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(Research Article)

Contribution of assisted natural regeneration (ANR) to climate change mitigation and diversification of ecosystem services in Dan saga village (Maradi-Niger)

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Abstract

As an agro-ecological intensification technique, assisted natural regeneration (ANR) protects agrosystems and guarantees cereal production in a Sahelian context of high demographic pressure and climate variability. This study aims to assess the local perception of assisted natural regeneration in mitigating the effects of drought and climate change and its impacts on soil fertility and crop production. Surveys, based on a participatory approach of individual and collective consultations, were conducted with stakeholders. The water profile and bulk density of areas under ANR and outside ANR were determined from soil samples taken in the rainy and dry seasons at different depths (0 - 200 cm). Vegetative growth and yield components were monitored on 100 plots of 100 m2 (10x10m) with 50 plots in ANR and 50 in non-ANR areas. The results showed that both zones had the same species composition for the dominant woody species, but their average densities were higher in the areas under assisted natural regeneration than in the areas without. Density is lower in the aureoles close to the village than those far from it in any zone. Soil moisture content is higher in the ANR and non-ANR areas than in the non-ANR area in the shallow horizons. However, in the deep horizons down to 200 cm, the volume moisture is higher in the Non-NAR and Uncovered NAR zones respectively than in the Under-Cover NAR zone. Apart from the seedling density, all agronomic performance parameters are significantly higher in the RNA zone than in the non-RAN zone. In terms of farmers' perception, the practice of ANR attenuates the impacts on natural resources (water, land, vegetation) and on production systems. More than 92.2% of the respondents reported that increased dust winds, increased night time temperature, decreased rainfall events as well as their amounts in height are the impacts experienced before the practice of ANR. The practice of ANR contributes to the mitigation of climate variability, improvement of soil structure and carbon sequestration.

Keywords: Agroforestry; Assisted natural regeneration; Climate variability; Farmers' perception

1. Introduction

The degradation of Sahelian agroecosystems is manifested by an accelerated reduction in plant cover and biodiversity, leading to intense water erosion and a decline in soil fertility [1, 2]. Indeed, the overexploitation of land reduces its

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production potential and affects the living conditions of rural populations who depend mainly on rain-fed agriculture and pastoral resources linked to the quality of fodder for their subsistence. Despite an increase in the area sown, the area farmed per worker is becoming smaller and smaller, and yields are stagnating and even declining in some cases [3] due to the population explosion and the fragmentation of cultivable land. Similarly, the effects of climate change [4, 5, 6] are being exerted on increasingly vulnerable populations and agroecosystems, leading them into a negative feedback loop under the pressure of a demographic transition that is still incomplete [7]. Indeed, the increase in human density and subsequent land pressure has contributed to a sharp decrease in the duration of following, which can even lead to its disappearance. However, the fallow system was used for a long time to mitigate soil degradation and increase soil fertility [8, 9].

In Niger, the duration of fallow has decreased globally from at least 15 years to 5 years or less between 1960 and 1985, with the ratio of fallow land to cultivated land decreasing from 7.1 to 2.9 [10, 11]. In semi-arid agricultural areas such as the southern Sahel, this development has led to a disruption of the balance of ecosystems, with the consequent triggering of the desertification process [12, 9, 2]. According to the [13], 75 to 250 million Africans are expected to suffer from water stress exacerbated by climate change and, in some countries, rainfed agricultural yields could fall by 50% by 2020. Like the entire Sahelo-Sudanian zone, the southern Sahelian strip of Niger has also been strongly affected by global changes over the past decades [14]. The agrosystems of this region suffered the most severe droughts in the world during the 1970s and 1980s [15, 16]. According to several climate scenarios, the area of African arid and semi-arid lands could increase by 5-8% by 2080 [13]. The Sahelian agricultural systems, being the most vulnerable, must therefore be protected to mitigate the effects of climate change and their production ecologically intensified if socio-economic activity is to be maintained in the long term while reducing food insecurity in rural areas.

Assisted natural regeneration (ANR), as a participatory approach, has produced inspiring results and revealed the existence of a strong capacity of local populations to innovate and organise themselves in community activities [17]. It constitutes an alternative to mitigate the effects of drought and climate change. Moreover, the multifunctional vocation of this system allows for the diversification of income sources in rural areas. Indeed, the density of trees in agroforestry parks resulting from the practice of ANR ranges from 10 to 70 trees/ha and the number of trees is about 210 million in Niger [18] and has allowed a remarkable change in the landscape in some areas. Despite this scaling up due to interest in the practice, the overall role of agroforestry in combating desertification, adapting to climate change and mitigating greenhouse gas (GHG) emissions is not sufficiently recognized. It is in this context that the present study aims to better understand farmers' perception of the role of ANR in mitigating climate change and increasing vegetation cover.

