ah, Bc, Bo, Bs	0,92
B. rufescens	Ab, ph	0,92	*A. nilotica*	Ab, Ph	0,87
Z. mauritiana	Ah, Ph, Sr	0,82	*C. micrantum*	Ab, Ah, Ph	0,69
A. nilotica.	Ah, Bc, Bs, Ph	0,71	*S. birrea*	Bs, Bc, Bo	0,65
P. juliflora	Ab, Ph	0,63	*C. glutinosum*	Bs, Bc, Bo	0,60
C. micrantum	Bc, Bs, Bo	0,51	*P. juliflora*	Ab, Ph	0,53
C. farinosa	Ab, Ah, Ph	0,46	*L. hastata*	Ab, Ah, Ph	0,50
C. glutinosum	Bs, Bc, Bo	0,44	*B. rufescens*	Ab, ph	0,38

The same procedure for calculating use values used at the agricultural sites was applied to the silvopastoral sites (Kiré-Kafada and Lalamna). In Lalamna, *Faidherbia albida* (3.23), *Sclerocarya birrea* (3.13), *Acacia tortilis* (3.01), and *Leptadenia hastata* (3.00) were found to be the most commonly used species. In the village of Kiré-Kafada, *Balanites aegyptiaca* (3.87), *Faidherbia albida* (3.34), and *Acacia tortilis* (2.71) were the most commonly used species.

Table 9: The use value of the sylvopastoral bench and sylvopastoral half-moon sites

Kiré-Kafada (sylvopastoral half-moon)			Lalamna (sylvopastoral bench)		
Species	**Uses**	**VU_T**	**Species**	**Uses**	**VU_T**
B. aegyptiaca	Ab, Ah, Bc, Bs, Bo, Ph	3,87	*F. albida*	Ab, Bc, Bs, Bo, Sr, Ph	3,23
F. albida	Ab, Bc, Bs, Bo, Sr, Ph	3,34	*S. birrea*	Ab, Ah, Bc, Bs, Bo, Sr	3,13
A. tortilis	Ab, Bc, Bs, Sr, Ph	2,71	*A. tortilis*	Ab, Bc, Bs, Sr, Ph	3,01
A. senegal	Ab, Bc, Ph, Sr	1,94	*L. hastata*	Ab, Ah, Ph, Sr	3,00
Z. mauritiana	Ah, Ph, Sr	1,73	*P. reticulatum*	Ab, Ah, Bc, Bs, Bo, Sr, Ph	2,58
C. glutinosum	Bc, Bo, Bs	0,9	*B. aegyptiaca*	Ab, Ah, Bc, Bs, Bo, Ph	2,3
B. rufescens	Ab, Ph	0,88	*C. micranthum*	Ab, Bc, Bo, Bs	0,92
C. farinosa	Ah, Ab, Ph	0,83	*A. nilotica*	Ah, Bc, Bs, Ph	0,45
S. birrea	Ab, Ah, Bc, Bs, Bo, Sr	0,65	*C. farinosa*	Ah, Ab, Ph	0,45
P. juliflora	Ab, Ph	0,61	*Z. mauritiana*	Ah, Ph, Sr	0,42
A. nilotica	Ah, Bc, Bs, Ph	0,4	*C. glutinosum*	Bc, Bo, Bs	0,27
G. senegalensis	Ab, Bc, Bs, Sr	0,21	*Acacia senegal*	Ab, Bc, Ph, Sr	0,17
L. hastata	Ab, Ah, Ph, Sr	0,17	*B. rufescens*	Ab, Ph	0,12
C. micranthum	Ab, Bc, Bo, Bs	0,14	*G. senegalensis*	Ab, Bc, Bs, Sr	0,09
P. reticulatum	Ab, Ah, Bc, Bs, Bo, Sr, Ph	0,12	*P. juliflora*	Ab, Ph	0,08

3. Cost-benefit analysis of ecosystem services

The cost-benefit analysis consists of two steps: a financial analysis which consists of assigning monetary values to all the products and services of the sites followed by an economic analysis which completes the financial analysis by taking into account other costs.

3.1. Financial analysis of the products obtained on the sites

It is important to note that the baseline scenarios are the situation "with" and "without" degraded land recovery techniques.

