Evaluation of Assisted Natural Regeneration (ANR) impacts on improving soil fertility and plant cover in the Simiri commune in Niger.

Abstract:

Aims: This study aimed to assess Assisted Natural Regeneration (ANR) impacts on improving soil fertility and plant cover through the physicochemical characterization of soil samples taken from ANR fields and control fields.

Study design: The experimental design is made up of a vegetation observation gradient along an East-West transect and a soil sampling gradient along a North-South transect.

Place and Duration of Study: This study was carried out in the Sahelian zone in the rural commune of Simiri in Niger between May and June 2023.

Methodology:

Data on the diversity of species predominant in the ANR system, the social categories of ANR users and farmers' perceptions of ANR were collected on a sample of 120 farmers chosen at random from three villages in the commune of Simiri.

Results: A sandy texture was recorded in all the samples submitted for analysis, with an overall acid pH. The proportions of the main nutrients (C, N, P, K, Mo, C/N) were relatively higher in the fields under ANR practices compared with the control fields. With regard to the dominant woody species, the results show that the stands are mainly based on Combretum glutinosum, Combretum micranthum and Guera senegalensis. The ability of woody species to withstand stressful conditions could act as a bulwark against climatic hazards. The strong dominance of these species is due, among other things, to their regenerative capacity, their rapid spread and, above all, their economic interest in the production of firewood and other ecosystem services.

Conclusion: The Assisted Natural Regeneration (ANR) adoption in farming practices has often been accompanied by the creation of village committees for the protection and management of trees and other areas of sustainable natural resource management. Despite mutilation and other illegal felling, the new agroforestry parks increase the resilience of agricultural production systems to climatic shocks and biotic stresses.

Key words: Woody species, ANR, stand, plant cover, dissemination, Simiri.

1. INTRODUCTION

The disruption of the ecological balance in the Sahel is mainly the result of the recurrent droughts that characterised the climate between 1970 and 1980 (Rinaudo, 2010). The consequences of this upheaval included energy and food crises, which caused communities to turn to forest areas to stem the energy crisis and meet the basic needs of an ever-growing population (Drame *et al*., 2008). As a result, the natural resources that contribute to the livelihoods of this population are in a state of advanced degradation under the combined effects of human actions and climate change (Lawali *et al*., 2018). In addition, strong demographic pressure on land has resulted in a sharp reduction in vegetation cover throughout the Sahel (Botoni *et al*., 2010). The scarcity or even disappearance of plant cover is causing the desert to advance, reducing soil fertility and lowering agricultural productivity, leading to food insecurity. In addition to this ongoing degradation of natural resources, the major challenge in developing countries remains, to a large extent, the issues of poverty and food security (Lawali *et al*., 2018).

Integrating multipurpose woody crops into the agricultural production system helps to mitigate deforestation, land depletion and poverty among rural populations (Bonkoungou, 1998). Faced with environmental degradation and strong land pressure, farmers in densely populated areas, particularly in south-central Niger, have intensified their agricultural production systems. They have done so by increasing the number of trees and shrubs in their fields, thus creating new agroforestry parks, the scale of which in the Zinder, Maradi and Tahoua regions is around 5 million hectares (Cotillon *et al*., 2021). However, despite the large-scale dissemination of these technologies, their adoption by certain communities remains timid (Zarafi *et al*., 2002). Numerous studies show that natural regeneration managed by farmers has increased crop yields from 31 to 350 kg/ha and ensured food security for families, even during drought years. However, cereal yields remain low and will not be enough to feed a rapidly growing population (Abassee *et al*., 2023). Moreover, ANR increases the incomes of all social categories, even the most vulnerable (men, women and young people). Pruning trees in the fields has also reduced the distances travelled by women to collect firewood. ANR has also increased the availability of fodder for farmers and agro-pastoralists, with ANR households harvesting 30 to 45 kg of fodder per day (Abassee *et al*., 2023).

Increasing the number of trees and shrubs per hectare has increased litter production. This improves soil structure and allows greater quantities of water to be stored. The addition of litter also helps to improve soil fertility. Certain species, which often dominate regeneration, such as Piliostigma reticulatum, Guiera senegalensis and Combretum glutinosum, have a positive impact on the content of chemical elements (carbon, nitrogen and available phosphorus) in the soil. ANR has enabled village communities to adapt better to climate change and to strengthen their resilience. Indeed, even when harvests fail, farmers can cut down certain trees and sell them on the market as firewood or service wood, enabling them to buy cereals. ANR also has a positive impact on crop yields, even in years with low rainfall (Abassee *et al*., 2023). Hence the interest of this study, which aims to assess the impact of ANR on improving soil fertility and increasing the density of woody plants in crop fields.