2. Material and methods

2.1. Study area

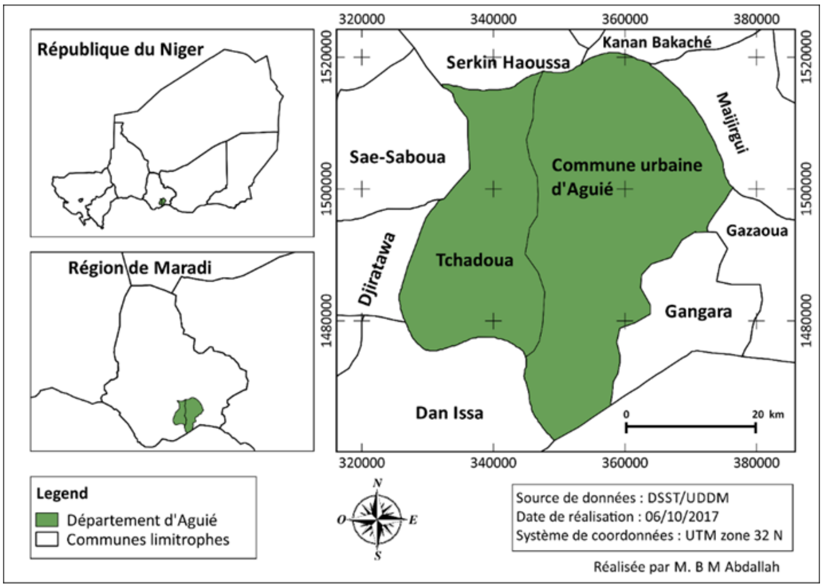

Figure 1 Location of the study area

Located in the south of the Maradi region, the department of Aguié lies between meridians 7°24' and 8°9' East and parallels 13°13' and 13°45' North (Figure 1). It covers an area of 1700 km^2, or 7.26% of the total area of the Maradi region. Figure 1 shows the location of the department of Aguié.

2.2. Socio-economic survey

Surveys were conducted among rural producers and resource persons to determine their perception of assisted natural regeneration in mitigating the effects of drought and climate change. A total of 100 farmers were sampled for the survey, representing a sampling rate of 15% of the total number of farm managers. After the interview sessions, visits were made to the farms concerned. This enabled the information collected during the interview to be compared with the reality in the field, and also to look for other information that was missing or not considered important by the farmers, and to take photographs to illustrate the situation.

2.3. Inventory of the woody stratum

The radial transect method was used, based on systematic sampling, in accordance with the recommendations of [19] for open forest formations. Thus, on each transect, plots of 2500 m^2 (50 m *50 m) were selected in agro-forestry systems and contracted formations. The method consists of placing a first plot 1 km from the village. The equidistance between two successive plots is 500 m along a transect (Figure 2). The plots were delimited using the right-angled triangle method (3. 4. 5). In each plot, all woody individuals in the area were counted exhaustively.

For each adult individual, the following parameters were measured

- The total height of each individual (graduated stakes)
- The circumference of the individual (tape measure)
- The average diameter of the crown along two perpendicular axes by simulating their vertical projections on the ground using a tape measure. This parameter is used to determine the overall cover of the woody plants.

Individuals with a circumference of less than 4 cm were counted in natural regeneration.

Fig. 2 below shows a schematic of the experimental set-up.

