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# Physical and Biochemical Characteristics of Soil in a Watershed of the *Valley of* Oueme: A Rice-based Agroforestry System in the South of Benin

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

The present study aimed to assess the sustainability of rice cultivation in regard to soil physical and biochemical characteristics within the watershed of the *Valley of Oueme.* by promoting agroforestry in rice-growing systems. For that concern, four kinds of areas were showcased for rice cultivation: *Adjido*. *Agondo*. *Dame,* and *Houedomey*. Eighty-nine thoughts of farmers on their knowledge of involvement of trees in field production were assessed. Soil samples were collected into rice fields and near of 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 field to study soil physical and chemical properties. Spores’ density of Arbuscular Mycorrhizas Fungi (AMF) in that soil and their diversity were assessed. A correlation test indicated regarding quantities of clay, silt, and sand, 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 and 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 that revealed weak. Soils appeared to be rich in exchangeable potassium (0.21 and 1.1 cmol/kg) with the highest proportion observed under the tree in the higher topographic altitudes 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 *Glomus* species of AMF were identified and the *Glomus multisubstensum* was the most abundant. The community of AMF was mostly diversified in the “under trees” soil, according to the Shannon index H = 5.5.

*Keywords: Soil parameters; AMF spore species; agroforestry systems; valley of oueme.*

## 1. INTRODUCTION

Ecological interactions on which trees initiate and induce incredible wealth are only a limited part of forest benefits. The man-friendly tree, more than being an ecosystem services supplying companion, can improve soil properties alongside subsidiary crops (Sterk 2003). Tropical regions are thus coping with the meteorological effects of disturbances, due to climate variability on the continent (Sivakumar 2005, Rodenburg et al. 2014, Rodenburg et al. 2022). 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 (Bright et al. 2007). The valley itself contains a series of natural formations (Sinsin and Kampmann 2010) in particular shrubby and wooded savannas. The Valley of Oueme includes a series of natural formations (Rodenburg et al. 2014, Rodenburg et al. 2022). and 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 (Scoones 2009, Spencer and Solomon 2015, Apuri et al. 2018). Moreover, trees are considered as Nature-based Solutions (Ozor and Nnaji 2011) against soil erosion, and have long been used for food in crops, which farmers often benefit and encourage them to keep trees as long as possible. In the valley, rice farmers have a perfect awareness according to the essential role of ligneous plants and confessed would even have preferred get more points of shade in farms during moments of rest (Basdew et al. 2017). Indeed, contrary to forecast speculations, rice farmers already knew how to get adapted to the presence of birds from the trees near of fields, through fine nets they put along the plots of the land (Middleton et al. 2019). They just remain skeptical regarding the particularity of fertilization of trees, not convinced to their usefulness, and critically fairing a reduction of the cultivable area without any comparative advantage (Rodenburg et al. 2014, Rodenburg et al. 2022, Kaya and Koitsiwe 2016). Then, they would agree to save trees once they be persuaded (Balgavy et al. 2018).

This research study deals with the physical, chemical and biological parameters of the soil contribution of an agroforestry system with rice-based cultivation. More specifically, it aimed to induce rice production sustainability in the watershed of the *Valley of Oueme* by promoting agroforestry in rice growing systems to improve its conservation. By putting the tree at the heart of this study, farmers would be highlighted on its multiple advantages throughout the agricultural cycle. Hence, what deal the soil's physical and biochemical characteristics in an agroforestry system with rice-based cultivation in the watershed of the *Valley of Oueme* in Benin? Firstly, data will be collected through a survey, the indigenous perceptions of farmers regarding relevance of tree conservation, then collected soil samples will be evaluated to assess physical and chemical properties, and lastly will examined the biological aspects of the soils collected under trees, to provide an additional wealth.

## 2. MATERIALS 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 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. The main characteristics are: latitude 6°34′42″ North, longitude 2°33′28″ East, with 34.000 hectares and 340.00 km².

