Soil's Physical and Biochemical Characteristics in a Watershed of the *Valley of* Oueme, a rice-based Agroforestry System in the South of Benin

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ABSTRACT

The present study aimed to assess the sustainability of rice cultivation in regard to soil physical and biochemical characteristics in the watershed of the *Valley of Oueme.* by promoting agroforestry in rice-growing systems. Four kinds of areas were showcased for rice cultivation: *Adjido*. *Agondo*. *Dame,* and *Houedomey*. Eighty-nine thoughts of farmers on their knowledge of the involvement of trees in field production were assessed. Soil samples were collected into rice fields and near, the "under trees" at 0-20 cm alongside the village of *Hetin-Houedomey* from April to June 2023. It was conducted into some of pieces of plots of lowland rice crop where soil physical and chemical properties. Spores' density of Arbuscular Mycorrhizas Fungi (AMF) in the soil and their diversity were assessed. A correlation test showed regarding quantities of clay, silt and sand, it appears there is a predominance of clay at the "under trees", and in the fields, that tends to disappear little by little as we move away from trees. The pH (water) of the soil sampled is acidic (varied from 4.37 to 5.44). For chemical analysis, the average rate of total nitrogen varied from 0.218% to 1.476%. The concentrations of available phosphorus in the *Valley of Oueme* varied from 2 to 7 cmol/kg. Soils appeared to be rich in exchangeable potassium (0.21 and 1.1 cmol/kg) with the highest proportion in the higher topographic altitudes at an "under tree" from the village of *Dame*. The Cation Exchange Capacity (CEC) for its part varied between 11.36 and 59.68 cmol/kg and with the highest value that is in higher topographic altitudes at the *Adjido* county. Sixteen (16) *Glomus* species of AMF were identified and the *Glomus multisubstensum* specy was the most abundant. The community of AMF was mostly diversified in the "under trees" soil (H = 5.5).

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Keywords: Savanna; arbuscular mycorrhizas fungi; agroforestry systems; Valley of Oueme; tropical ferruginous soils.

1. INTRODUCTION

Throughout the world, climate change is a source of bad weather, causing extreme phenomena, such as storms, floods, and erosions as it happens [1]. African tropical regions are thus exposed to climate variability and cases of crop failure are becoming increasingly common in sub-Saharan Africa. They cause many economic and social problems that are a distant third place [1]. Tropical regions are thus coping with the meteorological effects of disturbances, due to climate variability on the continent [2,3,4]. In addition, soil erosion caused by the annual flooding of the *River of Oueme* in the region, also reduces expected yields, limits harvests and exacerbates hunger [5]. The valley itself contains a series of natural formations [6], in particular shrubby and wooded savannas.

Due to their buffering effects, agroforestry systems are more tolerant to the consequences of climate change, mitigate extreme flooding situations in crops through the contribution of trees to the adaptation process [7,8,9]. Moreover, trees are considered as Nature-based Solutions [10] against erosion, and have long been used for food in crops, which farmers often benefit and encourage them to keep trees as long as possible. Rice farmers assume of the essential role of ligneous plants and would have preferred get more points of shade [11]. Also, contrary to speculations, they already knew how to adapt to the presence of birds from the trees near fields, through fine nets they put along the plots of the land [12]. However, they remain skeptical regarding the fertilizing effects of trees, always less agreed to accept them survive in the fields because critically fairing a poor growth of plantations [13]. Then they could provide they are convinced of it [14].

This research aimed to induce rice production in the watershed of the *Valley of Oueme* more sustainable by promoting agroforestry in rice growing systems. By putting the tree at the heart of this study, farmers would be highlighted on its advantages. Hence, what do the soil's physical and biochemical characteristics bring in an agroforestry system with rice-based cultivation in the watershed of the *Valley of Oueme* in Benin? We will first collect through a survey, the indigenous perceptions of farmers regarding relevance of tree conservation, then evaluate the physical and chemical parameters of the soil to access data collected, and lastly determine the biological aspects of the "under soil" of trees to provide an additional wealth.

2. MATERIAL AND METHODS

2.1 Study area

The study was carried out in the *Valley of Oueme* described as the wettest basin in its southern part. The village of *Houedomey* where was focused samplings is one of the seven (7) districts within the commune of *Dangbo* in the department of *Oueme* in Benin. *Houedomey* district is approximately located at 49.5 km from Cotonou city, Benin's country economic capital.
Main characteristics: Latitude: 6.57823, Longitude: 2.55766 6° 34′ 42″ North. 2° 33′ 28″ East. Area: 34.000 hectares 340.00 km^2.
Dangbo little country (Fig. 1.) is furthermore characterized by a Sudanese climate, and the average annual temperature sets between 28ºC. Also, the soil in the valley is of the hydromorphic type and has a sandy-silt one to clay-silt texture. The hydromorphic soils (gleysols) in the part of the region called the *delta of Oueme* are of good chemical fertility with a heavy composition, then a low permeability [6]. Within percentages of the physical and chemical observations, it results a good cation balance [15,16].