Table 2 Price of agricultural products/unit on the market

Agricultural products	Witnesses	Treaties
Price of one kg of millet (FCFA)	140	140
Price of a bundle of millet fodder (FCFA)	250	250
price of one kg of sorghum (FCFA)	240	240
Price (FCFA) of a bundle of sorghum stems	300	300
Price of one kg of cowpea (FCFA)	250	250
Price (FCFA) of a bundle of cowpea stem	400	400
price of a kg of peanuts (FCFA)	117,64	117,64
Price of one kg of peanut stalk (FCFA)	57,69	57,69
Price of Tiya sesame (FCFA)	1500	1500

For products from pastoral sites, animal fodder (straw) and other products gathered from the sites were included in this assessment and their prices differed from site to site (Table 3). These prices, although obtained at the same time, are different in the villages depending on the availability of products at the site. Labor costs and tools used were obtained from the socio-economic surveys.

Table 3 Prices of pastoral products on the market

Pastoral products	Witnesses	Treaties	Deviation
Unit price of one kg of straw (FCFA)	47,62	47,62	-
Price of a 23 kg bundle of wood (CFA)	350	1250	636,4
Price of a stere of wood (FCFA)	2000	2000	-
Carbon price (ton/ha) (FCFA)	-	23 235	-
Price of a cup of *L. hastata* fruit (FCFA)	300	225	53,03
Price of a cup of *Z. mauritiana* fruit (FCFA)	225	300	53,03
Price of a bunch of Andropogon (FCFA)	750	250	353,55
Price of a cup of fruit (FCFA)	215	450	166,17
Price of a bag of *A. tortilis* fruit (FCFA)	1500	350	813,17
Price of a cup of *Cassia tora* leaf (FCFA)	350	750	282,84
Price of a bag of NTFP pharmacopoeia (FCFA)	-	1700	-
Fruit prices: *P. reticulatum* (FCFA)	1750	1650	70,71

Two planning horizons were set (4 and 8 years) in the analyses to see the evolution of the system (Figure 2 and Figure 3). The calculation of the gross income (agricultural and pastoral) of the sites was based on the hypotheses that "production is constant over the duration of the analysis" for the control sites Witnesses Treaties 140 140 250 250 240 240 300 300 250 250 400 400 117,64 117,64 57,69 57,69 1500 1500 and increases on the recovered sites. An additional net profit was obtained according to the scenarios (with and without practice) which is the difference between the net profit without practice (control sites) and the net profit with practice (recovered sites).

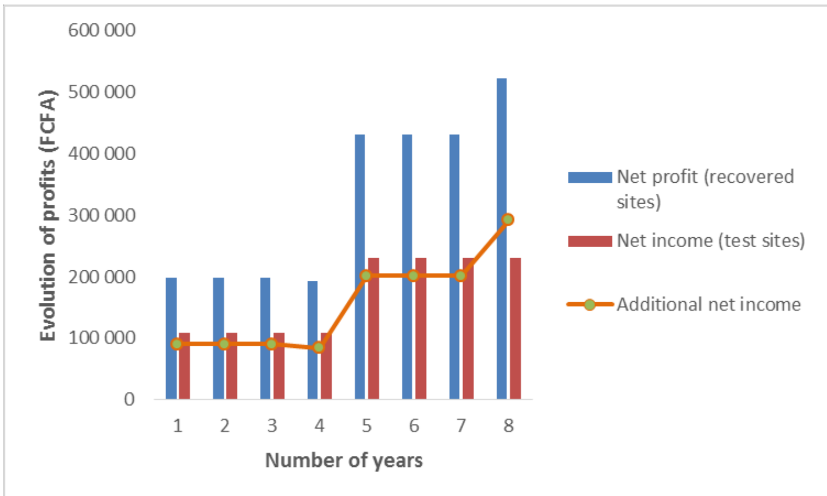

Figure 2: Evolution of the benefits of agricultural bench and rocky beach sites

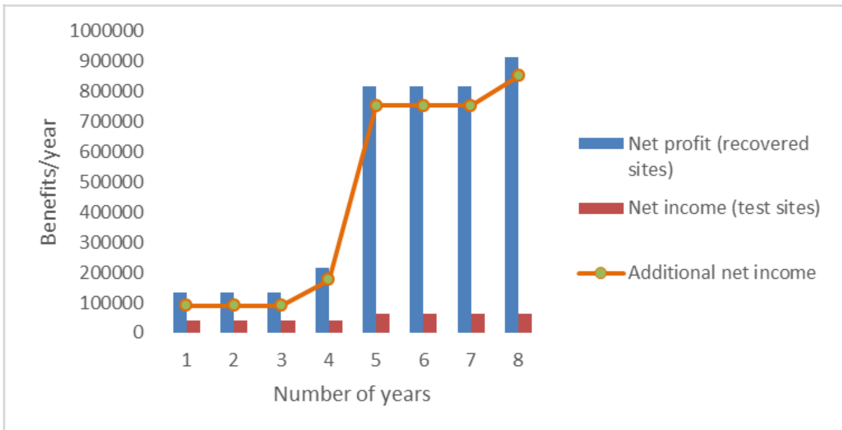

Figure 3:Evolution of the benefits of the Banquette and Half-moon sylvopastoral sites

