

Effects of Agro-ecological Practices on the Bio-functioning of Soil and Water Resources in the Rural Commune of Falwel (Dosso-Niger)

Djabri Hassimiou Halidou, Maman Manssour Abdou, Zoubeirou Alzouma Mayaki

Abstract— The decline in soil fertility, one of the main constraints of the agricultural sector in Niger, is still prevalent in several production areas where land is exploited every year without fallowing. Faced with this situation, various solutions such as the adoption of agroecological practices have been considered. In order to evaluate the level and constraints of adoption of these practices as well as their effects on the bio-functioning of soils and water resources, a study was conducted among 100 producers in the rural commune of Falwel. Soil samples were collected from the community sites and analyzed at the INRAN soil laboratory to assess the effect of reclaiming degraded land on soil fertility and vegetation cover improvement. The collected data were analyzed with Xlstat 2014 version 5.3 software. The results of the study showed that the practices of land restoration and promotion of ecological market gardening were adopted respectively by 35 and 64% of the producers surveyed because of their contribution to the improvement of soil fertility and their low-cost practice. On the other hand, the practice of over-digging surface water points was less adopted with an adoption rate of less than 20%. The reasons cited include the difficulty of implementing it on an individual scale, the lack of equipment and the arduousness of the activities. Moreover, physicochemical analyses have shown that the practices have had various effects on the physicochemical characteristics of these soils and the expected effects are sometimes not immediately observable.

Index Terms— Constraint, soil fertility, Productivity, water points, Niger.

I. INTRODUCTION

Soil fertility management and conservation practices can contribute to the improvement of food security and poverty reduction through better intensification of some agroecological practices [1]. Moreover, these practices allow producers to increase income and improve their food security system capable of meeting the demands of national as well as international markets [2]. However, land degradation associated with climate change, reduces the water retention capacity of soils and the resistance of crops to drought. The current majority practices are still those of the intensive conventional agricultural model, which has developed

strongly over the past decades. This type of agriculture, in which organic inputs have been gradually replaced by synthetic fertilizers, has caused numerous problems for the fertility of agricultural land, particularly in terms of a drop in the level of organic matter, which has led to a high degree of sensitivity to erosion due to a loss of structural stability [3].

Faced with this situation, the challenge for agricultural research is enormous. It must increase the productivity and competitiveness of agriculture by improving crop yields, product quality while conserving the environment [4].

Indeed, good physico-chemical conditions (air and water circulation, temperature and pH) will promote good biological activity which in turn will generate good soil structuring (formation of pores and aggregates in the soil, humification and mineralization of OM and thus release of nutrients for plants, etc.). We can then speak of a "virtuous circle of soil functioning" essential to the proper development of crops [5]. Soil fertility and its management represent a major issue for limiting climate change, as well as for maintaining sustainable agricultural production, even if current and majority agricultural practices do not currently take into account all the means to ensure this fertility in the future [6]. Breaking with the objectives of intensive conventional agriculture, the principles of agroecology suggest that the conduct of plant production should be based on "the constant improvement of soil fertility and biological activity while giving priority to the contribution of organic amendments. It is thus a matter of feeding the soil to feed the plant" [7-8].

Agriculture, the activity of which it is the support, can reverse, accelerate or even provoke evolutions in such a way that some of these evolutions can call into question the agricultural potential of the soil or, in other words, its fertility [9]. Indeed, due to the great diversity of crops and the intensification of production on a limited area, agricultural production often rhymes with intensive use of the soil through repeated tillage interventions and rapidly degraded organic fertilizer inputs [10]. These practices have often been justified by expected benefits on the quantity and quality of products but in the short and medium term, risks of decreasing soil fertility are conceivable [11]. However, at present, it is rather the efficiency of nutrient metamorphosis that is coming to the forefront as a measure of soil fertility [12], as we realize that this fertility is the result of the expression of biological, physical and chemical components of soils and their interactions that influence this nutrient cycle in particular [13]. Hence the importance of better knowledge of different endogenous land management practices in the context of agroecological sustainability for better agricultural

Hassimiou Halidou DJABRI Sustainable Crop Production Department, Boubacar Bâ University of Tillabéri, BP 175 Tillabéri, Niger
Abdou MAMAN MANSOUR, Sustainable Crop Production Department, Boubacar Bâ University of Tillabéri, BP 175 Tillabéri, Niger
Alzouma Mayaki ZOUBEIROU, Department of Biology, Abdou Moumouni University of Niamey, BP 10662 Niamey-Niger

productivity. Moreover, in recent years, few cultural practices generating better soil fertility management have been developed, with the exception of agroecological practices in particular [14]. Indeed, there are no ready-made answers but rather combinations of practices and actions to promote production practices and approaches that conserve soil and water resources [15]. It is in this perspective that the present study was initiated and aims at evaluating the effect of agroecological practices on soil and water bio-functioning in order to ensure food security of farm households.