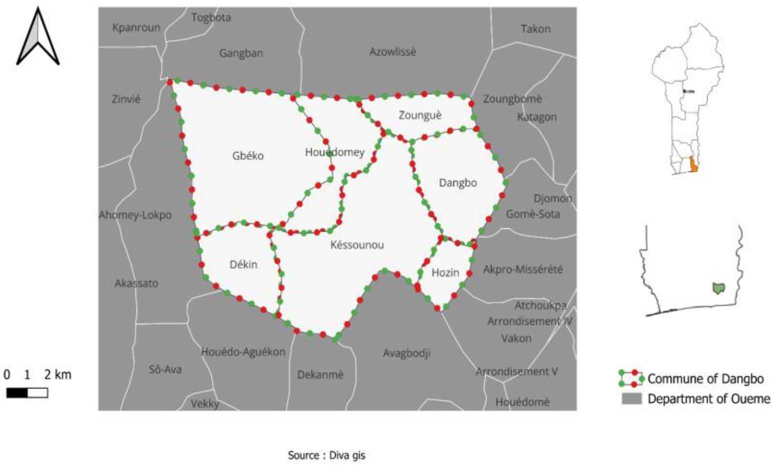

Fig. 1. Geographical map of the *Valley of Oueme*, south of Benin

2.2 Biological material

The study was conducted on the ***soil*** composition in a lowland rice field. The trees under which soil was sampled were overall kind of: *Vitex doniana, Moringa oleifera, Bambusa* (Bamboo), *Phragmites australis, Acacia oriculusformis, Triplochitone scleroxylone, Pterocarpus yamesens* and *Elaeis guineensis*.

2.3 Survey method

In seeking of a complete information on rice farming techniques in the *Valley of Oueme,* we got interviewed group of rice growers: *Bidossessi* and *Houindomanbou* from *Adjido,* and *Dame,* made up of nine (9) and eleven (11) members respectively. As for the districts of *Houedomey* and *Agondo,* they are located other two (2) groups with thirty-two (32) and thirty-seven (37) rice farmers respectively: *Aidete*, *Jesutin*, *Enagnon*, *Missimide* and *Djromahouton*. Thus, out of the total of eighty-nine (89) members belonging to the seven (7) communities, eighty-six (86) were present and therefore met either in the fields or into one of the halls of the district.

2.4 Soil sampling and preparation for the laboratory analysis

The soil samples were collected at 20 cm depth in four communities (Fig. 2.): *Houedomey, Adjido, Agondo* and *Dame* of the *Valley of Oueme* from April to June 2023. For each county of the valley, soil was removed under a foot of tree at the upper, into the fields and on the lower. The samples were mixed to obtain a representative composite sample per tree, 12 in total. In the laboratory, each pack of sample was air dried and sieved at 2 mm in order to remove the rough materials. These samples were used for the soil physical and chemical analysis and for the AMF spore’s extraction.

2.5 Soil physical and chemical analyses

Soil physical and chemical analyses were performed in the Laboratory of Soil, Water, and Environment of Benin National Research Institute (L2A2S2E/INRAB) following procedures developed by [17]. Soil analyses were carried out on particle size (Robinson's pipette method), pH(water) and pH(KCl) (using a glass electrode in 1:2.5 v/v soil solution), total N (Kjeldahl digestion in a mixture of H_2SO_4-Selenium followed by distillation and titration), available P (Bray 1 method), exchangeable cations (1 N ammonium acetate at pH 7), organic carbon (Walkley & Black method) and Cation Exchange Capacity (1 N ammonium acetate at pH 7).

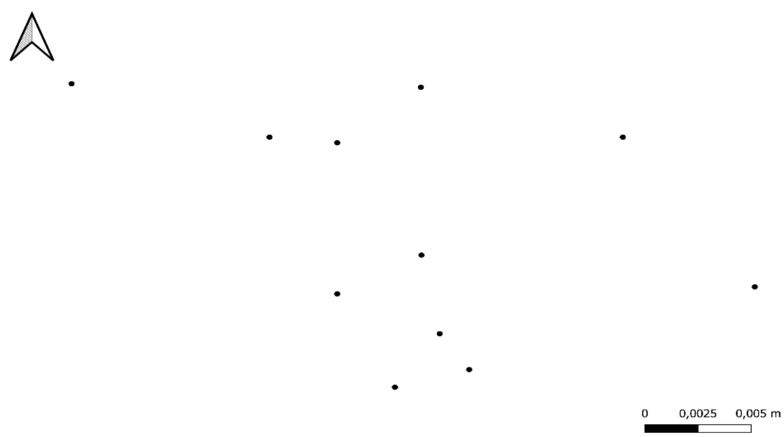

Fig. 2. Random distribution of sampling points within the valley

2.6 Biological extractions

For the biological analysis of the soil, the AMF' spores extraction and counting were assessed according to method described by [18]. After obtaining samples, they were left to dry at ambient air, then put aside a representative quantity of 100 g of each. Water was added until 900 ml and after shaking the whole mixture for homogeneity, the content is poured out in three (3) different sieves such as 125 µm, 50 µm, and 32 µm, according to the method described by [18]. After four repetitions to avoid spores remaining in soil micro-aggregates or surrounded by clay particles, the 50 µm and 32 µm contents were collected and mixed for almost 5 minutes in a sugar water solution after an abundant rinsing. Spores were observed using a stereomicroscope at x 40 (Stemi DRC Zeiss) and grouped according to their morphological characteristics (spore size. color and hypha attachment). Thus, only healthy spores, i.e. those with a nucleus, were considered [19]. The number of AMF spores was expressed per gramme dry soil.