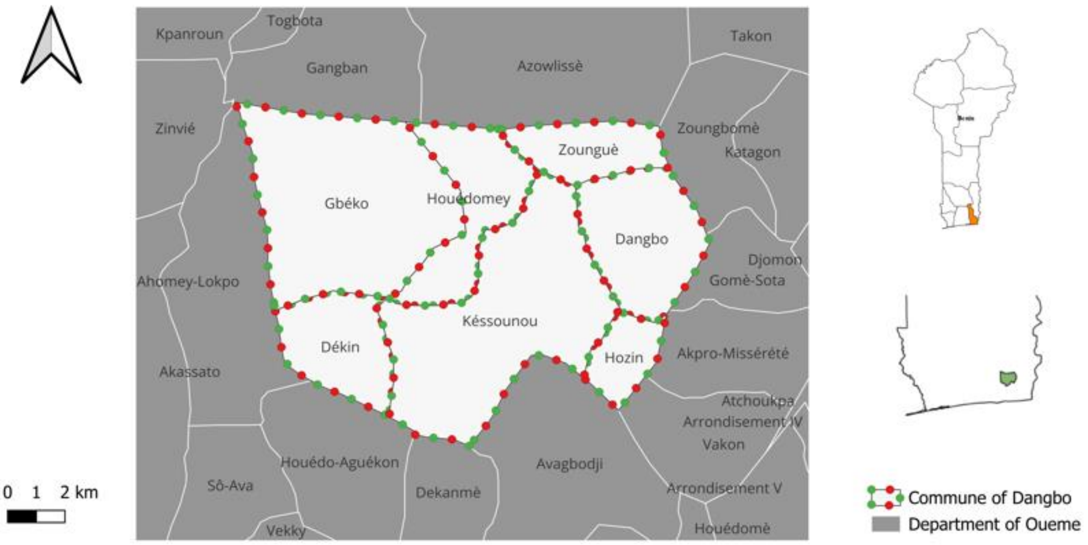
*Dangbo* little county (Fig. 1) is furthermore characterized by a Sudanese climate, and the average annual temperature sets between 28ºC. Also, the soil in the valley is of the hydromorphic type and has a sandy-silt one to clay-silt texture. The hydromorphic soils (gleysols) in the part of the region called the *delta of Oueme* are of good chemical fertility with a heavy composition, then a low permeability (Sinsin and Kampmann 2010). Within percentages of the physical and chemical observations, it results a good cation balance (Petric et al. 2011, Barbagelata and Antonio 2012).

### 2.2 Biological Materials

The study was conducted on the soil 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 Methods

In seeking of a complete information on rice farming techniques in the *Valley of Oueme,* we got interviewed group of rice growers. This is *Bidossessi* and *Houindomanbou* from *Adjido,* and *Dame* communities, made up of nine and eleven members; *Aidete*, *Jesutin*, *Enagnon*, *Missimide,* and *Djromahouton of th*e district of *Houedomey* and *Agondo,* with thirty-two and thirty-seven rice farmers respectively. Thus, it was out of a total of eighty-nine members those belong to seven organized communities.




Source : Diva gis

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

## 2.4 Soil Sampling and Preparation for the Laboratory Analysis

The soil samples were collected at 20 cm depth in four communities: *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 of the valley, into the fields and on the lower. The samples were mixed to obtain a representative composite sample per tree, we had twelve (two of the sample sites overlapping because quite close since representing a landscape that is both bare on one part and wooded on the other). In the laboratory, each pack of sample was air dried and sieved at 2 mm in order to remove the rough materials.

Sifted 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 (Amonmide et al. 2019). 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).

## 2.6 Biological Extractions

For the biological analysis, AMF spore extraction and counting were assessed according to method described by (Boureima et al. 2019). 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 different sieves such as 125 µm, 50 µm, and 32 µm, according to the method described by (Boureima et al. 2019). 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 (Collins et al. 2009). The number of AMF spores was expressed per gramme dry soil.

The relative abundance of spores (RAS) was determined by (Schûβler et al. 2001) formula such as:

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

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 (Schûβler et al. 2001, Houngnandan et al. 2009, Johnson et al. 2013, Balogoun et al. 2015).

## 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 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.

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 (Balogoun et al. 2015) is a mathematical measure of species' distribution in a community which shows up the number of morphological 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:

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

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 (Mosbah et al. 2018) varies from 0 to 1. It shows an equitable distribution of genus in soil when it approaches 1, close to 0, it indicates that some genera are prevailing.