The additional net benefits were used to calculate the financial net present values of the different land reclamation works considered in this study. These values are greater than zero regardless of the type of practice or its vocation (agricultural and silvopastoral) (Table 4 and Table 5).

Table 4 Financial sustainability indicators for agricultural sites (Nagaroa and Tambass)

Practices		Economic indicators	4 years 1ha	8 years 1ha
Agricultural bench	Financial analysis	NPV (10% discount rate)	195 405	590 934
		TRI	5428%	
Stone cordon		NPV (10% discount rate)	321 213	1 060 477
		TRI	704%	

Table 5 Indicators of financial viability of silvopastoral sites (Kiré-Kafada and Lalamna)

Practices		Economic indicators	4 years 1ha	8 years 1ha
Half-moon sylvopastoral	Financial analysis	NPV (10% discount rate)	839 364	2 588 185
		TRI	518%	
Silvopastoral bench		NPV (10% discount rate)	52 481	188 580
		TRI	261%	

3.2 Economic analysis of the products obtained on the sites

The economic analysis includes, in addition to the financial analysis, all non-market services that have an economic value but were not included in the financial analysis. Thus, the main elements that were added to the economic analysis are the payment consents for ecosystem services such as wind protection, flood control, carbon sequestration. There is also the removal of the subsidy on state-subsidized inputs (transfer payment), applying mainly on chemical fertilizer for this study. Wages have been taken into account. The conversion factor for labor and the exchange rate is 0.6 and 0.98 respectively. The results of the economic calculations (Table 6 and Table 7) show a calculated NPV greater than zero even without the cash for work.

Table 6 Economic profitability indicators for agricultural bench and stone barriers

Practices	**Year**	**4 years old**					
Agricultural bench	Discount rate	1%	10%	20%	50%	100%	1000%
	NPV (FCFA)	702 490	435 431	272 718	89 690	25 220	74
	TRI	1 997 %					
Stone cordon	NPV (FCFA)	1 157 850	721 220	454 048	151 131	42 704	-153
	TRI	694 %					

Table 7 Indicators of economic profitability of silvopastoral benches and half-moons

Practices	Year	4 years old					
Silvopastoral bench	Discount rate	1%	10%	20%	50%	100%	1000%
	NPV (FCFA)	309 016	188 580	115 738	35 162	8 122	-270
	TRI	236%					
Half-moon sylvopastoral	NPV (FCFA)	4 213 493	2 619 829	1 644 231	539 286	146 782	-1 529
	TRI	476%					

The practice of benches, stone barriers and half-moons generates a positive financial and economic NPV and an IRR >0 regardless of the planning horizon (4 or 8 years) and respecting the technical standards or not at a discount rate of 10%. The Table 8 summarizes the results of the overall calculation of benefits over 4 years for the four practices. These benefits were compared to the costs of implementation per hectare for each site.

Table 8 Overall result of the cost-benefit analysis (4 years of analysis)

	Agricultural sites		**Silvopastoral sites**	
Practices	**Benches**	**Stone cordon**	**Benches**	**Half moons**
Profits (FCFA)	1 089 678,95	2 696 364,08	1 060 145,68	9 342 864,90
Cost/ha (FCFA)	924 600	501 800	924 600	1 162 407
Cost/Benefit	1,18	5,37	1,15	8,04

3.3.Sensitivity analysis

The sensitivity analysis tested the parameters and assumptions used in the financial and economic analysis. This analysis was performed by changing the prices of variable products during the year. For our study, the sensitivity analysis is essentially about the products sold on the market. Thus, for the baseline of the cost-benefit analysis, conservative assumptions regarding the estimation of market prices of the products (agricultural and pastoral), taking the lowest prices (agricultural products) or average prices of the given price range (straw) are taken into account. Given the scarcity of products, the price of foodstuffs increases considerably and can soar to its maximum value. For this sensitivity test, the highest price values of the given range are considered (Table 9).