The relative abundance of spores (RAS) was determined by [20] formula such as:

$$\text{RAS} = \frac{\text{Total number of spores observed for one specie}}{\text{Total number of spores observed for all species}}$$

The spores were identified using information from the International Culture Collection of Vesicular and Arbuscular Mycorrhizal Fungi website (http//www.invam.caf.wdu.edu). They were named according to the current valid taxonomy [20,21,22,23].

2.7 Statistical analysis

The data processing was done by *R* software, which was also been used to get the average values. Considered as a normality test, Shapiro-Wilk test was used to know if a series of data follows a normal law or not. If the probability p associated with the Shapiro-Wilk test is greater than 0.05, we conclude that our data are significantly normal at the 5 % threshold. This test was applied to the data in this research work study to determine whether the non parametric analysis assumptions of the biological, physical, and chemical variables observations were met.

The correlation test makes it possible to show the reciprocal links, through a correlation coefficient, of a set of variables. Those variables are represented here by sampled soil physical and chemical parameters.

This test is a non-parametric one and compares two (2) samples. The box plots resulting from the analysis show significant differences between the AMF spores observations according to the sieve dimensions.

The diversity of AMF was analyzed using the specific richness (S), the *Shannon* diversity index (H) and the *Pielou* index of evenness (E). The specific richness (S) was edited as a number of genus recorded.

The *Shannon* diversity index [23] is a mathematical measure of each species distribution in a community which show up the number of morpho species and their abundance. A low value of H generally suggests few dominant species, while a high H value suggests considerably more species.

The *Shannon* diversity index (H) was estimated by the following:

$$H = -\sum (P_i \mathrm{Log}_2 P_i)$$

Pi is a relative frequency of species i may be generated by:

$$P_i = \frac{\text{Number of spores for specie i}}{\text{Total number of spores}}$$

The *Pielou's* evenness index [24] varies from 0 to 1. It denotes an equitable distribution of genus in soil when it approaches 1. However, when it is close to 0, it indicates that some genera are prevailing.

The Pielou's evenness index (E) was calculated using the following formula:

$$E = \frac{H}{\mathrm{Log}_2(S)}$$

H is the Shannon diversity index and S is the specific richness.

3. RESULTS

3.1 Survey results

Farmers believed overall in their soil. While asking how they used to deal with various random atmospheric phenomena (birds, floods, infertility…), they didn't feel wanting associate *trees* for certain benefits in any of their answers. Some of them (less than assumed themselves can easily say that « flood in this region is their great benefit » because it fertilizes soil all the year. Whatever they are only able to cultivate six months sometimes under the twelve, they didn't mention any kind of problem or difficulty to manage their business.

Preference for trees according to age may depend without a significant variation. All (100%) farmers interviewed know the importance of trees close to them, that's why they hadn't explained their importance. They just needed to know that they had and do without them that's why there are no more trees alongside the region. Depending on the experience of farmers in their respective activities, their preference for the presence of trees may differ. Thus, those who have experienced several years of natural disasters (over 40) regret the absence of trees today and recognize their long-term importance for the survival of plantations. From all those above, independently of climate change impacts, farmers know the richness of their soil and are aware to take care of it. Thus, they don't think needing other supports to increase soil activity for their fields.

3.2 Effect of the trees on soil physical and chemical parameters

The correlating proportions on soil physical particles are presented in Table 1. These results revealed that, the proportions of clay are generally high in the fields (Agondo: 72.89%; Adjido: 76.78%; Houedomey: 51.76%; Dame: 63.8%) and lower than the average norm at the foot of trees exiting from the villages except in Houedomey (73.16%): (Agondo: 28.66%; Adjido: 23.97%; Dame: 32.51%).
As for silt and sand, we observed respectively low results in bared fields (Agondo: 23.93 & 3.18%; Adjido: 21.24 & 1.97%; Houedomey: 43.46 & 4.77%; Dame: 15.06 & 21.14%) those are yet different for the most to the end of the region, as the following details may represent: Agondo: 25.27 & 46.06%; Adjido: 21.62 & 54.41%; Houedomey: 23.08 & 3.77%; Dame: 36.36 & 31.13%).
However, similar proportions in most cases were found at the entrance of the village, put respectively for clay, silt, and sand: Agondo: 58.7, 34.04 & 7.26%; Adjido: 84.31, 14.89 & 0.8%; Houedomey: 76.94, 20.7 & 2.32%; Dame: 46.53, 30.88 & 22.59%).
The bared soils into the fields are mostly played with a clay content of more than 50% and sandy-silt in places. The silt content varies from 14.89 to 43.46% and clay from 23.97 to 84.31%. The sand content varies from 0.8 to 54.41%. Also, the proportion of clay is generally high in the fields and lower than the average norm at the "under trees" toward the exit of the villages.