II. MATERIALS AND METHODS

2.1 Study site

The study area is composed of four villages in the rural commune of Falwel. Figure 1 below shows the geographical location of the study sites.

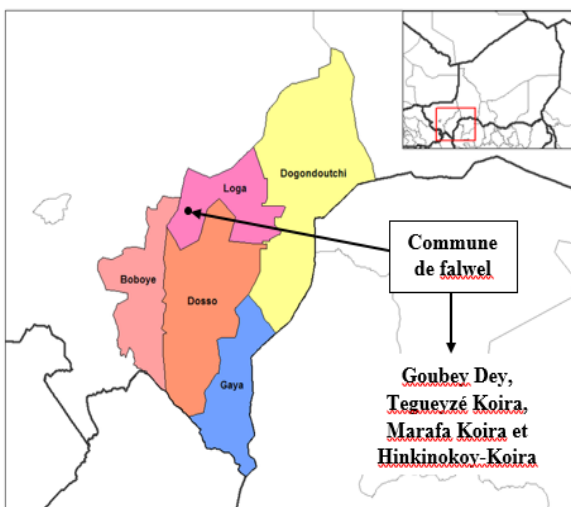


Fig. 1: Map of the geographical location of the study area

2.2. Collection and analysis of soil samples

In order to evaluate the effect of agroecological practices on the bio-functioning of soils and plant cover, soil samples were taken. A total of nine (9) soil samples were taken at a depth of 25 cm on three separate sites. The samples were sent to the soil laboratory of INRAN in Niamey for physico-chemical analysis. The physico-chemical parameters of the soils were determined according to AFNOR NF X31-130 standards.

2.3. Field investigation

To assess the level and constraints of agro-ecological practices adoption, a survey was conducted in December 2020 among 100 randomly selected producers in four villages of the commune of Falwel. This sample represents 37.59% of the beneficiaries of the emergency interventions. The survey unit was the head of the beneficiary household. The collection tool used was a structured interview guide. The information contained in this guide relates to the socio-economic characteristics of the farms (age, gender, level of education,

etc.), as well as information on the effects of the practices on soil fertility, water resources and the constraints related to their use. Agroecological soil fertility and water resource management practices include:

- Restoration of degraded lands (CES/DRS) ;
- Over sinking of surface water points ;
- The promotion of home gardens.

2.4. Data analysis and processing

Descriptive statistics was used to characterize the effects of technologies on soil physicochemical characteristics and water resources availability. Discriminant and multivariate analyses were done with Xlstat-2014 version 5.3 software to identify the interrelationship between agroecological practices and soil and water resources bio-functioning. Pearson correlation matrix (n) was used to determine the correlation between soil fertility variables and associated factors.

III. RESULTS

3.1. Agroecological practices and associated effects

➤ Overburdening of water points

Overflowing the water points is a long-term solution to the plight of the people in the area, particularly the conflicts between farmers and herders over access to water resources. Indeed, before the adoption of the project, the storage capacity and the duration of water conservation of these ponds were very limited because the ponds dried up after two months after the rainy season and the village ponds were the only water points that people and animals shared while waiting for the next season. Following the work of sinking these ponds, which has been doubly beneficial (local labour, works) to the beneficiaries, the storage capacity has increased by several thousand cubic metres and the duration of drying up has been extended by more than six months after the rainy season. In addition, the producers have all the time they need to harvest their agricultural products and collect the residues before the animals descend on the village watering holes. The water from these ponds is also used for other purposes, including the harvesting of late season legumes (voandzou and groundnuts) by moistening the compacted soil by pouring water around the root zone. The making of banco bricks and

the drawing of water for the construction of houses are also done around semi-permanent ponds following interventions. Fig 2 and 3 below illustrate respectively the ponds developed (Bangou Béri and Bangou Touganté).