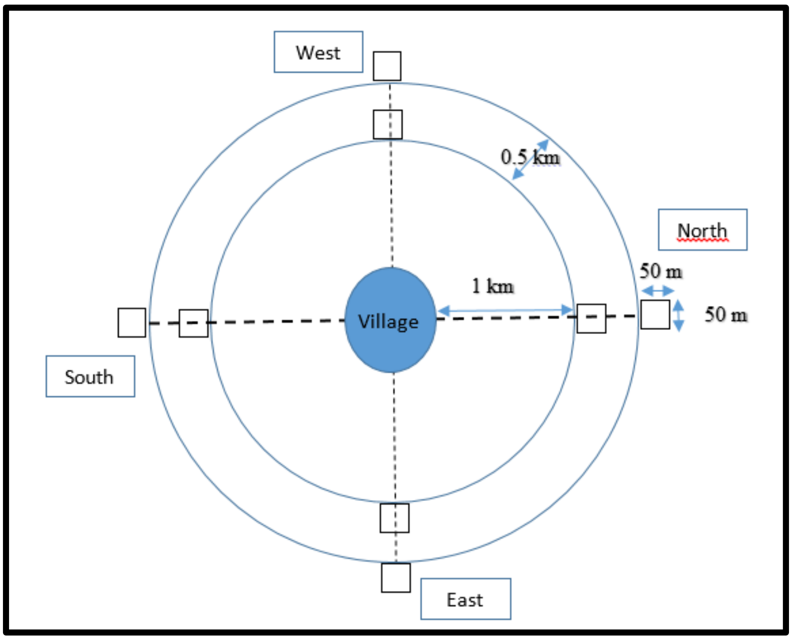

Figure 2 Diagram of the inventory system

2.4. Water profile monitoring

Soil samples were taken in the rainy and dry seasons at depths of 0-50 cm, 50-100 cm, 100-150 cm and 150-200 cm using a specific auger (SDEC-France, EIJKELKAMP) and their wet and dry weights were determined. Thus, the soil water profile of the study area under RNA (uncovered and under tree cover) and outside RNA was made from the determination of the weight of the wet and dry soil samples. The soil bulk density was determined from the following formula [20] :

$$d_a = {}^{P}\!/_{V}$$

where P is the dry weight of the sample and V is the volume taken and dried

2.5. Yield assessment and estimation of carbon sequestration

To determine the impact of ANR on crop production, 100 plots of 10 m x 10 m (100 m^2) were set up, 50 in ANR areas and 50 outside ANR. The parameters concerning vegetative growth and yield components were monitored. These are as follows

- Number of plots sown ;
- Number of plots at emergence;
- Vigour at emergence,
- Number of bunches at harvest;
- Number of ears at harvest;
- Gross weight (ear weight) ;
- Net weight (grain weight)

Yield components were analyzed to determine the productivity of dune farms under and without assisted natural regeneration in the study area. The carbon sequestration potential is determined through the carbonization coefficient using the values of the quotients per stem size category according to the isohyets.

$$Ba = e^{-1.996+2.31*In(D)}$$

$$Ba = average\ of\ quotients\ according\ to\ isohyets;\ In = number\ of\ individuals;\ D = circumference.$$

$$For\ areas\ between\ 300\ and\ 500\frac{ml}{year}, the\ average\ quotient\ is\ 0.094. Thus:\ Q = number\ of\ stems * 0.5$$

$$*\ average\ quotient\ based\ on\ isohyets\ (Ba\ ).$$

$$The\ 0.5\ corresponds\ to\ the\ carbon\ sequestered\ by\ 1\ m3\ of\ wood\ (1\ m3\ of\ wood\ corresponds\ to\ 325\ kilograms).$$

2.6. Data processing and analysis

The dendrometric and survey data obtained from the different stakeholders were processed and analysed by SPSS, V1.0. Following the analysis of the survey data, the stakeholders' perceptions of the effects of ANR on drought mitigation and climate change adaptation as well as the agronomic, environmental and socio-economic impacts were determined.

3. Results

3.1. Characterization of the woody cover

The average densities of the dominant woody species in the ANR and non-ANR areas of Dan Saga are presented in Table 1.

Although the species composition is the same, the density is always higher in the area under RNA (89.68 ft ha-1) than in the area outside RNA (27 ft ha-1). In general, regardless of the zone, the density is lower in the aureoles close to the village than those far away.

Table 1 Average densities of dominant woody species in RNA and non-RNA agrosystems in Dan Saga

Context	Average density of woody plants (feet ha-1)				Dominant species in descending order of density.
	1st halo 1 km	2nd halo 0.5 km	3rd halo 0.5 km	Average density	
RNA	78	88	103	89.67	Combretum glutinosum, Piliostigma reticulatum, Guiera senegalensis et Faidherbia albida
non RNA	23	27	31	27	Combretum glutinosum, Piliostigma reticulatum, Guiera senegalensis, Faidherbia albida et Acacia nilotica

3.2. Carbon sequestration potential

- In RNA area, Q = 89.67*0.5*0.094 = 4.214 m^3*325 = 1.4 Tons/ha ;
- In non RNA area, Q = 27*0.5*0.094 = 1.269 m^3* 325 = 0.425 Tons/ha.

It can be seen that the amount of carbon sequestered in the area under ANR is greater than in the area without ANR.