Table 1. Correlating proportions on soil physical particles (%)

Variables	Clay	Silt	Sand
Clay	1	-0.26	-0.91
Silt	-0.26	1	-0.62
Sand	-0.91	-0.62	1

From the Table 1:

- There is a strong negative correlation (-0.91) between clay and sand: the more clay a sample contains the less sand it contains.
- A moderately negative correlation (-0.62) exists between silt and sand.
- Clay and silt have a low correlation (-0.26), indicating that their variation is not strongly related.

  By the way, clay and silt presence in the soil would be unevenly distributed (Fig. 3.) depending on different environments. Therefore, ligneous would be complementary in fallows.

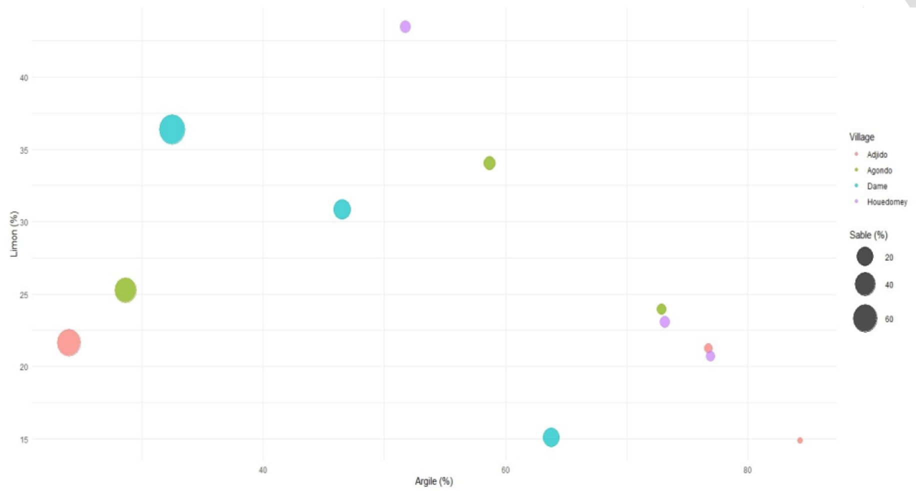

Fig. 3. The soil physical parameters variables correlation (R generating)

According to the values above, the correlation is deemed to be more significant between some of parameter and less for others. Table 2 presents as for it, the correlation matrix of relation between the chemical parameters and the figure, a representative distribution (Fig. 4.).

Strong positive correlations can be seen between most parameters. For instance, "%V = S/T *100" and "Som. cations" have a high correlation with each other (0.92), and "Ca" shows high correlations with other parameters like "Som. cations" (0.99) and "CEC" (0.87).

Table 2. Correlating proportions on soil chemical particles (%)

	C/N	M/O	pH_{water}	pH_{KCl}	Ca (meq /100g	Mg (meq/ 100g)	K (meq/100 g)	Na (meq/100 g)	Som. cations (meq/100 g)	CEC (meq/ 100g)	%V = S/T *100	P (ppm)
C/N	1	0.87	0.85	0.85	0.84	0.81	0.61	0.63	0.84	0.73	0.82	0.88
M.O	0.87	1	0.86	0.83	0.83	0.80	0.59	0.62	0.82	0.69	0.81	0.85

pH_{water}	0.85	0.86	1	0.97	0.77	0.77	0.68	0.74	0.75	0.68	0.74	0.80
pH_{KCl}	0.85	0.83	0.97	1	0.72	0.73	0.67	0.73	0.71	0.66	0.71	0.75
Ca (meq/100g	0.84	0.83	0.77	0.72	1	0.96	0.63	0.65	0.99	0.87	0.91	0.88
Mg (meq/100g)	0.81	0.80	0.77	0.73	0.96	1	0.61	0.63	0.94	0.88	0.90	0.83
K (meq/100g)	0.61	0.59	0.68	0.67	0.63	0.61	1	0.90	0.66	0.60	0.61	0.68
Na (meq/100g)	0.63	0.62	0.74	0.73	0.65	0.63	0.90	1	0.71	0.66	0.68	0.74
Som. cations (meq/100g)	0.84	0.82	0.75	0.71	0.99	0.94	0.66	0.71	1	0.88	0.92	0.87
CEC (meq/100g)	0.73	0.69	0.68	0.66	0.87	0.88	0.60	0.66	0.88	1	0.93	0.79
%V = S/T *100	0.82	0.81	0.74	0.71	0.91	0.90	0.61	0.68	0.92	0.93	1	0.83
P (ppm)	0.88	0.85	0.80	0.75	0.88	0.83	0.68	0.74	0.87	0.79	0.83	1