Fig. 2: Overview of the Bangou Beri pond (source author 05/12/2020)



Fig. 3: Nomadic communities drawing water at the edge of the Bangou Touganté waterhole (05/12/2020)

➤ Restoration of degraded lands

Reclamation of degraded land or glacis in crop fields is also highly valued among innovative soil fertility and water resource management practices. Indeed, the restoration of land and its development have contributed to the increase of soil fertility and the improvement of vegetation cover in the restored areas. Moreover, this intervention has allowed the expansion of the technique in the personal fields of all the beneficiaries and beyond to the entire population of the area. In addition, this work has greatly contributed to the reduction of rainwater runoff that was invading the dune fields and some residential areas. The increase in biological diversity, the creation of a microclimate in the area and the return of

small fauna are other effects of the recovery of land on the ecosystems of the study area.

Fig 2 and 3 below illustrate respectively *Community field rehabilitated by CES/DRS techniques* and Construction of anti-erosion works (multifunctional half-moon) on a degraded site.



Fig. 4: Community field rehabilitated by CES/DRS techniques



Fig. 5: Construction of anti-erosion works (multifunctional half-moon) on a degraded site

➤ Intensification of ecological vegetable gardening

The promotion of home gardens is a very relevant resilient intervention in that it allows beneficiaries to be autonomous in feeding themselves without depending on external food aid. Indeed, market gardening constitutes an alternative to climatic constraints in favourable areas because it offers producers the opportunity to produce outside the wet season and to overcome climatic adversity. This contributes to the availability of agricultural products throughout the year and to better support the lean season. Producers with a substantial food stock can better tackle field work during the rainy season than those who have to ensure their daily life before thinking about field work through endless acrobatics throughout the

season while waiting for the new harvest. The photo below illustrate the home gardens in the village of Tegueyzé Koira zeno. Fig. 6 below illustrate the overview of a hut garden..



is adopted by 35% of the respondents. The development of water points is the least adopted practice of all (18%). Several reasons were given to explain the low adoption rate. The respondents mentioned the lack of equipment (98%). Indeed, this technology requires a lot of investment (12%) and a certain technicality for its application. In addition, this technology can only be applied to large or small areas of water and requires a lot of time to implement.

The results show that hut gardening is adopted by 64% of producers. On the other hand, the restoration of degraded land

Fig.6: Overview of a hut garden in Tegueyzé Koira Zeno (05/12/2020)

3.2. Level and constraints of adoption of agroecological practices

The level of adoption of agroecological practices is presented in Table 1

Table 1 : Adoption level of agro ecological practices

AE Practices	Adoption	WOMAN	MAN	Total
Restoration of degraded lands (CES/DRS)	NOT	35	30	65
	YES	14	21	35
Development of water points	NOT	37	45	82
	YES	3	15	18
Promotion of home gardens	NOT	3	33	36
	YES	47	17	64

AE: Agroecology

3.3. Effects of AE practices on the physico-chemical characteristics of soils

Physical characteristics of soils

Num Ech.	Site	Depth (cm)	Clay (%)	Silt (%)	Fine Sand (%)	Coarse Sand (%)
1	Goubey D	0-25 cm	15.92	10.61	30.26	43.21
2	Goubey D	0-25 cm	8.89	1.21	35.75	54.29
3	Goubey D	0-25 cm	15.71	0.70	29.01	54.58

4	Marafa K	0-25 cm	23.37	7.68	43.85	25.10
5	Marafa K	0-25 cm	19.99	5.10	34.12	40.78
6	Marafa K	0-25 cm	29.18	5.85	31.12	33.85
7	Tegueyzé K	0-25 cm	13.84	21.62	27.84	36.70
8	Tegueyzé K	0-25 cm	25.91	3.23	28.86	42.00
9	Tegueyzé K	0-25 cm	22.72	8.95	37.77	30.56

The results of the physical analysis of the soil are presented in Table 2.