3.3. Water profile, water availability and soil bulk density

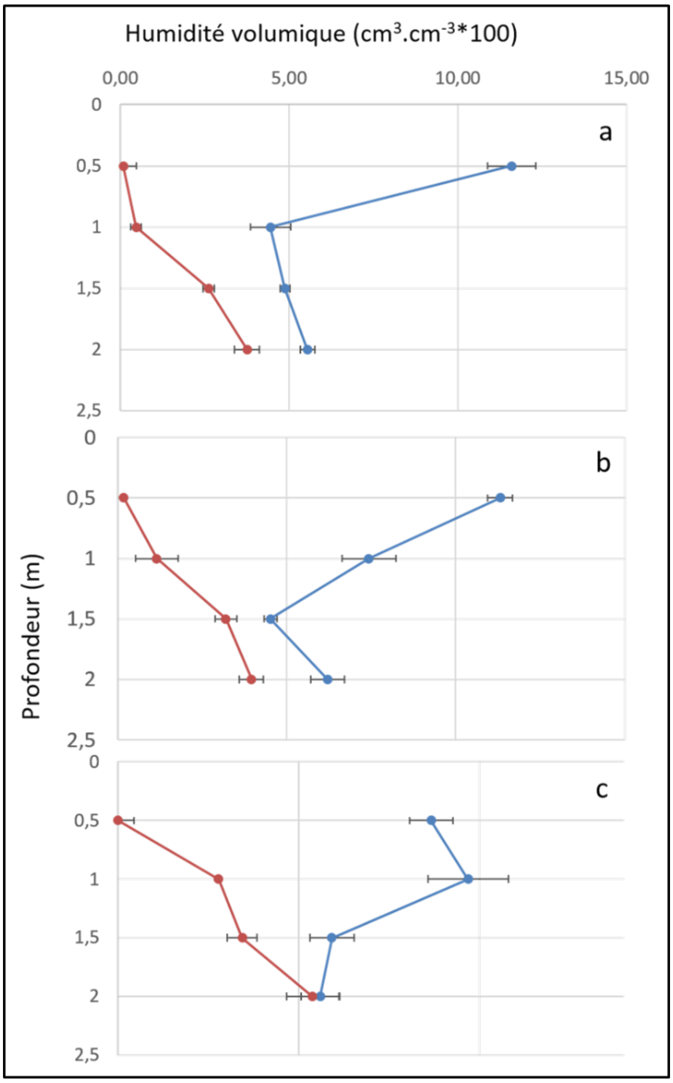

Figure 3 Oil moisture profiles under RNA (a), outside the RNA canopy (b) and outside the RNA canopy (c) with dry season volume moisture in red and rainy season volume moisture in blue

Fig. 3 shows the seasonal variation of soil moisture content as a function of depth and area: under ANR (under cover = HC ANR and under cover = SC ANR) and outside ANR.

In the superficial horizons (first 50 cm), the soil volume moisture is higher in the SC RNA and HC RNA zones than in the H RNA zone. However, in the deep horizons down to 200 cm, the volume moisture is higher in the H RNA and HC RNA zones respectively than in the SC RNA zone (Fig. 3).

Fig. 4 shows the variation of soil bulk density as a function of depth and according to the zone: under RNA (without cover = HC RNA and under cover = SC RNA) and without RNA.

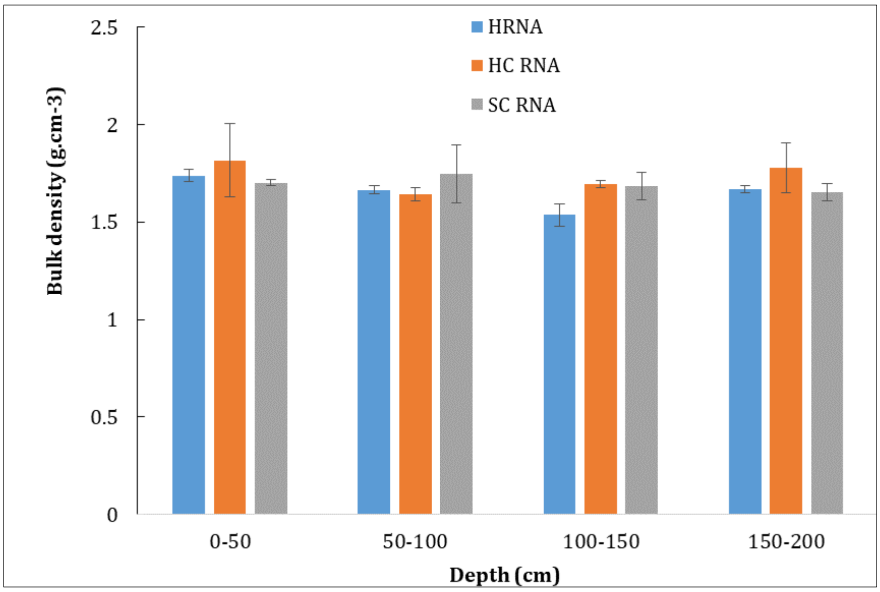

Figure 4 Variation of soil bulk density as a function of depth and area: under RNA (without cover = HC RNA and undercover = SC RNA) and without RNA

In the 0-50cm and 150-200cm soil depth ranges, bulk density is higher in the HC RNA zone, but with higher variability, than in the H RNA and SC RNA zones. However, in the 50-150cm band, bulk density is higher in the SC RNA zone than in the other two zones.