2. MATERIALS AND METHODS

2.1 Study area

The study was carried out in the rural commune of Simiri and covered three villages in the area: Guessé Gao banda, Guessé Sinsan and Simiri.

The rural commune of Simiri is 80 km north of Niamey in the Ouallam department. The climate is arid, Sub-Sahelian, with annual rainfall varying between 400 and 600mm (Saadou, 1990). It is irregularly distributed in time and space. The rainy season extends from June to September. The average maximum temperature varies from 24°C in January to 33°C in April, with a temperature range of 9°29. The representative toposequence of the region is characterised by a succession of four major zones typical of the tropical ferruginous plateaux of the Sahel: the armoured plateau, the sandy skirt, the glacis and the lowlands (Ambouta *et al*., 1996). Skeletal soils of the rigosol and lithosol types formed on terminal continental clayey sandstones are found on the plateaux (Ambouta, 1997). The sandy skirt and glacis contain sandy tropical ferruginous soils with little leaching, followed by alluvial soils in the lowlands. The natural vegetation consists of shrub steppe on the glacis and shrubs to trees in the lowlands, while a contracted formation subject to severe degradation can be seen on the plateaux (Boubacar *et al*., 2013). The main woody species are Guiera senegalensis, Combretum micranthum and Combretum glutinosum. The herbaceous layer is dominated by Mitracarpus scaber, Eragrostis tremula and Cenchrus biflorus. Figure 1 below shows the geographical location of the Simiri commune.

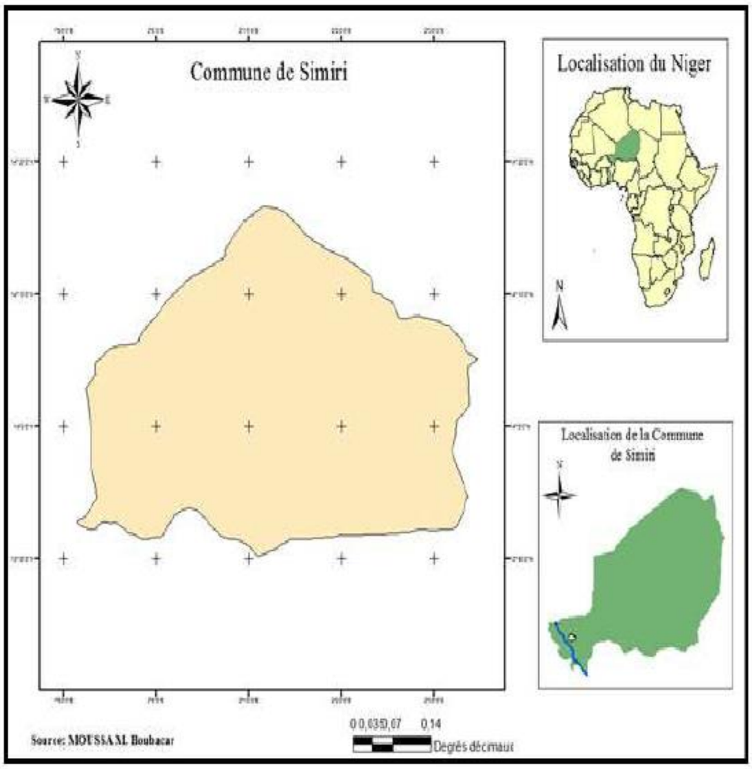

Figure 1: Location map of the rural commune of Simiri (Source: Moussa Boubacar, 2019)

2.2. Documentary research

This phase involved gathering the documentation needed to understand the subject properly and to establish the state of knowledge on the subject. It was carried out using databases (website, scientific journals), activity reports and scientific publications.

2.3 Field investigation

To collect both quantitative and qualitative data, individual interviews were conducted with a sample of 120 farmers practising ANR in their fields. These farmers were located in three villages in the rural commune of Simiri: Guessé Sinsan, Guessé Gaobanda and Simiri. The interviews were conducted using a semi-structured questionnaire. A systematic inventory of woody species was carried out in the fields in order to assess the diversity of species used in ANR.