The results of the granulometric analyses show a dominance of the sandy texture on the whole of the samples with a strong tendency towards coarse sand except for the first sample of the site of Marafa Koira where the sandy proportion is largely dominated by the fine sand fraction (43,85 %). As for the clay content, the control sample of Marafa Koira presents the best content with a rate of 29.18% against respectively 25.91% for Tegueyzé Koira 2, 23.37% in Marafa Koira 1. The lowest clay rate (8.89%) was observed in the sample 2 of Goubey Day. The silty fraction presents slightly variable contents with extremes of 0.70% and 21.62%. The determination of the texture of the soils according to the textural triangle proposed

by the Agronomic laboratory of Normandy on the basis of the percentages in clay and silt makes it possible to note the following respective textures :

Goubey Day 1: Clayey sand (L=10,61%, A=15,92%), Goubey Day 2: Pure sand (L=1,21%, A=8,89%), Goubey Day temoin: Clayey sand (L=15,71%, A=0,72%), Marafa koira 1: Clayey sand (L=7,68%, A=23,37%), Marafa Koira 2 : Clayey sand (L=5.10%, A=19.99%), Marafa Koira temoin: Very sandy clay (L=5.85%, A=29.18%), Tegueyzé Koira 1 : Sand (L=21.62%, A=13.84%), Tegueyzé Koira 2: sandy clay (L=3.25%, A=25.9%) and Tegueyzé Koira control: clayey sand (L=8.95%, A=22.72%).

➤ **Chemical characteristics of soils**

a) Descriptive statistics

Table 2: Descriptive statistics of soil physico-chemical characteristics

Variable	Minimum	Maximum	Average	Standard deviation
pH	3,6300	5,3200	4,5200	0,5037
CE	0,0200	0,0800	0,0322	0,0192
CA ⁺⁺	2,9000	6,5000	4,8056	1,2778
Mg ⁺⁺	0,2540	0,7710	0,4582	0,1569
Na ⁺	0,0960	0,1470	0,1223	0,0194
K ⁺	0,0870	0,3080	0,1667	0,0796
CEC	3,9300	7,1200	5,7611	1,1721
AE	0,0000	0,5290	0,2091	0,2179
P _{ass}	3,8100	7,6900	6,1478	1,5020
Carb.	0,0700	0,2600	0,1622	0,0696
Azote	0,0180	0,0530	0,0298	0,0123
C/N	3,0000	13,0000	6,4444	3,1667
M.O	0,1200	0,4400	0,2767	0,1162

From this table (2), it can be seen that all the samples analysed have a very acidic pH with an average of 4.52 (≤ 5.5) and a standard deviation of 0.5237. The agricultural soils have a pH between 4 and 9, with rare exceptions. The pH value is subject to seasonal variations depending on the water

status of the soil, its temperature, the presence or not of a crop in active growth period. Electrical conductivity varies slightly (0.0322 on average). As for the exchangeable bases, they present low values except for CA⁺⁺, whose content is more or

less appreciable compared to Mg^{++} , Na^+ and K^+ with an average of 4.80 meq/100g.

b) Correlation between variables and factors

The distribution of these different variables according to the sites is highlighted by a principal component analysis in which the first two axes explain 58.26% of the total variance. (fig7).

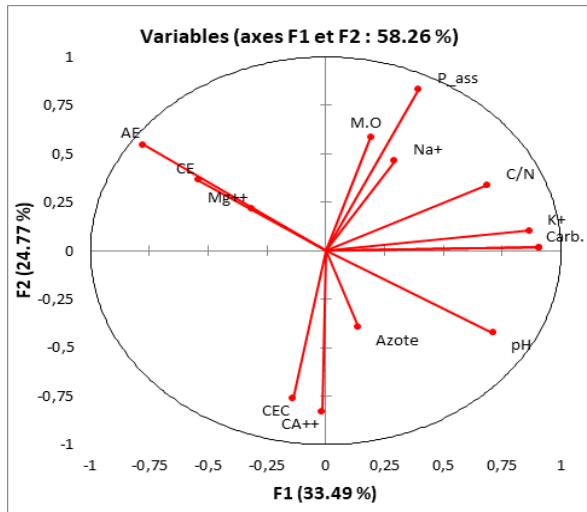


Fig.7: Principal component analysis of soil chemical characteristics

The F1 axis contributes to 33.49% of the total inertia of the variables against 24.77% of the total inertia for the F2 axis. The F1 axis carries on its positive part the variables : Organic matter (0.909), total carbon (0.907), C/N ratio (0.688), potassium (0.863), sodium (0.291), assimilable phosphorus (0.393), magnesium (-0.315), electrical conductivity (-0.541) and exchange acidity (-0.775) which are respectively opposed to pH (0.711), calcium (-0.014), cation exchange capacity (-0.138) and total nitrogen (0.139) carried by the negative part of the F1 axis. The same distribution of variables can be observed on the F2 axis, which also isolates the variables with a low contribution to the total inertia (CEC, Ca^{++} , EC, AE and Mg^{++}) compared to the other variables. It is therefore an axis of good soil condition. It thus opposes the soil fertility parameters on its positive part to the structuring and consistency parameters on its negative part Axis 1 is an axis of expression of the different variables according to the agroecological practices. It therefore highlights the behaviour of each parameter under different treatments.

c) Variables contribution

The figure below shows the contribution of the variables to the total variance.