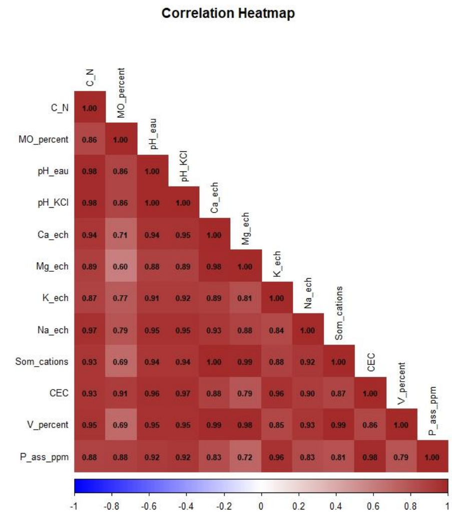

Fig. 4. The soil chemical parameters variables correlation (R generating)

3.3 AMF species developing mutualistic relationship with the trees

The species of AMF associated with the trees were presented in Tables 3 and 4. The Shannon index (H) and Pielou uniformity (E) indexes data values, distinctly taken per village, show a high diversity of AMF (Table 3).
These results in Table 4 revealed the AMF spores counted belong to the branch of *Glomeromycota*, the genera *Glomus* and the family *Glomeraceae*, sixteen species identified. They show that, in general, *Glomus multisubstensum* species are more abundants (19.79%) in the soils under the different trees while, *Glomus halonatum* (1.04 %) and *Glomus macrocarpus* (0.63 %) were almost absent.

Table 3. Diversity of AMF associated with trees

Village	Number of species	%	Relative abondance of species (%) (pi)	pi *100	H (Shannon index)	E (Pielou uniformity index)
Houedomey	42	0.42	0.08	8.75	-0.52	-0.09
Agondo	163	1.63	0.33	33.95	1.14	0.15
Adjido	128	1.28	0.26	26.66	0.45	0.06
Dame	147	1.47	0.3	0.003	0.81	0.11
Total						**480**

Table 4. Characteristics of different species of AMF associated with trees

Species	Characteristics	Total spores	Relative abundance (%)
Glomus aggregatum	Small brown AMF with specific hyphal spores for some and in colonies. however sometimes alone. Most were observed in	20	4.17

	50 µm sieve measurements		
Glomus fasciculatum	Brown AMF spores most irregular. Translucents. they are the largest of the Glomus aggregatum upper	15	3.12
Glomus albidum	Possibility for the spores to get yellow to brown color at observation. They are globular and less alone	40	8.33
Glomus fulvum	Yellow color spore with an oblong elliptical to oval. rarely nearly spherical	75	15.62
Glomus ambisporum	Darkness color. brown to black sometimes. globose and often highly variable. with a single spore hyphal	19	3.96
Glomus constricted	Spores are thick. dark brown and lonely	62	12.92
Glomus desert	Spores are borne singly. globose to subglobose. thickened and clogged with a dense material. The species are divided into a yellow. medium brown. and black wall	8	1.67
Glomus geosporum	A yellow-brown color to dark yellow-brown in appearance. spores are also shaped with a hard perceptible hyaline hypha	13	2.71
Glomus macrocarpus	Brown. turning dark color. with a globular spore that is less regular. With an alone or not layer. it has a thick hypha that may be absent	3	0.63
Glomus radiata	A generally flattened and lobed spore. with a peridium absent or present hypha. Its light brown color distinguishes it from others	15	3.13
Glomus halonatum	A light brown to brown color. hyaline and laminated wall. this spores' hyphae linked is globulous in size.	5	1.04
Glomus reticulatum	This spore is light brownish to black color. globose and looks thick. two-layered	9	1.87
Glomus intermedium	Spores are globose. light brown to brown. hyaline to sub hyaline color. thick. with a thick hypha	7	1.46
Glomus monosporum	Globose spores to ellipsoid. thick. dull brown to the pale brown that were seen sometimes as red color	73	15.21
Glomus warcupii	Globose and all thick. its brown and irregular color. as a big translucid white sometimes	21	4.37
Glomus multisubstensum	Chlamydospore are alone or compacted. and golden turns to brown color spores are between 150 – 210 µm. They are thick spore walls and regularly linked	95	19.79
Total		480	100

3.4 Physical parameters correlation values with AMF species

The calculated correlation coefficients for "Clay %", "Loam %", "Sand %", and "AMF proportion %" are as follows:
Clay % and AMF proportion %: -0.523
Silt % and AMF proportion %: -0.315
Sand % and AMF proportion %: 0.707

Knowing that "Clay %" and “Silt %” have a moderate negative correlation, meaning that higher clay content might be associated with lower AMF proportion (Fig. 5 & 6). Conversely, “sand” is found for the most at the “under tree”, the stronger correlation (positive) is between "Sand %" and "AMF proportion %", which indicates a relationship where the higher the sand content, the higher the AMF proportion (Fig. 7).

As for chemical values (Table 5), positive correlations [C/N, pH_{water}, pH_{KCl}, Mg (meq/100 g), CEC (meq/100g), and P ass (ppm)] indicate that as the parameter increases, the AMF proportion tends to increase, while negative correlations for the others, suggest the opposite (Fig. 8).