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

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

## 3. RESULTS

### 3.1 Survey Results

While discussing with farmers on how they may use to deal with various random atmospheric phenomena (birds, floods, infertility…), they didn't feel wanting to associate *trees* benefits in any of their answers confident on that « flood in this region is their great benefit » because it fertilizes, providing nutriments crops need. Whatever, farmers 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 the age may depend without a significant variation. All (100%) farmers who got interviewed know the importance of trees. However, depending on their experience within their respective activities, their preference for trees' presence may differ. Thus, those who have lived some of natural disasters (over 40 of age) regretted the sad absence of many 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 field crops.

### 3.2 Effect of the Trees on Soil Physical and Chemical Parameters

The correlating proportions on soil physical particles are presented in the Table 1. Results show that, clay proportions are generally in an highly presence within 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, 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%; and Dame: 46.53, 30.88 & 22.59%).

The bared soils into the fields are mostly represented by 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 with high quantity in the fields and lower than the average norms at the "under trees" toward the exit of the villages.

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

According to the values in Table 1, the correlation is deemed to be more significant between some of parameters and less for others. Table 2 presents as for it, the correlation matrix of relation between the chemical parameters, and the next figure, a representative distribution (Fig. 2).

### 3.3 AMF Species Developing Mutualistic Relationship with Trees

The species of AMF spores associated with the trees were presented in Tables 3 and 4.

Furthermore, the Shannon index (H) and Pielou uniformity (E) indexes data values, distinctly taken per village, show high diversity of AMF (Table 3).

These results in Table 4 revealed the AMF spores proportion collected by counting, that belong to the branch of *Glomeromycota*, the genera *Glomus* and the family *Glomeraceae*, and sixteen species were identified.

Hence, 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 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.*