Table 9 Price variations during the lean season

Welding price	Normal price		
Agricultural products (sold by producers)	**FCFA**	**FCFA**	**Deviation**
Price of one kg of millet	140	300	113,14
Price of a bundle of millet stalk	250	500	176,78
price of one kg of peanuts	117,64	333	152,28
Price of one kg of peanut husk	57,69	100	29,92
Price of one kg of cowpea	250	500	176,78
Price of a bundle of cowpea tops	400	500	70,71
Tiya sesame price	1500	1700	141,42
price of one kg of sorghum	240	300	42,43
Price of a bundle of sorghum stalk	300	500	141,42
Price of one kg of straw (fcfa/kg)	68,02	100	22,61
Price of a bundle of wood	350	500	106,07
Price of a bag of NTFP pharmacopoeia	1700	1800	70,71
Price of one cup of *Leptadenia hastata* leaves	175	-	-
Price of one cup of *Leptadenia hastata* fruit	275	-	-
Price of a cup of *Acacia tortilis* fruit	500	750	176,78

The increase in the price of agricultural or pastoral products has no consequences and does not compromise the profitability of the recovery works for degraded land considered by this study. The results of the sensitivity analysis (Table 10) show only an increase in the calculated net present value (NPV > 0) and the internal rate of return (IRR).

Table 10 Case of a sensitivity analysis of the agricultural bench site

Calculation horizon	4 years old					
Discount rate	1%	10%	20%	50%	100%	1000%
NPV (FCFA)	1 927 090	1 228 274	795 384	291 063	97 159	1 074
TRI	19783%					

Discussion

1.Ecosystem services

The reclamation of degraded lands in the villages of Nagaroa, Tambass, Lalamna and Kiré-Kafada provide a range of ecosystem services (food, harvesting products, animal straw, protection against wind, runoff, etc.) to the inhabitants of this area. The quantification of provisioning services shows a clear difference in the quantity of products obtained between the reclaimed sites and the control sites with respect to agricultural production for the agricultural sites. The same is true for wood production (timber, service wood and firewood) and biomass production (straw for animals). The Lalamna sylvopastoral bench site has a low dry matter production (140 kg of Dry matter/ha or 11% of the total). This is due to the permanent presence of animals on this site. This explains why overgrazing is one of the factors that promote land degradation with a negative impact on the environment, the disappearance of vegetation cover that leads to soil erosion.

2. Uses of woody species

Surveys conducted among the population composed of farmers, herders and agro-breeders in the villages where the four restored sites are located reveal a good knowledge of the most commonly used woody flora. Thus, the populations do not generally cut down woody species for food or medicinal use, but they do so for plants used for energy wood (firewood) and lumber (wood used to make objects). The population responses show that the plant organs are not valued equally. The results reveal that at the agricultural sites, the leaves of L. Hastata, B. aegyptiaca and C. farinosa are more used for human consumption. While those of F. albida Calculation horizon Discount rate are consumed by aniamux. The fruits of P. reticulatum are used in both human and animal food. The wood of plants such as C. micrantum, G. senegalensis and C. glutinosum are used in the construction of huts and firewood etc. The same species are appreciated by the population of the villages of Kiré-Kafada and Lalamna. The leaves of L. hastata, B. aegyptiaca and C. farinosa are all used in human food. While the leaves of F. albida (51.07%) and A. tortilis (40.02%) are more used in animal feed. In all the villages of the sites, the roots of the plants are less appreciated because they are mainly used in the traditional pharmacopoeia and many people do not use them. The superiority of the frequency of use of these three types of organs (leaf, fruit and branch) over the others was found by Traore et al., (2011) in southwestern Burkina Faso. However, several species are involved in the provision of ecosystem services, especially in the provisioning services to local populations. These species do not have the same importance in terms of use by the population, which is why their use values differ from one species to another or from one village to another. The calculation of the total use value of the selected woody species shows that the species with the highest total use values at the agricultural sites are F. albida (3.86), A. tortilis (1.93), P. reticulatum (1.88) and B. aegyptiaca (1.60) in Nagaroa and C. farinosa (1.52), G. senegal (1.44), B. aegyptiaca (1.40), A. senegal (1.14) and F. albida (1.07) in Tambass. These species not only improve the living conditions of the population but also the fertility of the environments in which they are found. At the level of pastoral sites, for example at Kiré-Kafada, the species with the highest use values for the farmers of these sites are B. aegyptiaca (3.87), F. albida (3.34) and A. tortilis (2.71), while at Lalamna F. albida (3.23), S. birrea (3.13), A. tortilis (3.01), and L. hastata (3.00) occupy the highest places. Across the four sites studied and characterized by legume dominance, F. albida (3.86), A. tortilis (2.71), P. reticulatum (2.58), and B. aegyptiaca (2.30) are most preferred in fields and pastoral rangelands. These results are similar to those found by Ibrahima et al., (2017) in Senegal, showing that the total use values of Cordyla pinnata (3.56) and B. aegyptiaca (3.72) followed by F. albida (3.46) testify to the central role of these species in agroforestry systems. Generally, the highest use value species are represented by the multiple use species that are involved in almost all use categories (Gning et al., 2013). This shows that the importance given to a species does not depend on its availability but on its ability to satisfy the needs of populations in different use categories (Mangambu et al., 2015).