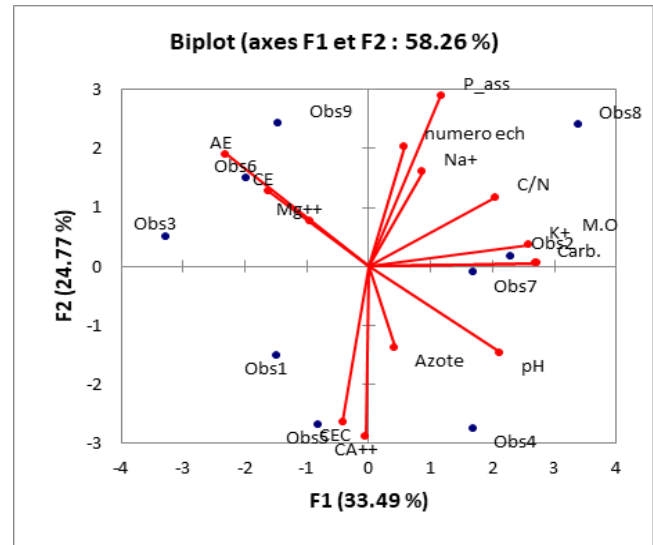


Fig. 8: Biplot contribution of variables
Discriminant analysis grouped the different observations according to their similarities, as determined by the responses of fertility level and soil structure (figure 2). From this figure, it appears that the principal components (CP1 and CP2) contributed at 58.26% of the variance. Based on the correlations between variables and factors, total nitrogen; organic matter, potassium, C/N ratio, sodium, assimilable phosphorus, calcium and CEC are associated with observations 2, 4, 8 and 5 for the formation of axis 1. pH, total carbon, magnesium, electrical conductivity, and exchange acidity, participate with observations 1, 3, 7 and 9 in the formation of axis 2. This separation shows that most of the variables were similar for all observations. The CP1 axis presents the overall result on the different variables. Indeed, the score or coordinate of these observations on the CP1 axis follows the same ranking as that of the overall average of each parameter on all observations. Moreover, the highest observation on the graph (obs8) with the highest coordinate on the CP2 axis comes from soil restoration as an agroecological practice, the results of which are more contrasted, unlike observation 4. This graph also shows that observations 2 and 7 have a score close to 0 on the CP2 axis because they have very homogeneous values for all the variables (pH, EC, AE, CEC, Na^+ , K^+ , Mg^{++} , Ca^{++} , C, N, C/N, Mo) but at different levels. The CP2 axis thus contrasts the level of fertility with the soil structure.

d) Pearson correlation matrix (n)

The results of Pearson correlation between parameters and observations are presented in the table 4.

The analysis of the table 4 shows a correlation between the different variables. Thus, a positive correlation was observed between pH and potassium (K+), electrical conductivity (EC) and exchange acidity (EA) respectively. On the other hand, a significant negative correlation was observed between pH and exchange acidity (-0.9073) Exchangeable bases are correlated with cation exchange capacity (0.9797), assimilable phosphorus (0.7632), C/N ratio (0.7428), exchange acidity (-0.7024), total carbon (0.6748), organic matter (0.6786), respectively. Organic matter is strongly correlated with total carbon and C/N ratio.