3.4. Agronomic performance of millet

The comparison of the agronomic performance of millet grown in the different contexts, under RNA and Non-RNA, is shown in Table 2.

Table 2 Comparison of the agronomic performance of millet grown in the different contexts, under RNA and Non-RNA, à Dan Saga

	Context			
Agronomic performance parameters	Non-RNA	Under **RNA**	***F***	***P-value***
Number of pits sown (NPS)	55.76 ± 4.50	56.82 ± 4.98	*01.20*	*0.2756*
Number of bunches at emergence (NBE)	36.46 ± 10.75	47.04 ± 8.60	*30.29*	*0.0000*
Vigour at emergence (VAE)	20.38 ± 9.06	27.92 ± 17.02	*07.59*	*0.0070*
Number of bunches at harvest (NBH)	33.34 ± 9.20	49.08 ± 6.91	*95.77*	*0.0000*
Number of ears at harvest (NEH)	134.36 ± 71.35	217.98 ± 91.16	*26.60*	*0.0000*
Gross weight of the ear (GWE)	70.5 ± 31.90	114.34 ± 17.88	*74.73*	*0.0000*
Net seed weigh (NSW)	24.28 ± 11.50	42.18 ± 11.64	*57.21*	*0.0000*

Table 2 shows that the variation in germination rate is much higher in the plots under RNA (82.78%) than in those without RNA (65.38%).

3.5. Farmers' perception of climate variability

3.5.1. Drought & Climate Change before the adoption of ANR

Fig. 7 presents the results on farmers' perception of drought and climate change before the practice of ANR.

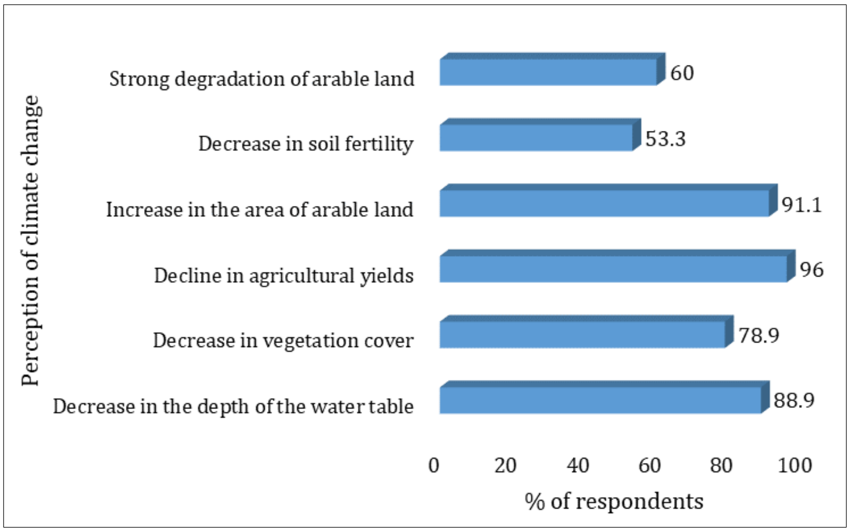

Figure 5 Farmers' perceptions of the effects of climate change in the study area

More than 92% of the respondents reported an increase in dusty winds, night temperatures, a decrease in the frequency of rainfall and its low quantity before the practice of ANR. Similarly, more than half of the respondents (60-76%) reported irregularity at the start of the rainy season (late and early) and a mismatch between the crop cycle and the length of the rainy season.

3.5.2. Impacts of climate variability experienced by Populations

Fig. 6 shows the main impacts of climate variability experienced by the populations.