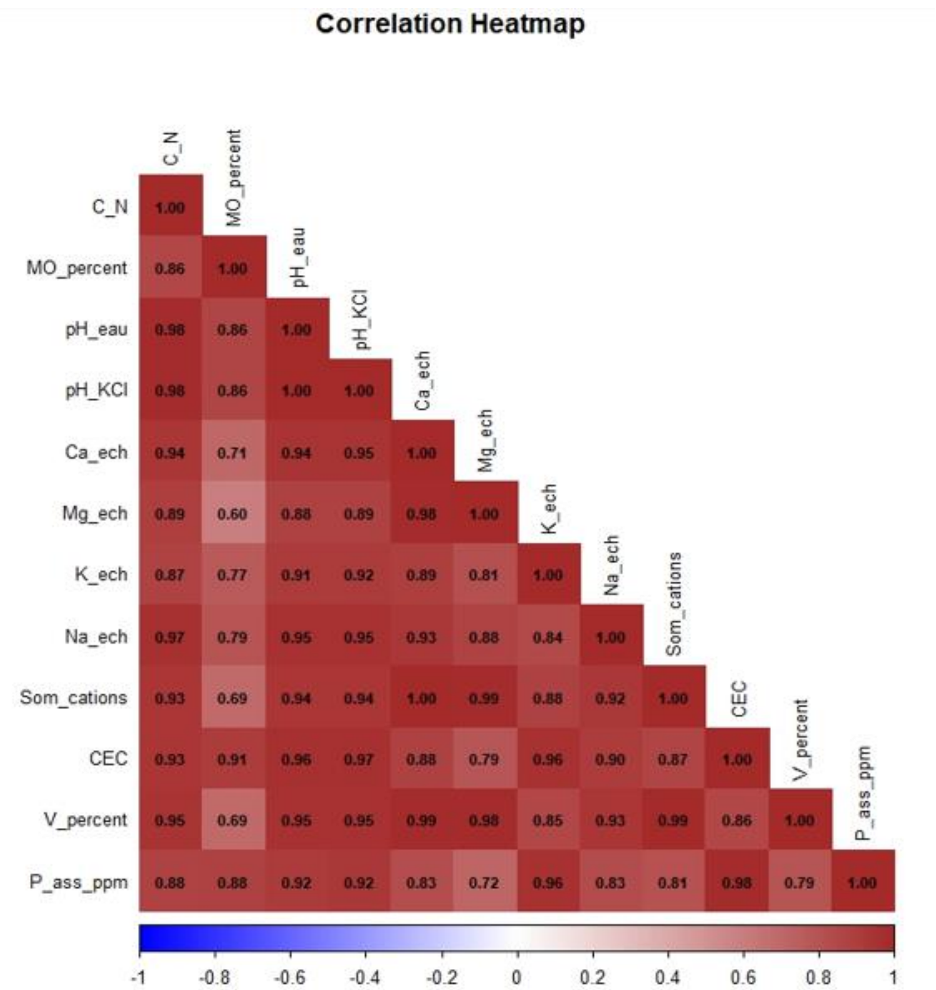



**Fig. 2. The soil chemical parameters variables correlation (R generating)**

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

| | C/N | M/O | $pH_{water}$ | $pH_{KCl}$ | Ca (meq/100g | Mg (meq/100g) | K (meq/100g) | Na (meq/100g) | Som. cations (meq/100g) | 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 |

*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" parameter shows high correlations with other parameters like "Som. cations" (0.99) and "CEC" (0.87).*

**Table 3. Diversity of AMF associated with trees**

| County | 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 50 µm sieve measurements. | 20 | 4.17 |
| *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 | 7 | 1.46 |

| Species | Characteristics | Total spores | Relative abundance (%) |
|---|---|---|---|
| | hyaline color, thick, with a thick hypha. | | |
| *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 translucent 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 %", "Silt %", "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 (Figs. 3 & 4). 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. 5).

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. 6).