IV. DISCUSSION

The results on the level and constraints of adoption of agroecological practices showed that the restoration of degraded lands and the intensification of ecological market

Table 4: Correlation matrix between variables

Variables	pH	CE	CA++	Mg++	Na+	K+	CEC	AE	P_ass	Carb.	Azote	C/N	M.O
pH	1	-0,7450*	0,1430	-0,2318	-0,0838	0,5926*	-0,0050	-0,9073*	-0,0759	0,4511	0,0538	0,3096	0,4533
CE	-0,7450	1	-0,0744	-0,1821	0,1084	-0,4555	-0,0096	0,6705*	0,0556	-0,3405	-0,4092	0,0228	-0,3433
CA++	0,1430	-0,0744	1	-0,3083	-0,1239	-0,0415	0,9797**	-0,3466	-0,6007*	0,0589	0,3421	-0,3420	0,0700
Mg++	-0,2318	-0,1821	-0,3083	1	-0,3674	0,0055	-0,1599	0,2595	0,0757	-0,3765	-0,2361	-0,2319	-0,3825
Na+	-0,0838	0,1084	-0,1239	-0,3674	1	0,1231	-0,1195	0,2191	0,7632*	0,3717	0,2461	0,0176	0,3873
K+	0,5926	-0,4555	-0,0415	0,0055	0,1231	1	-0,1041	-0,7024	0,3930	0,6748	-0,2384	0,7428*	0,6786*
CEC	-0,0050	-0,0096	0,9797	-0,1599	-0,1195	-0,1041	1	-0,2019	-0,5654	-0,0431	0,3118	-0,4359	-0,0311
AE	-0,9073	0,6705	-0,3466	0,2595	0,2191	-0,7024*	-0,2019	1	0,2165	-0,5902*	-0,0905	-0,4535	-0,5893*
P_ass	-0,0759	0,0556	-0,6007	0,0757	0,7632	0,3930	-0,5654*	0,2165	1	0,4015	-0,1365	0,3569	0,4084
Carb.	0,4511	-0,3405	0,0589	-0,3765	0,3717	0,6748	-0,0431	-0,5902	0,4015	1	0,3518	0,6018*	0,9995**
Azote	0,0538	-0,4092	0,3421	-0,2361	0,2461	-0,2384	0,3118	-0,0905	-0,1365	0,3518	1	-0,4167	0,3529
C/N	0,3096	0,0228	-0,3420	-0,2319	0,0176	0,7428	-0,4359	-0,4535	0,3569	0,6018	-0,4167	1	0,5923*
M.O	0,4533	-0,3433	0,0700	-0,3825	0,3873	0,6786	-0,0311	-0,5893	0,4084	0,9995	0,3529	0,5923	1

Indeed, in crop production fertility management is crucial in that agronomically, fertility is a quantitative measure related to the richness of the soil in mineral elements and its management is particularly important as its maintenance is necessary for the sustainability of organic systems [16-17].

In Niger, farmers adapt certain practices such as crop association, soil fertility management practices and tillage to the surface variability of the soil in their fields. These different processes are responsible for the interest in farmers' management of trees and shrubs such as assisted natural regeneration (ANR) and, more broadly, agroforestry practices for land rehabilitation, combating soil depletion and improving crop production [18-19]. The low rate of adoption of water point over-digging can be explained by the fact that

gardening through home gardens were adopted by more than 49%. This is due to the decline in soil fertility caused by overexploitation and low levels of organic amendment. The improvement of soil fertility through the adoption of agroecological practices has become a necessity without which the producer would not get good yields due to the high pressure on arable land and lack of fallow land [4].

this technology is labour intensive which requires its practical application and is only applied periodically. The extension of this technology will require capacity building of the farmers so that they can take ownership of the technology. If producers do not adopt the technology sufficiently, it is partly due to lack of information [4]. Indeed, the lack of available information on the performance of innovative cropping systems leads farmers to evaluate these systems based on their experience and knowledge [20]. Thus, a better knowledge of biotic and abiotic properties of soils and their interactions is essential for the development of agroecological practices that aim both to deliver quality agricultural products in sufficient quantity and environmental services [21]. The results of the particle size analysis showed

that these soils are predominantly sandy in texture with a predominance of coarse sand. Soil texture affects other soil properties, such as water availability, nutrient supply, and to some extent pH values, which in turn determine microbial growth and activity [22-23-24].

The cation exchange capacity of the soil represents the size of the reservoir allowing the reversible storage of certain cationic fertilising elements (potassium, magnesium, calcium, etc.). The CEC is linked to the clay-humus complex. The value of the CEC of a soil is therefore a function of the quantities of clay and OM it contains, but also of the nature of these elements and the pH of the soil. Thus, a soil with a clay content of 20% may very well have a lower CEC than a soil with a clay content of 15%, depending on different geological supports, pedoclimatic past and development mode [25].