Figure 2: Interview with an ANR practitioner in Guessé (Daouda, 2023)

2.4. Soil sampling and analysis

A total of twelve (12) soil samples were taken from all three sites, with three samples per site and three controls. The soil samples collected were analysed at the INRAN Niamey soil science laboratory using standard methods (Mathieu and Pieltain, 2003). The physico-chemical parameters used to characterise the soil were : granulometry by the Robinson pipette method; pH by determination of hydrogen ions; cation exchange capacity (CEC) and the sum of exchangeable bases (S) by the silver thio urea method; total nitrogen by the Kjeldahl method; organic carbon by the Walkley & Black method; assimilable and total phosphorus (P) by the Bray1 method, electrical conductivity by the conductimetry method, exchange acidity, organic matter and exchangeable bases. The figures 3 and 4 below show respectively the packed soil samples and an overview of a field under ANR practices.

Figure 3: packed soil samples (Daouda, 2023)

Figure 4 Overview of a field of RNA (Daouda, 2023)

2.5. Data analysis and processing

The survey data were tabulated and analysed using Excel, then subjected to descriptive analysis using SPSS software. The soil analysis results were also subjected to discriminant analysis in order to identify similarities between variables at different sites.

3. RESULTS

3.1 Breakdown of producers by sex and age

Figure 5 below shows the breakdown of NAR users by gender and age group.

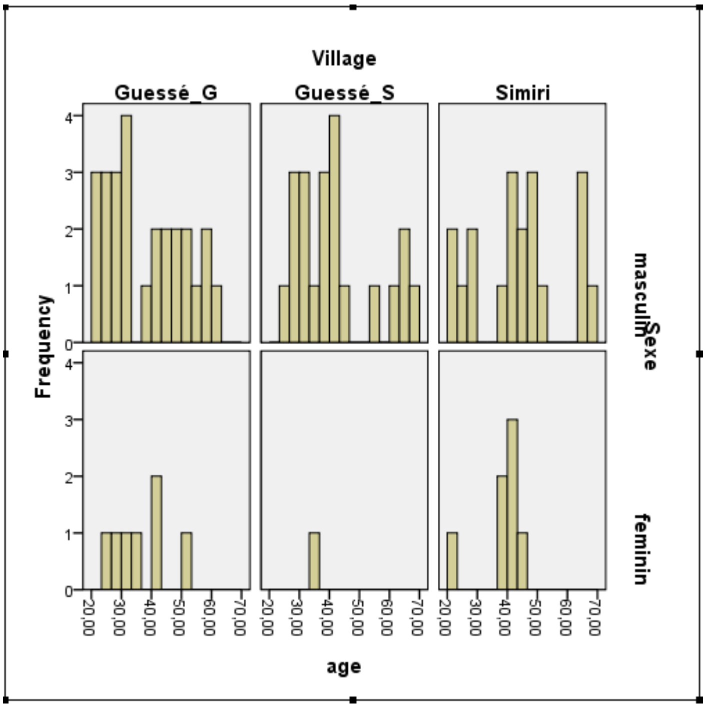

Figure 5: Breakdown of respondents by gender and age group

This graph shows that the average age of respondents is 39.97±12.76, with a minimum of 20 and a maximum of 67 Regardless of the sites, women are in the minority in the practice of ANR.