Table 5. Correlating proportions on soil chemical particles within AMF random distribution (%)

Chemical Parameters	**Correlation with AMF Proportion**
C/N	0,85
M.O	-0,45
pH_{eau} (1/2,5)	0,12
pH_{KCl} (1/2,5)	0,02
Ca éch. (méq/100g	-0,67
Mg (méq/100g)	0,49
K éch. (méq/100g)	-0,34
Na éch. (méq/100g)	0,15
Som. cations (méq/100g)	-0,12
CEC (méq/100g)	0,29
%V = S/T *100	-0,18
P ass (ppm)	0,23

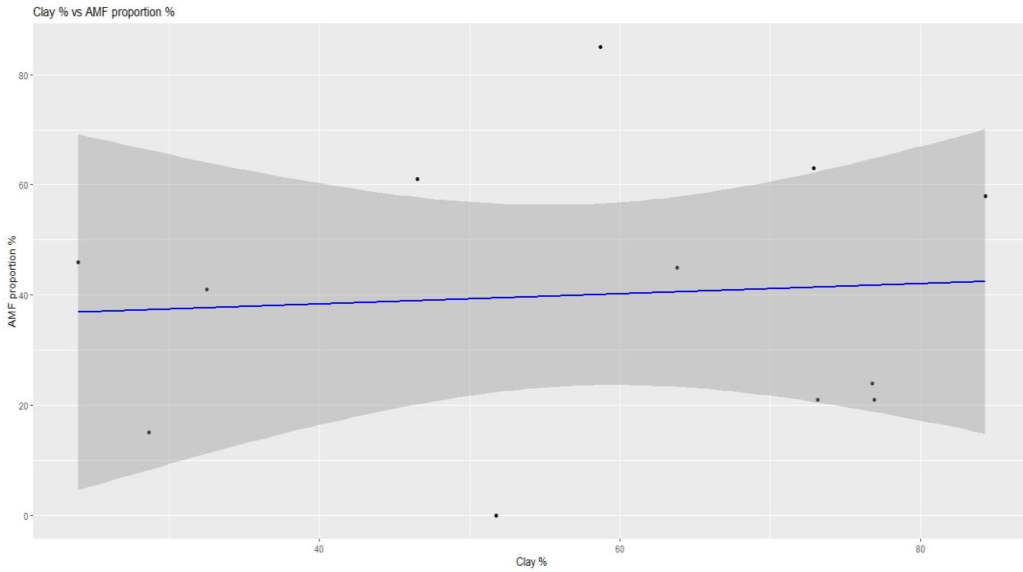

Fig. 5. The soil parameter (clay) variables correlation within AMF random distribution (R generating)

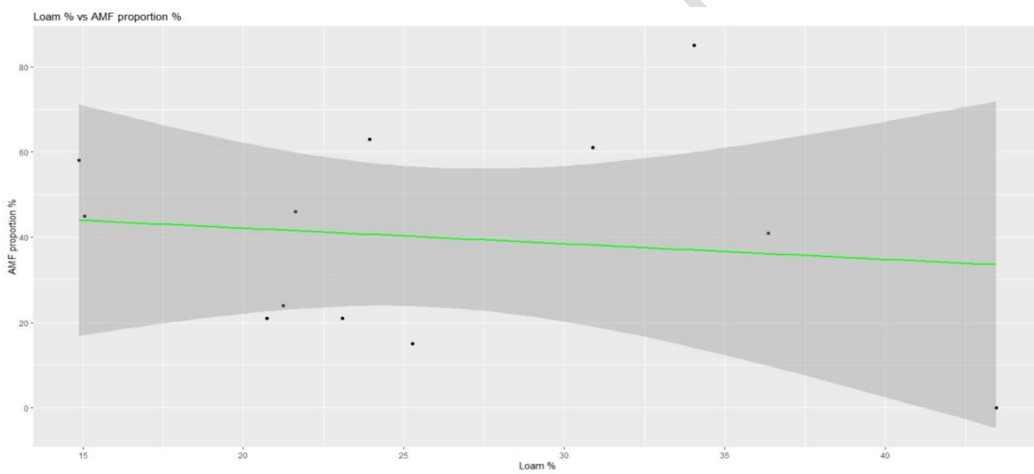

Fig. 6. The soil parameter (silt/loam) variables correlation within AMF random distribution (R generating)