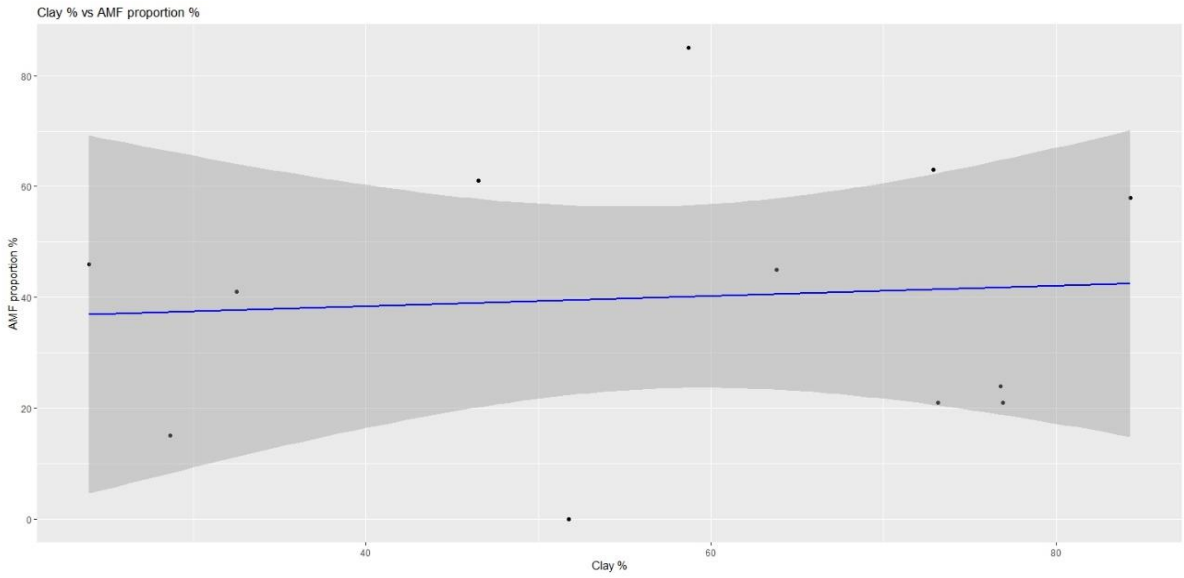



**Fig. 3. The soil parameter (clay) variables correlation within AMF random distribution (R generating)**

**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 |

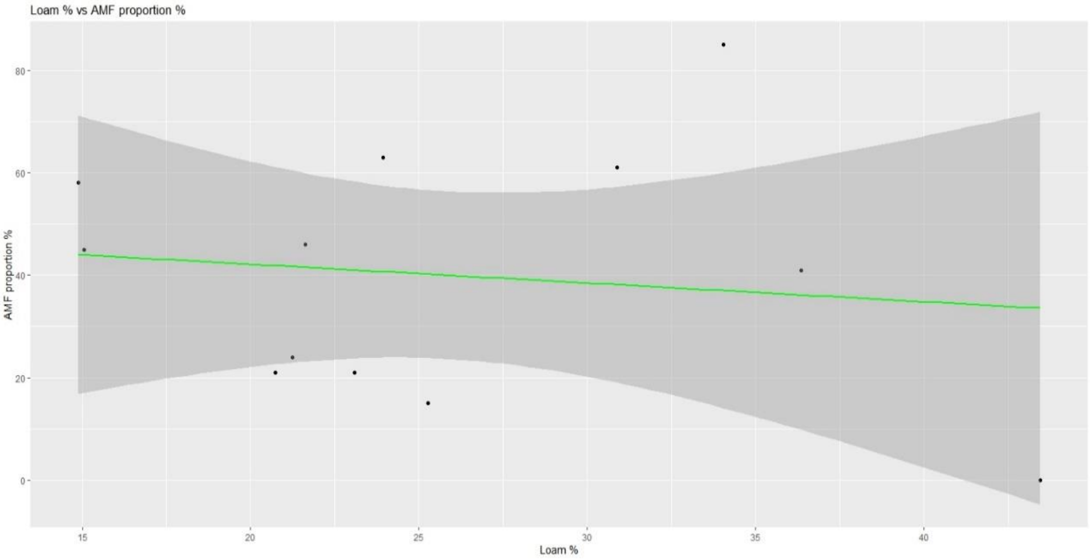



**Fig. 4. The soil parameter (loam) variables correlation within AMF random distribution (R generating)**

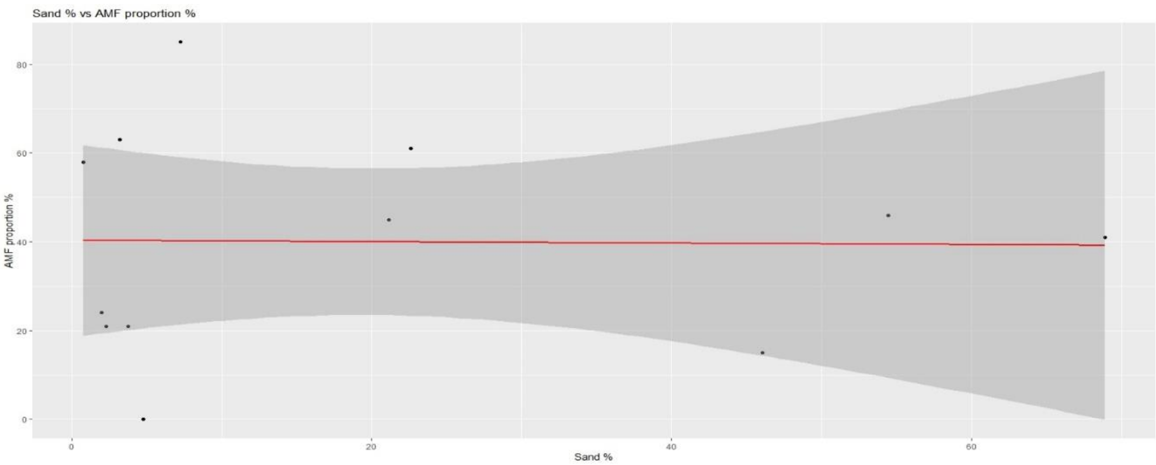



**Fig. 5. The soil parameter (sand) variables correlation within AMF random distribution (R generating)**

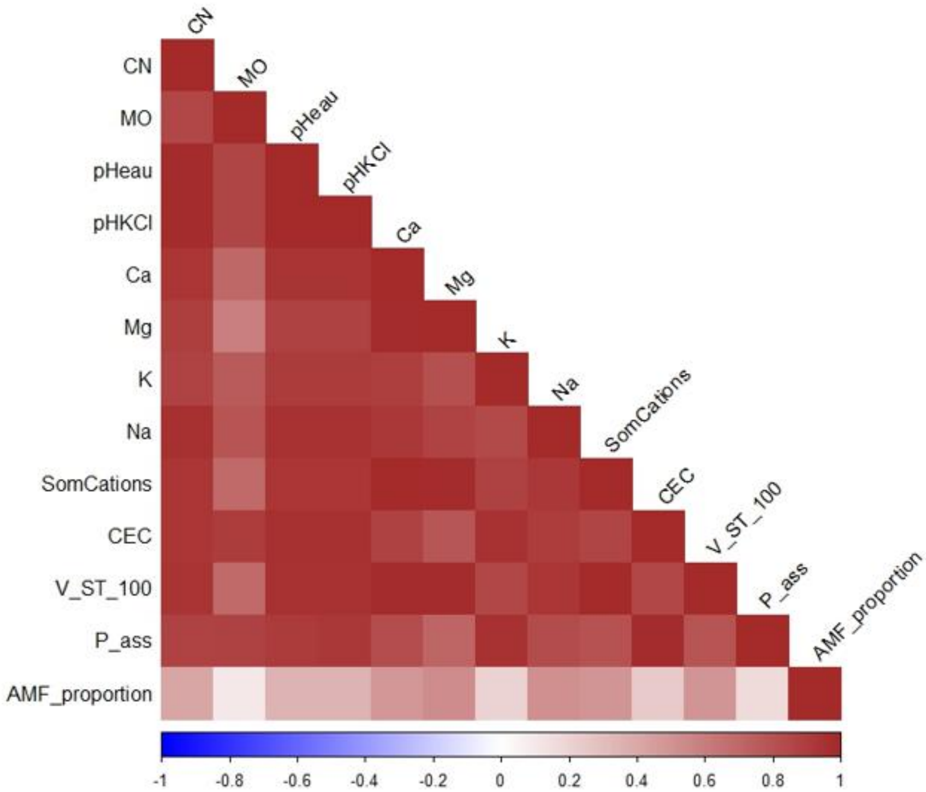



**Fig. 6. The soil chemical parameters variables correlation within AMF random distribution (R generating)**

## 4. DISCUSSION

### 4.1 Indigenous Perceptions of Farmers

It may appear very 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 (Kaya and Koitsiwe 2016). Interestingly, much like our own speculations, scientists' perspectives often differ from those of farmers concerning the severity and extent of wind erosion problems that also 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 (Sterk 2003). 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 (Apuri et al. 2018) 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, and 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, (Basdew et al. 2017) 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 months, 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 fog 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 absence of morning fog indicates impending rain, though crops might not grow optimally. 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 soil physical and chemical parameters 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 that it’s acidic.

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 phosphate enzymes. It may appear a lack of phosphorus (P) with the acidic soil aspect, the higher proportions of P the 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. However, crops would draw an additional source of energy that may contribute to soil fertility and increase production consequently, regardless of their lack (Saidou et al. 2012).