3.2. Dispersion of soil physicochemical parameters by site

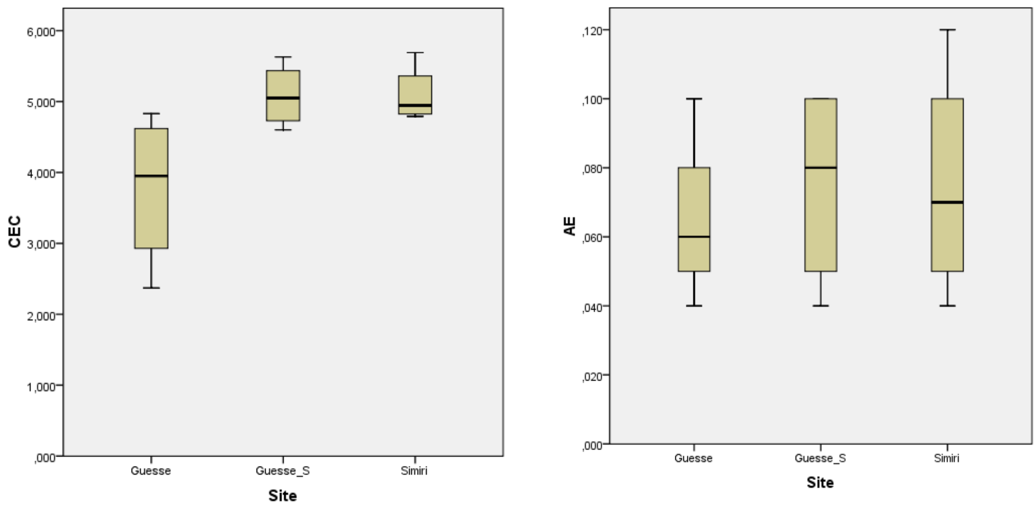

Figure 6: Dispersion of CEC and exchange acidity (EA) values by site

This figure shows that the CEC values recorded at the Simiri and Guessé Gao-Banda sites are scattered around the average, unlike those obtained at the Guessé Sinsan site, which are close to the general average. On the other hand, the variation in exchange acidity values shows that the Simiri and Guessé Gao-Banda sites have values well above the general average, while the

Guessé Sinsan site has values below the average. This indicates a fairly clear dispersion of this variable between sites and cultivation practices at these sites. In addition, low CEC and AE values were observed at the control sites that were not under ANR practices.

3.3 Constraints to adoption of ANR in the farming environment

The figure below illustrates the main constraints to adoption of ANR according to the farmers surveyed

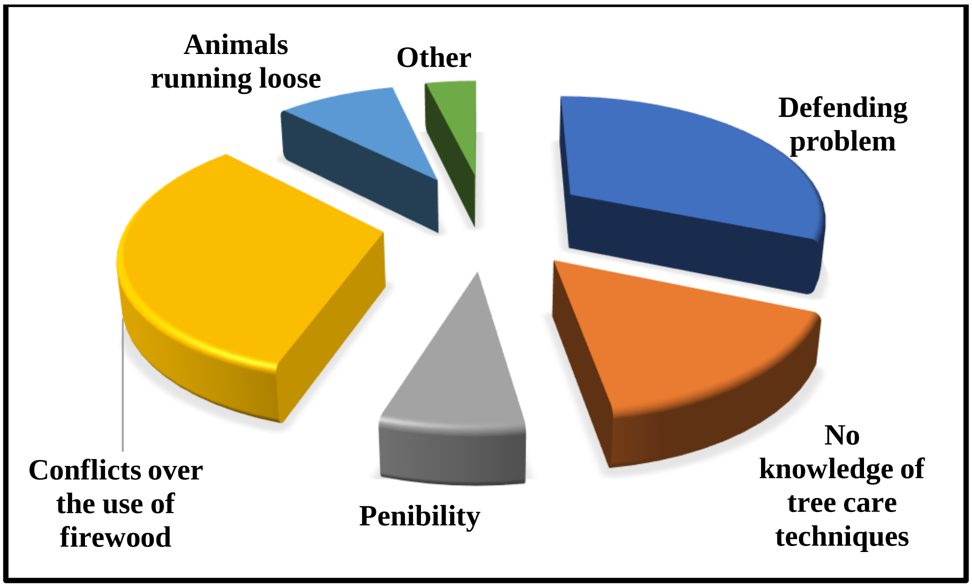

Figure 7: Constraints to adoption of ANR

The figure shows that conflicts over wood harvesting, the problem of defending fields under ANR and poor knowledge of young shoot maintenance techniques are the main constraints faced by farmers in adopting ANR, with proportions of 32.5%, 31.25% and 16.25% respectively.