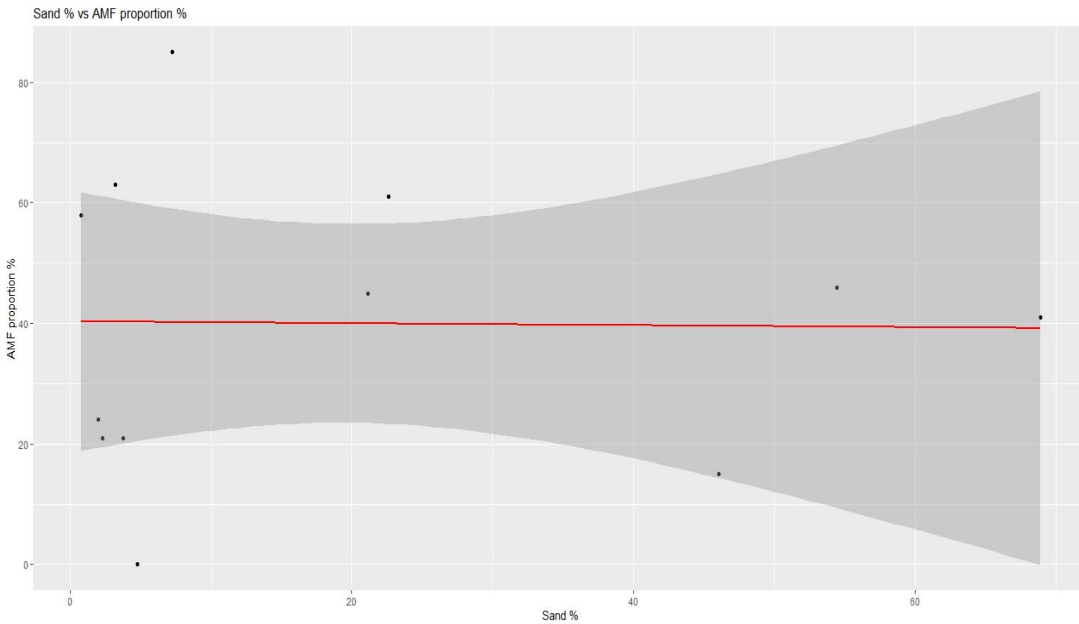

Fig. 7. The soil parameter (sand) variables correlation within AMF random distribution (R generating)

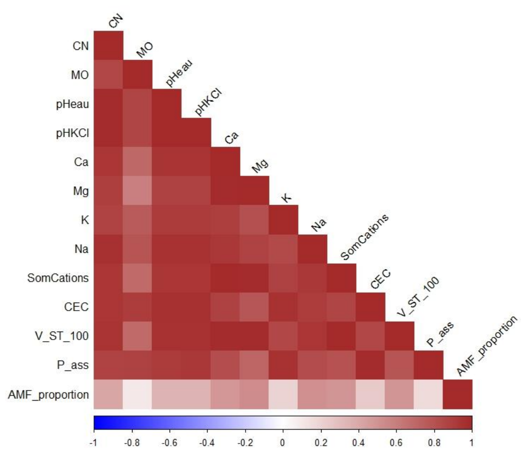

Fig. 8. The soil chemical parameters variables correlation within AMF random distribution (R generating)

4. DISCUSSION

4.1 Indigenous perceptions of farmers

It is important to recognize that climatic variations can lead to sequences of heavy rains. which can also damage crops. Recent observations in the East African continent have shown an increase in instances where the amount of rainfall significantly exceeds expectations. In such cases, the damage caused by excessive rain can be as detrimental as that caused by drought, often leading to famine [13]. Interestingly, much like our own speculations, scientists' perspectives often differ from those of farmers concerning the severity and extent of wind erosion problems often differ from those of farmers. This observation underlines the importance of evaluating preconceived ideas and comparing them with farmers' knowledge and experiences of farmers before drawing conclusions. In our particular case, similar to flood-related concerns, farmers tend to perceive wind erosion as a non-existent problem [1]. This may be due to their crop choice, which is usually sown later in the rainy season when wind erosion activity decreases. This adaptive measure is akin to the practices of farmers in *Hetin-Houedomey* who prefer harvesting before the peak of adverse weather. In contrast to our findings, a study by [9] reported a more advanced awareness among the target population, farmers in their study demonstrated a broader understanding, supported by concrete observations of rainfall and temperature trends. A significant percentage of agroforestry farmers (88%) noted a decrease in rainfall, while about 9% observed an increase, and 3% reported no change. Such results indicate variations in meteorological knowledge, but overall, the focus group demonstrated a high level of awareness of recent climate change impacts. It shows that overall, despite the contrast, the population is aware of the climate variations observed in recent years and which are noticeable through the yields in the fields. Thus, both for floods and belly storms, it seems undeniable that in the face of climate risks, farmers develop adaptation methods to cope with damages. Also, it appears that for each type of climate risk, the population prioritizes anticipation over real adaptation measures linked to the involvement of trees. Furthermore, [11] highlight differently to our fieldwork study, the existence of local indicators used by farmers to predict weather changes. For example, some phases of the moon, such as a descending crescent, are associated with rainfall in the next three (3) years, while a moon with a halo signals good rainfall ahead. Farmers have also found that the absence of morning fog is a sign of impending rain, although crops may not grow optimally. Traditional knowledge also includes the use of frog behavior as an indicator of impending thunderstorms. These diverse practices reflect a long tradition of looking for hope and rain in the midst of changing climate conditions. They use several similar methods throughout to prevent the rains and hardly be surprised. Thus, farmers noted that the absence of morning fog indicates impending rain, though crops might not grow optimally. Traditional knowledge also includes using frog behavior as an indicator of upcoming thunderstorms. These diverse practices reflect a longstanding tradition of seeking hope and rain, changing climate conditions. Therefore, the present research work study, along with other similar research, contributes to the understanding of erosion's impact on agricultural systems. To formulate effective strategies, it is crucial to bridge the gap between scientific perceptions and farmers' experiences while considering their rich traditional knowledge of climate change and weather predictions.