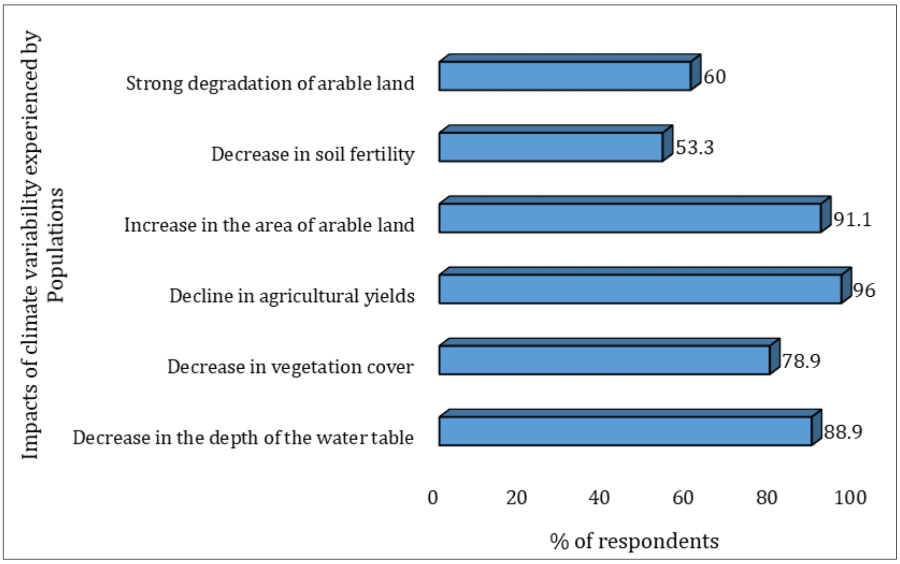

Figure 6 Impacts of climate variability experienced by Populations

The majority of respondents (91.1%) reported the absence of fallow land, a decrease in agricultural yields, and, consequently, an increase in the area sown to crops, as the main impacts of climate variability. A fairly large proportion of respondents (78.9 to 88.9%) cited impacts related to the reduction in woody cover, the reduction in water resources with the disappearance of ponds, and, consequently, a drop in the piezometric level of the water table. Finally, 53.3% indicated that the impact of climate variability was the strong degradation and decline in soil fertility.

3.6. Endogenous adaptation strategies implemented

A distinction is made between adaptations initiated by local people and those initiated by projects and other partners. The populations make efforts of their own accord by taking initiatives to adapt to climate change. They accompany the projects and make significant efforts to adapt agriculture, livestock and natural resources (Table 3). Irrigation is also an excellent means when rainy seasons become more unpredictable and less frequent due to climate change, according to the 64% of respondents in some localities who resort to market gardening.

Table 3 Adaptation measures initiated at local level

Domains	**Structures for implementing the initiatives**	
	Communities/population	**State & technical and financial partners**
Agriculture	Use of short-cycle varieties,	Improved varieties;
	Purchase of new fields ;	Irrigated crops
	Use of organic and chemical fertilizers	Agroforestry ;
		Input banks and credit systems ;
		Cash transfer.
Breeding	Feed supplements	Pastoral boreholes
	Introduction of breeds and mixed breeding	Pastoral boreholes et
		zootechnical inputs;
		Limiting animal passage corridors.
Natural resources	Agroforestry ;	ESC /DRS;
	Preservation of biodiversity RNA	Afforestation and reforestation;
		Agroforestry.
		Introductions of exotic species

4. Discussion

The results of this study allowed us to understand the farmers' perception of the role of assisted natural regeneration in mitigating the effects of drought and the strategies for adaptation to climate change. They also allowed us to determine the impacts of the practice of ANR on the diversity and density of woody species and to characterise the functional and agronomic impacts of trees in the village of Dan Saga.

The potential benefits of agroforestry practices compared to the situation without the practice are diverse and can be grouped under the term ecosystem services. Indeed, increased crop production, contribution to food security, increased earnings, economic efficiency, erosion control, increased landscape biodiversity, reduced greenhouse gas emissions, and reduced household vulnerability are some of the benefits identified from good agroforestry practices that can reduce vulnerability and strengthen resilience to climate shocks, thereby contributing to GHG mitigation. According to [21], woody plants in agroforestry systems are not only chosen because they provide wood but also because they have a positive and sustainable effect on the environment, helping to maintain soil fertility by reducing the force of the wind, creating micro-climates favourable to crops and improving the carrying capacity of the herds. The added value made on the sale of wood and non-wood products is difficult to estimate and varies according to the practices, periods, and places where they are sold [21].

The products of ANR occupy an important place in consumption. The greatest wealth of these products is in the nutrients they can provide to people in critical times [22]. Non-timber forest products (NTFPs) are often seen as excellent resources for reducing the risks of vulnerability within the household, primarily because of the multiple services they can provide. For example, they can provide good food resources when agriculture is doing more or less well [23], and the sale of products can also lead to a reduction in household risk as the income can help to meet the primary needs that families are exposed to [24].