3.4 Socio-economic impacts of ANR

3.4.1. Impacts on household living conditions

Figure 8 below presents the impacts of the ANR on household living conditions

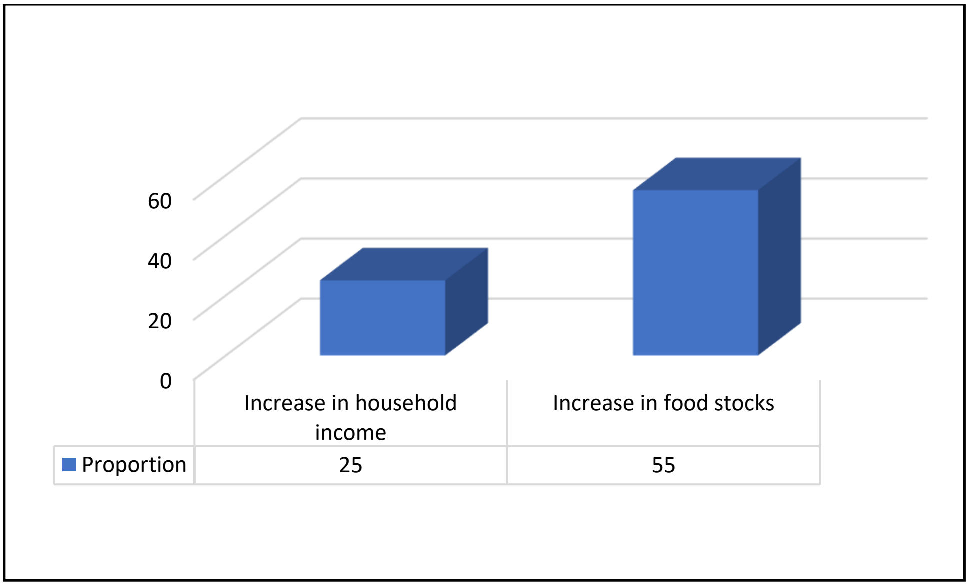

Figure 8: Impact of the NAR on household living conditions

The graph shows that 68.25% of respondents said that the use of ANR in crop fields had increased their food stocks, compared with 31.25% who said that it had clearly increased their income, in particular through the sale of firewood, service wood and non-timber forest products. This income is then used to reconstitute part of the food stock in addition to that derived from the production of fields whose fertility is improved by these practices.

3.4.2. Impacts on soil and climate components

The figure below illustrates the main advantages of ANR.

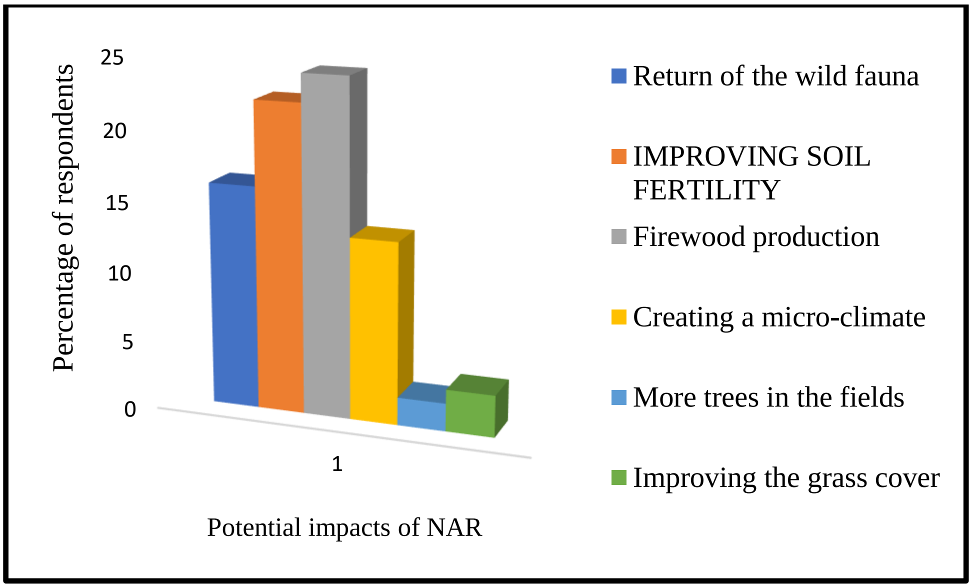

Figure 9: Main advantages of ANR

There are several advantages to implementing ANR in cropping systems. Indeed, the following main benefits emerge from this graph: Return of wild fauna, improved soil fertility, and firewood production with a preponderance of 30%, 27.5% and 20% respectively.