3.Cost-benefit analysis

The benefits reported by the land reclamation activities are from the products obtained during the 2018 agricultural season. Nevertheless, only the benefits related to cash-for-work activities are from the year of the intervention and their impacts are related to the work of implementing the works on the sites. It is estimated that these benefits may last longer under our second assumption (8 years in the analysis). For the newly developed land, these are the benefits that households will derive from the land developed with benches, half-moons, and stone barriers in terms of grain and fodder production. The financial analysis of the agricultural sites (bench and rocky ridge) showed that the profits from their products are almost constant for the first four (4) years, and increase considerably from year 4ème to year 8ème before tabilizing. At the level of the pastoral sites (bench and half-moon), the profits increase from the 3ème year of their realizations. This confirms the hypothesis that production progresses linearly over three years to reach the values of the sites treated in year 4. These results indicate that the services rendered by the recovery works for degraded land are not obtained in one or two years of the intervention, but from year 3ème to year 4ème of the intervention. The net present value calculation showed a positive value at a discount rate of 10% regardless of the planning horizon chosen. This implies that the work is financially and economically profitable. The results of the economic analysis show that even without the donor investment in the form of cash for work, the calculated NPV remains positive regardless of the practice at the 10% discount rate. This implies that the implementation of these structures is economically profitable and that cash for work is no longer a blockage to the implementation of these types of structures. The net present values of the silvopastoral benches, stone barriers and half-moons are negative with the discount rate of 1000%. In addition, the ratio of benefit to cost of the structures gives 1.18 for agricultural benches, 5.37 for stone barriers, 1.15 for sylvopastoral benches and finally 8.04 for sylvopastoral half-moons. In other words, for every 1 franc invested in the realization of the sites of the agricultural stone banks and cordons, the sylvopastoral bank and half-moon, 0.18 and 4.37, 0.15 and 7.04 francs of profit are realized. These results are similar to those obtained by Hamidou, et al, in 2012 in Niger and by Angèle et al, in 2012 in Burkina Faso who found that the cost/benefit ratio of the activities of recovery of degraded lands generates respectively 0.11 and 2.38 euros of profit.

The results of the sensitivity test show that the general conclusion does not change, i.e., that the practice of agricultural banks and stone barriers, and silvopastoral banks and half-moons are economically profitable even in an unfavorable agricultural production situation where prices increase during the year. The increase in prices of the services rendered according to the periods, is thus not a blockage for the economic profitability of the works even in a situation of unfavorable agricultural production where the prices are very high.

Conclusion

At the end of this study, it can be said that the sites are home to a very large number of plant species and ecosystem services provided by the installation of land reclamation structures. However, the inhabitants of the home villages of these sites benefit from important ecosystem services provided by the installation of these structures. Some of these services are food, such as most of the provisioning services, and some are economic services for the country in general (carbon sequestration) and the family in particular. The total use values of species across the seven use types show that the silvopastoral bench and half-moon sites have higher use values of plant species compared to the agricultural bench and rocky ridge sites. The financial and economic analysis applied to the four restoration techniques in the commune of Badaguichiri highlighted not only the profitability of these techniques with or without cash for work but also their ecological efficiency. The subsidies generally provided by the State or technical and financial partners to encourage the population to use these techniques can be directed to the rural development sectors. However, if it is established that these techniques are profitable, i.e., that there is no economic blockage, what are the constraints that justify the non-adoption of these techniques on a large scale by farmers? This study has shown that the techniques for reclaiming degraded land are the most appropriate means of combating environmental degradation and the rural exodus of the population due to the lack of land for cultivation.

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