In addition, all the agronomic benefits of trees promote crop stability [25] and the economic benefits enable the vulnerable population to meet their food needs and especially to cover the lean season. The marketing of non-timber agricultural products (NTAPs) is one of the factors that determine whether farmers maintain traditional agroforestry practices or adopt good agroforestry practices [26]. The practice of ANR in the Dan Saga area has not improved the diversity of woody plants. However, the practice simply resulted in an increase in the density of woody species. These results are consistent with those of [27] who reported low diversity with very high densities of multiple-use woody species in the Dan Saga terroir. Indeed, agroforestry is an age-old practice in sub-Saharan Africa consisting of associating woody species with crops. However, woody species are chosen according to their usefulness (fertilizing, non-competitive, emergency food for humans and animals, etc.). ANR remains an agroforestry practice based on the choice of woody species and the improvement of the conditions for the development and growth of these recruits leading to "revegetation" based on an increase in density. Nevertheless, this increase in woody density would lead to an improvement in wildlife habitat and diversity. Grouzis & Akpo, (2006) [28] demonstrated that in semi-arid Sahelian zones, trees influence the floristic composition of the herbaceous stratum, favor the phenology, productivity and quality of spontaneous or cultivated herbaceous vegetation due to the improvement of edapho-climatic conditions under shade. Furthermore, numerous studies [29] have also shown a strong similarity between the microbial and fungal flora of undisturbed ecosystems and those of agroforestry systems. Our results suggest that the practice of ANR, by increasing the density of woody species, improves both the floristic composition of herbaceous plants and soil microorganisms. With regard to soil structure, our results did not indicate a significant improvement, as the bulk densities determined remained within the range of values known for sandy soils (1.0 to 1.6 g.cm-3) [20]. On the other hand, the practice of ANR improved soil water availability in the superficial horizons that are favorable to the crop. Indeed, our results suggest that the density of trees in the fields, through the shading effect and the reduction of wind speed, would have allowed the reduction of evapotranspiration which is very important in this region (~2000mm/year) [30]. More generally, it has been reported that because the practice of ANR attenuates the desiccating effect of air, it favors seedling survival [18].

5. Conclusion

ANR, which is a practical part of the concept of sustainable development, is proving to be a concrete tool for enhancing the multifunctionality of agriculture. This versatility contributes to the growing interest of economic development actors in agroforestry practices, which are integrated into various planning and development projects. In light of the results of this study, it is clear that several practices are already being developed by both producers and technical development partners to reduce vulnerability and strengthen the resilience of the population. However, many of these practices are little known or poorly known by development actors in Niger. Other practices require the implementation of a consistent policy at the national or sub-regional level. These include FMAFS practices, where the investment cost of an operating unit requires not only a significant financial contribution but also trained and competent staff. Niger's future environment will have to be based on agroforestry in order to guarantee the dual objective of livelihoods and environmental sustainability.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors have declared that no competing interests exist.

References

[1] Loireau, M., 1998. Spaces, resources, uses: spatialization of dynamic interactions between social and ecological systems in the Niger Sahel. PhD thesis, Montpellier III University, France;

[2] Leblanc M, Favreau G, Massuel S, Tweed S, Loireau M, Cappelaere B (2008) Land clearance and hydrological change in the Sahel: SW Niger. Glob Planet Change 61:135–150 ;

[3] Guengant JP, Banoin M (2003) Population dynamics, land availability and land tenure adaptation: Niger. Pub. FAO-CICRED, Rome (ITA), Paris, 142 pp;

[4] Rockström, J., & Ada, L. (1993). Diagnosis of the agrarian system of central Zarmaganda (Niger). Final thesis, Institut National Agronomique Paris-Grignon (INA-PG), 50 p.

[5] Le Houerou RN., 1994. Climate change drought and desertification, Intergovernmental Panel on Climate Change, Genève, Weather Mundial Organization (W.M.O.), 38 p;

[6] Gonzalez, P., Tucker, C.J., Sy, H. 2012. Tree density and species decline in the African Sahel are attributable to climate. Journal of Arid Environments 78: 55-64;

[7] Guengant JP., 2015. Emergence, demographic transition and contraception: what links? [Policy Brief]. PRB Blog Post, 2015, (2015/03/25), 6 p;

[8] Floret Ch., Pontanier R. (eds), 2001. Fallowing in tropical Africa. From natural fallow to improved fallow. The state of knowledge. Paris, John Libbey Eurotext, 356p.