3.4.3 Impacts of ANR on soil physicochemical properties

Table 1: Physico-chemical characteristics of the soil in the fields under practice

N° Lab.	Identification	Prof. en cm	pH		Mèq/100 g							Phosphore ppm		Fer %		%			
			H_2O	C.E m^s/cm	CA^{++}	Mg^{++}	Na^{+}	K^{+}	Tot	CEC	AE	Assim.	Tot	Libr	Tot	Carb.	M.O	Azote	C/N
2023/188	Simiri Témoin	0-25	5.18	0.01	1.10	3.48	0.165	0.071		4.86	0.04	8.11	0.122			0.26	0.44	0.022	12
189	Smiri 1	0-25	5.62	0.04	1.25	4.11	0.174	0.092		5.69	0.06	6.31	0.110			0.10	0.18	0.009	11
190	Simiri 2	0-25	5.45	0.04	1.15	3.56	0.174	0.071		5.03	0.08	5.80	0.122			0.28	0.47	0.024	12
191	Guessé Gao banda Témoin	0-25	5.46	0.04	1.20	3.34	0.157	0.071		4.83	0.06	2.56	0.134			0.21	0.36	0.018	12
192	Guessé Gao banda 1	0-25	5.45	0.05	1.05	1.21	0.044	0.021		2.37	0.04	14.51	0.108			0.18	0.31	0.016	11
193	Guessé Gao banda 2	0-25	5.51	0.06	1.25	2.03	0.078	0.036		3.49	0.10	4.61	0.125			0.28	0.49	0.025	11
194	Guessé Gao banda 3	0-25	5.38	0.05	1.25	2.89	0.165	0.046		4.41	0.06	8.28	0.106			0.09	0.45	0.023	04
195	Guessé Gao banda	0-25	5.38	0.05	1.25	3.16	0.183	0.077		4.79	0.12	2.99	0.098			0.07	0.12	0.006	12
196	Guessé Sissan Témoin	0-25	5.46	0.05	1.50	3.43	0.183	0.066		5.24	0.06	2.82	0.125			0.08	0.13	0.007	11
197	GusséSissan 1	0-25	5.10	0.02	1.50	3.77	0.165	0.092		5.63	0.10	12.38	0.153			0.06	0.10	0.005	12
198	Guessé Sissan 2	0-25	5.07	0.02	1.40	2.98	0.087	0.092		4.60	0.04	7.43	0.129			0.10	0.18	0.009	11
199	Guessé Sissan 3	0-25	5.33	0.05	1.40	3.12	0.174	0.066		4.86	0.10	6.83	0.108			0.22	0.39	0.020	11

EC: electrical conductivity; CA++: calcium; Mg++: magnesium; Na+: sodium; K+: potassium; CEC: cation exchange capacity; AE: exchange acidity; assimilable phosphorus; carb: carbon; Mo: organic matter; C/N: carbon to nitrogen.

The soil analysis results show that the fields under RNA have fairly variable characteristics and an acceptable level of fertility. The pH was generally acidic in all samples (5.07 - 5.62), with relatively low levels of organic matter, carbon and total nitrogen. In addition, the predominantly sandy texture of the soil samples justifies the low CEC values, which vary according to OM content. The slider between calcium and magnesium depends on the size of the CEC. Figure 10 below illustrates the variation in the cation exchange capacity of the soil in fields under ANR according to the Ca++ /Mg++ slider.