4.2 Effect of different trees on soil physical and chemical properties

The concentrations of low proportions observed are recorded in wet soils that are nevertheless rich in organic matter for the most part, and therefore, in humus. The analysis of the correlations between the different soil chemical parameters can be translated like: the relation between most of the parameters are close and may tend to increase or decrease together; except variables of water, pH, K sometimes, and P coefficients are greater than 0 and indicate a positive association of the variables relating to the chemical parameters; the soil is less provided in phosphorus and proved acid.

The decomposition of organic matter releases certain organic acids which can form iron phosphorus or aluminum-phosphorus complexes into more stable complexes. Organic additions of matter prove to be essential in the synthesis of phosphatase enzymes. It appears trough this study, a lack of phosphorus (P) with the acidic soil of the *Valley of Oueme* even though the higher proportions of P are most seen in the upper basin under areas colonized by trees. Although the gap looks important to release the soil quality as expected, farmers don't perceive it, certainly because of any other elements' presence. Crops would draw an additional source of energy that may contribute to soil fertility and increase production consequently regardless of the lack [25].

4.3 Biodiversity of the AMF associated with trees

Trees have AMF spores on cultivation sites with low binding energy for phosphorus. facilitating its availability. that is why plants that have them are very popular in fields, even a little far from crops [17]. A diverse range of AMF spore populations were observed in each of the soil samples collected, probably due to the subtle physical or chemical variations between the samples. Even though the present study doesn't show any significant relation between soil characteristics, human activities and fungal abundance, parameters may significantly influence the AMF spores formation. Also, because AMF spores observed on bare soil appear to be significantly lower than those near trees, flood-retaining trees would fight against flooding and retain other nutrients against their leaching [24]. Despite the soil fertility claimed by farmers due to plenty of yields, this study conveniently had the advantage of detecting a lack in soil characteristics such as acidity and poor proportion of phosphorus (P). Like ours, results from [26] show that when the soil doesn't receive a sufficient proportion of P. it leads to a decline in soil fertility over time. However, in our case, the acidity of the soil, as well as the low rate of P may have been compensated by the AMF spores presence whose massive production is facilitated by the trees [26].
In parallel, [27] and [28] have found fascinating characteristics of AMF spores that look like ours. The diversity of the spores obtained would also be justified by the presence of trees, listed by our studies. The presence of trees would therefore promote the abundance of spore populations and adequately better soil fertility [29], list some factors that can modify the biological composition of the soil such as temperature and the soil temperature obtained through our study alongside the sampled spaces indeed varies, to say the least. Then, many particles interact in the soil and even if our study did not focus on the microparticles present, this could easily be proven in subsequent studies [30]. However, unlike us, the no significance of the Wilcoxon test performed by [30] seems disconcerting, there would be no resemblance, contrary to what we have found, between distributions of AMF spores populations observed from the 32 and 50 µm sieve dimensions. All those above allow us to evoke a complementarity of the different analyzed parameters and of the AMF spores. Hence, thanks to tree presence, an acidic and low P-rich environment did not prevent reporting such plenty AMF spores and therefore a rich soil for rice production in the Oueme Valley [26]. Thus, the chemical analysis of the soil reveals variations in the phosphorus content in different areas. The highest amount of phosphorus was encountered in the upper valley at Dame, probably due to the presence of trees that enable non-abundant water in this part of the valley, which the flood does not reach and thus, soil does not erode [31]. They would contribute to the richness of the soil and provide plants with the soil nutrients they lack. Today, the clear difference between AMF spores in agroecosystems compared to non-intercropping systems that dispense with tropical trees may be seen more evident, examined more closely. Nevertheless, the density of AMF spores here appears relatively low compared to previous findings by [31] (an average of 202 spores per 100 g of soil compared to our findings which capitulate by 50 for the same weight). This could more again be due to the low presence of trees and similar to results of [31] who observed in some other food crops (groundnuts, cotton) in Benin and other West African countries. All findings above are the main reason why agroforestry may become the best way for rice farmers from the Valley of Oueme with intercropping trees in cultures. To properly address

the advantages of that method, we might go forward to science policy and population good practices so as to encourage Nature-based Solutions throughout the region.

5. CONCLUSION

This study shows that the soil and low presence of phosphorus would be a crucial factor of low yields in Valley of Oueme of Benin, that is why AMF spores found under trees were significantly an additional support for rice yields in the fields. This research confirmed such a presence of AMF spores at the trees' foot than blank fields that facilitates and which significantly contributes to nearby rice crops production. With nearly five hundred (500) colonies of Glomus observed across twenty (20) hectares of various crops, the region appears to be well-populated, holding promising prospects for production. These mycorrhizae, which are beneficial root fungi, have a positive complementary impact on the soil acidity and lack of P, retaining nutrients to boost production independently of its weakness. By adopting good practices such as conserving trees in wealthy fields, farmers would be able to receive protection against floods and storms all year.
The research further convinces of the opportunity to preserve trees in the Valley, not only for their buffer effect against natural disasters but also thanks to their added value in soil fertility. It might adopt good practices such as stopping trees cutting and get accountability of promoting agroforestry systems as Nature-based Solutions for science-policy practical applications to save forests.

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