[9] Mahamane A.; Ichaou A.; Ambouta K.; Saadou M.; Morou B.; Amani I.; Mahamadou H.; d'Herbès J.M.; Gineste P. & Wata I., 2007. Ecological indicators of the optimal period for recultivation of fallow lands in Niger. Sécheresse vol. 18, No. 4, October-November-December 2007: 1-7 ;

[10] Wezel A., Boecker R. 1998. Fallow plant communities and site characteristics in semi-arid Niger, West Africa. Journal of Arid Environments, in press ;

[11] Valentin C., Rajot J.-L., Mitja D. 2004. Responses of soil crusting, runoff and erosion to fallowing in the sub-humid and semi-arid regions of West Africa. Agriculture, Ecosystems and Environment 104: 287–302;

[12] Hiernaux, P. Turner, M.D. 2002. The influence of farmer and pastoralist management practices on desertification processes in the Sahel. In: Reynolds, J.F., Satfford Smith, D.M. (Eds.), Global Desertification: Do Humans Cause Deserts? Dahlem University Press, Berlin, pp. 136–147;

[13] Mahamane A.; Saadou M.; Bakasso Y.; Abassa I.; Ichaou A. & Karim S., 2008. Diachronic analysis of land use and vegetation characteristics in the commune of Gabi (Maradi region, Niger). *Sécheresse*; 18 (4): 296-304;

[14] GIEC, 2007. Rapport du Groupe I du GIEC: Bilan 2007 des changements climatiques, les bases scientifiques et physiques (ww.IPCC.ch)

[15] Descroix L, Genthon P, Amogu O, Rajot JL, Sighomnou D, Vauclin M (2012) Change in Sahelian Rivers hydrograph: the case of recent red floods of the Niger River in the Niamey region. *Glob Planet Change* 98–99:18–30.

[16] De Miranda, E. (1980) « Essay on the ecological and agricultural imbalance of a semi-arid tropical region: The case of the Maradi region in Niger », Academy of Montpellier, University of Sciences and Techniques of Languedoc.

[17] White F., 1983. The vegetation of Africa. In Unesco/AETFAT/UNSO (Ed), Unesco, Paris, 356 p.

[18] Yamba, B., 2006. Sahelian Study: Report on the study of land tenure, local institutions and the evolution of poverty", Centre Régional d'Enseignement Spécialisé en Agriculture (CRESA), Niamey, Sahelian Study;

[19] Larwanou M. et Saadou M., 2006: « Evaluation of the flora and vegetation in treated and untreated sites in the Tahoua, Maradi and Tillabéry regions", Regional Center for Specialized Education in Agriculture (CRESA), Niamey), Niamey, Sahelian study;

[20] Boudet G., 1984 - Manual on tropical pastures and fodder crops. Paris, The Doc. French, Inst. of breeding and vet. med. of tropical countries., 266 p ;

[21] Yoro G & Godo G., 1990. Methods of measuring bulk density: Analysis of the dispersion of results within a given horizon. Notebook. ORSTOM, series. Pedology., vol. XXV, n "4, 1989-1990 : 423-429;

[22] Baumer M., 1997. Agroforestry for livestock production Nairobi; Wageningen : ICRAF ; CTA, 340p

[23] FAO, 1991; Non-wood forest products: the way ahead, FAO, Rome, 37 p.

[24] Altieri M. A., Anderson M., Kat M., Laura C., 1987. Peasant agriculture and the conservation of crop and wild plant resources, Conservation biology, Vol.1: 49-58.

[25] Arnold J.E.M., 1996. Economic factors in farmer adoption of forest product activities, Document électronique disponible à http//www.fao.org/docrep/W3735EE.

[26] FAO, 1997 Estimating biomass and biomass change of tropical forests: a primer. FAO.

[27] Falconer J., Arnold J.E.M., 1996. Household food security and forestry; socio-economic impact analysis, FAO. Rome, 154p;

[28] Boubé Morou, Haoua Ounani, Abdoulaye Amadou Oumani, Abdoulaye Diouf, Chaïbou Guero et Ali Mahamane, 2016. Characterization of the demographic structure of woody plants in the agroforestry parks of the Dan Saga area (Aguié, Niger), *Int. J. Biol. Chem. Sci*. 10(3): 1295-1311 ;

[29] Michel Grouzis, Léonard Elie Akpo . Tree-grass interactions in the Sahel. Science and global change / Drought. 2006;17(1):318-325 ;

[30] Wilian França Costa, Fabiana Soares Santana, Allan Koch Veiga, Antonio Mauro Saraiva, 2012. New Paradigms for Ecological Research and Data Management, Object Based Image Analysis Techniques Applied to Species Distribution Modelling, 5P.