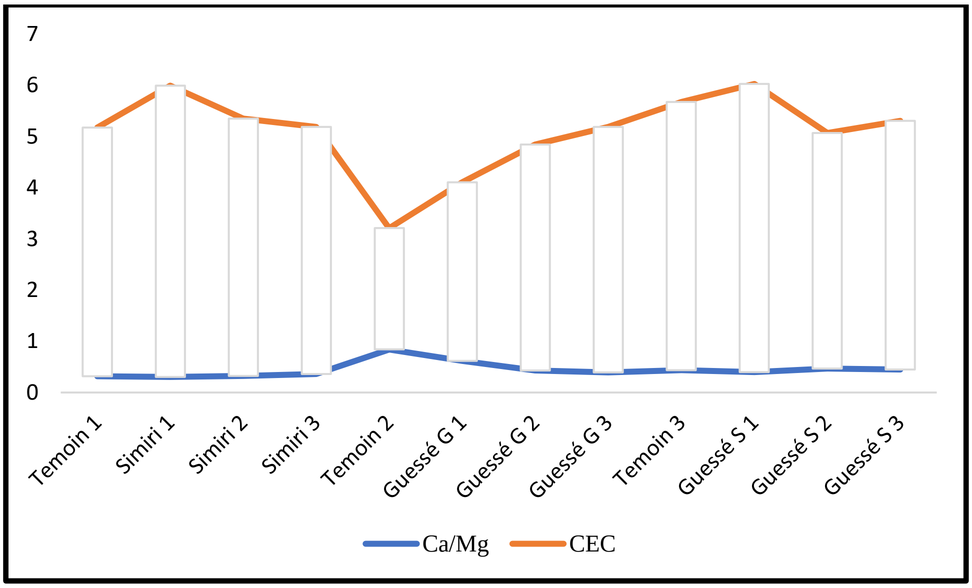

Figure 10: Ca^{++}/Mg^{++} complex and CEC in soil

This graph shows that the CEC of the soils varies from one site to another, unlike the Ca^{++}/Mg^{++} complex, which shows little variation from one site to another. In terms of soil texture, the results show that all the samples are predominantly sandy, with relatively low clay and silt content. The proportions of fine and coarse sands dominate the texture of these soils. The figure shows two peaks (convex and concave) representing the two extreme values for the Ca++/Mg++ complex and the CEC for all the samples analysed.

3.4.4 Diversity of woody species in agroforestry parks under ANR

The figure below shows the diversity of woody species in fields under ANR practices in the Simiri zone.

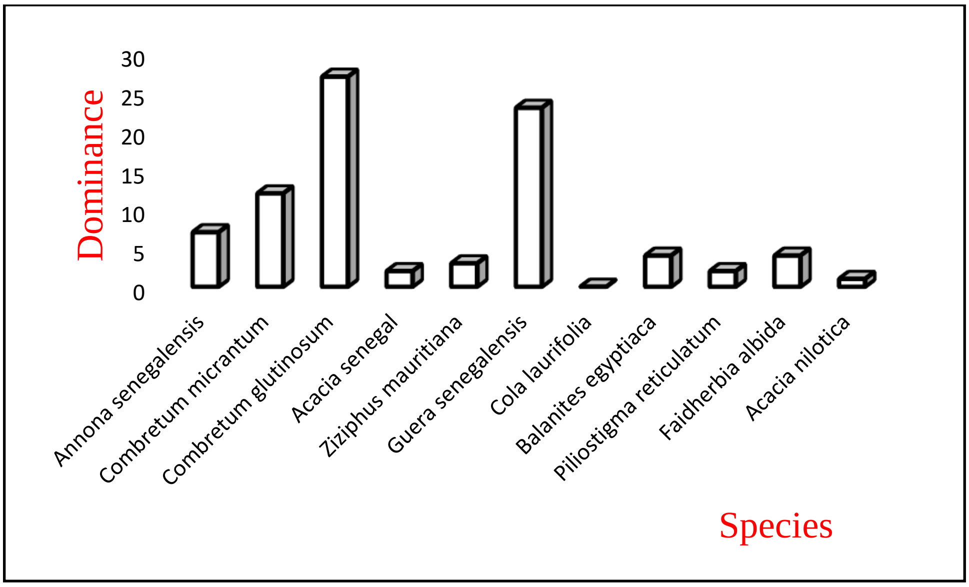

Figure 11: Diversity of woody species used in ANR

This figure shows that several woody plant species are used in ANR systems. These include Combretum micrantum and glutinosum, Guera senegalensis and Annona senegalensis, which are the most predominant species in agroforestry parks in the Simiri zone.