### 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 colonised by AMF spores are very popular in fields, even a little far from crops (Amonmide et al. 2019). A diverse range of AMF spores 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 and human activities, social aspects may affect biological parameters as such as tree planting depend of them.

Also, since 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 (Mosbah et al. 2018). Despite the soil fertility claimed by farmers due to plenty of yields, other studies conveniently had the advantage of detecting a lack in soil characteristics such as an acidity and a lack of phosphorus (P) generally filled by subsidiary contributions from trees (Alary et al. 2011). It also highlights 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 trees (Alary et al. 2011).

In parallel, Rosendahl (2008) with Österr and Austrian (2008) have found fascinating characteristics of AMF spores which diversity obtained would also be justified by trees we talked about. The presence of trees would therefore promote the abundance of spore populations and adequately better soil fertility (Oehl et al. 2004). Some further factors may be used to modify the biological composition of the soil such as temperature and the soil temperature. Then, many particles interact in the soil and even if our study did not focus on the micro-particles present, this could easily be proven by subsequent studies (Alrajhei et al. 2022).

Soils parameters show an incredible complementary with 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 (Alary and Lemiere 2011). 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 the *Dame* county, 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 (Bainard et al. 2011). 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-inter cropping 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 (Bainard et al. 2011) (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 (Bainard et al. 2011) 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 inter cropping 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 against extreme weather and for good harvests.

## 5. CONCLUSION

This study brought back that soil characteristics would be a crucial factor of low yields within the *Valley of Oueme* from Benin, that may be such critical, 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 Phosphorus (P) revealed, 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.

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 be appreciated to adopt good practices such as stopping trees cutting and get accountability of promoting agroforestry systems as an amazing science-policy practical applications to save forests.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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