In this study, the results show that the CEC is very low (5.76 on average), which can be explained by the fact that these soils are relatively poor in clay and organic matter at the beginning. However, the restoration work carried out on these sites could contribute to a significant improvement in the organic matter content and therefore the fertility of the soil. Indeed, the reduction of surface runoff, the stabilization of the soil by the root system of young tree shoots contribute to the improvement of the soil surface condition [15]. Since, CEC varies greatly, especially in a pH range from 5.5 to 7.0, the capacity of the soil to retain alkali and alkaline earth cations (Ca^{++} , Mg^{++} , K^{+} , in particular) is higher the closer the pH is to neutrality (pH~7.0), and vice versa [26]. Moreover, the variation of the surface electric charge (CEC) until its cancellation is at the origin of hydrophobic properties, especially at low pHs, for organic materials used for example in horticultural substrates [27].

The results of the chemical analyses (Table 2) show that these soils have highly variable organic matter levels. This proves that the clay-humus complex of these soils is highly appreciable in the sense that the samples present a clay content varying from 8.89% to 29.18%. Organic matter and clay content are closely related in that an organic matter content between 20 and 30% and a clay content between 22 and 30% indicate a soil with moderate organic matter. In addition, a clay content of less than 22% and an organic matter content of between 30 and 40% indicate that the soil is

well supplied with organic matter [25]. Stable soil organic matter (humus) is derived from the gradual decomposition of crop residues, plants, animals and other biological organisms living in the soil (mites, fungi, microfauna, microflora...). Thus, the organic matter content of these soils varies from 3 to 13% and this variation reflects the low carbon and nitrogen contents. Moreover, microbial activity favours water infiltration and also plays an important role in the recycling and decomposition of plant residues; this leads to an increase in the organic matter, nitrogen, phosphorus and potassium content of soils [28-29]. As for the exchangeable bases, they present more or less appreciable values. Calcium plays a decisive role in the physical (stability of soil structures, sensitivity to slaking, gas and water exchanges, etc.), chemical (functioning of the CEC, desalination, etc.) and biological (activity of the microbial biomass, etc.) fertilities of the soil. The C/N ratio is an essential factor in the dynamics of carbon and nitrogen. This C/N ratio provides useful information on the evolution of soil organic matter [30], and is an indicator that allows us to judge the degree of evolution of organic matter, i.e. its ability to decompose more or less rapidly in the soil [31]. In this study, the average C/N ratio is (6.44%), a low value ; which therefore reflects very favorable conditions of strong mineralization of organic matter following a good biological activity in the soil [32]. Variations in soil properties and yields in agricultural plots are often attributed to differences in topography and microtopography [33-34]. Application of organic manure in constrained areas is the main strategy against soil crusting and declining soil fertility. [35], showed that organic manure application is the most effective solution to maintain fertility and sustainability of production systems on all soil types in West Africa.

V. CONCLUSION

The study analysed the constraints related to the adoption of some soil and water management and conservation practices and their effects on the physicochemical properties of the soil. The lack of information and equipment on agroecological practices leads producers to poor application of these technologies such as ecological market gardening, which does not require a large workforce. On the other hand, practices such as the over-digging of water points and the

reclamation of land require not only a large workforce but also, and above all, a certain technical skill for their implementation. These elements have contributed to the low level of adoption of these practices. The over-digging of water points, although not widely adopted, remains one of the most beneficial agro-ecological practices in that it increases water storage and conservation capacity, allows production activities (vegetable gardening, aquaculture) to be carried out around water points after the winter season, and reduces conflicts over access to water. The low level of popularization of these practices is a hindrance to their large-scale adoption.

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Hassimiou Halidou Djabri: Ph.D student in Agronomics Sciences option: Agroecology. Master in climate change and resilience, bachelor in Biodiversity and environment management. Author of five scientific articles and 1 book.

Abdou Maman Mansour, *Ph.D* in Agronomics Sciences, option: Agropedology; Assistant Professor of CAMES Universities. Author and co-author of about ten publications in the field of pedology and agro-pedology

Alzouma Mayaki Zoubeirou, full professor in soil microbiology. Director of several theses in agricultural and environmental sciences. Author and co-author of about fifteen publications in the field of pedology, agro-pedology, agroecology, agroforestry, food security and nutrition.