3.5 Discussion

Increased degradation of cultivated land and other special ecosystems has led to massive investment in restoration activities in Niger. For this reason, the country has signed up to the African Forest Landscape Restoration (AFR100) initiative, which aims to restore 100 million hectares by 2030. To honour this commitment, there are plans to further promote agroforestry practices, including assisted natural regeneration for the rapid reforestation of agricultural areas, which will ensure the productivity of Niger's agro-ecosystems. In this study, the results showed a good perception of ANR by the producers surveyed, hence the involvement of all socio-professional strata in the adoption of this practice. The farmers surveyed said that they had intensified their agricultural production system by increasing the number of trees in their fields. This increase does not result from new plantings but rather from the protection and maintenance of young tree shoots that appear spontaneously in the fields, contributing in the long run to the formation of agroforestry parks with, in particular, various centers of interest for the communities and the landscape. These results are in line with those of several authors who find that ANR is a good way of improving agricultural production and combating food insecurity. Furthermore, these authors state that ANR could be a strategy for combating food insecurity through the sale and marketing of woody forest products (Sitou *et al*., 2018; Ado et al., 2019). Various woody species are protected and maintained in crop fields, providing multiple ecosystem services, including soil fertilisation through litter from dead leaves, climate regulation, carbon sequestration, recreation and runoff reduction. The most dominant species are Guera senegalensis, Combretum micranthum, Combretum glutinosum and Annona senegalensis. These results corroborate those of Baggnian et al (2014); Moussa et al (2015); Mamane (2017) and Maâzou (2019), who state that woody stands in fields under RNA are most often dominated by Combretum glutinosum, Combretum micranthum, Piliostigma reticulatum, Guiera senegalensis, Faidherbia albida and Prosopis africana. According to these authors, the specific contribution of each species is highly variable, ranging up to more than 50% of the total tree stand. Improving soil fertility under RNA is one of the primary objectives of this agroforestry practice. Farmers invest in trees mainly to maintain or improve the fertility of their soils, and the impact of certain species on chemical fertility has been confirmed by several studies (Mansour et al., 2013; Camara et al., 2017; Dan Lamso et al. 2015a, 2015b; Zounon et al., 2020; Traoré, 2012; Bodo et al., 2019). Soil analysis results showed that the content of certain nutrients was much higher in fields under RNA compared with control areas not under RNA. These include C (%), N (%), K (meq/100g) and C/N. This suggests that an increase in tree density is always followed by an improvement in soil fertility. A study by Dan Lamso et al (2022) showed that ANR is an effective fertility management practice for tropical ferruginous soils cultivated in Niger. The results of the household surveys showed that the practice of ANR in the fields generates additional income for practising households in addition to the increase in cereal production in the fields. This increased income comes from the sale of wood and non-wood forest products from the ANR. Although this income has not been accurately evaluated in this study, the producers claim that the sale of ANR products considerably reduces the poverty level of households and, in turn, enables them to obtain food supplies. This protects them from food insecurity and increases the duration of their food stocks. These results are in line with those of Baggnian (2010), who states that the action of trees increases the duration of agricultural production stock by 5 to 7 months on average, which contributes significantly to food stability.

The management of ANR is often accompanied by better consultation and organisation within villages in order to manage the new tree capital effectively.

Several constraints limit the use of ANR in the villages covered by the study. These are mainly conflicts over wood harvesting (33%), problems with defending fields under ANR (31%) and lack of knowledge of techniques for maintaining young shoots (16%). These results are similar to those of Kabirou (2022), who notes that transhumant herders, who generally come from elsewhere during the dry season, carry out severe pruning, which more often than not compromises the survival of the trees. Similarly, the animals of local livestock farmers, which are sometimes left to roam, graze on the new shoots left in the fields. This leads to frequent physical conflicts. In addition, young people and women from the villages fraudulently cut down plant species in the fields without considering the consequences. Also, woodcutters from several localities cut down trees clandestinely at ground level in the absence of the field owner, often late at night (Kabirou, 2022). Finally, the partial application of the provisions of the forestry code by rural actors and the inadequacy of forestry regulations that take into account the status of regenerated trees in the fields are constraining ANR in the study area (Kabirou, 2022). The introduction of ANR has often been accompanied by the creation of village organisations for the protection and management of trees. These organisations have adopted community regulations against tree felling and theft, and this new social capital helps to ensure the sustainability of the tree capital established in the fields. The new agroforestry parks increase the resistance of agricultural production systems to climatic shocks and sequester large quantities of carbon.

Conclusion

At the end of this study, the results show that ANR is an effective agroforestry practice for integrated management of soil fertility, crop productivity and the improvement of farmers' sustainable livelihoods. Given its multiple benefits, it encourages a clear awareness and willingness on the part of small-scale farmers to protect and manage woody species. The adoption of this practice is closely linked to the farmers' perception of the causal link between the presence of woody species in high densities in the fields and the level of fertility of the fields, and between the level of fertility of the soil and the productivity of the land. Furthermore, the soil and climate conditions (sandy soil, semi-arid climate) are undeniable advantages for the adoption of ANR in the villages of Guessé and Simiri. The fact that this practice is accessible to all social categories is conducive to its widespread adoption. In addition, farmers derive significant income from ANR through the sale of firewood and other tree products. Women benefit from ANR because it increases the availability of fuel, reducing the distances they have to travel to collect wood. It also increases non-timber forest products, which help to improve family nutrition and the quality of life.

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