Original Research Article

Effects of spacing between stone-rows on the chemical and biological fertility of lixisoils in eastern Burkina Faso

.

ABSTRACT

|  |
| --- |
| The effect of stone-rows spacing on soil fertility parameters in a farm and the likely occurrence of a fertility gradient were assessed. The study was conducted in a rural setting in the Sampieri agricultural area in eastern Burkina Faso in a Sudano-Sahelian environment on lixisols with a medium slope of up to 5%. The experimental design included three plots where stone bunds were installed. In the first plot, the spacing between the bunds was 15.5 m (P1), 18.5 m (P2) in the second and 22 m (P3) in the third. Samples were taken at intervals ranging from 0 to 15 m beyond the overall assessment in these plots. The 0-10 and 10-20 cm horizons were sampled. Soil organic carbon, total nitrogen, pH and soil microbiological activity were assessed. The study showed that C, N, P and pH levels improved better on plots P2 and P1 than on plot P3. However, although differences were noted for microbiology, they were not statistically significant. There was a correlation between the area of plots with stone bunds and most soil fertility parameters. However, no soil fertility gradient appeared as a function of slope when moving away from the first line of stone-rows. It can be concluded that the optimal spacing between stone ridges is 18.5 and that it is difficult to deduce a fertility gradient within this interval. But this study deserves to be repeated for validation and confirmation. |

*Keywords: Agroecological, Stone-rows, soil parameters, Lixisols, Burkina Faso*

1. INTRODUCTION

In the Sudano-Sahelian zone, recurrent droughts since the 1970s, demographic pressure, as well as extensive agro-pastoral production systems, have had the immediate consequence of increasing the vulnerability of agro-ecosystems. Indeed, the green revolution, symbol of agricultural intensification (or industrialized agriculture) based on tillage, massive use of mineral and synthetic inputs of industrial origin (fertilizers, pesticides and energy) and a small number of cultivated species (Sainju et al., 2003; Goïta, 2014) has had as a corollary the increase in cereal crop yields (Sainju et al., 2003; Gomiero et al., 2011). Globally, the consequences of this modernization have included a tenfold increase in cereal production yields and cultivated areas per farmer, a sharp increase in livestock production, and a more than hundredfold increase in gross agricultural labor productivity (Mazoyer et al., 2002). In Africa, this has resulted in an increase in yields estimated at around 14%, but with a parallel doubling of cultivated areas (Soule and Gansari, 2010). However, this type of agriculture results in a reduction in biodiversity, the degradation of arable land, the alteration of water quality and quantity, and a negative contribution to climate change (Gomiero et al. 2011). The most characteristic consequence is, in practice, a continuous decline in land productivity, which reflects a complex process of deterioration of the chemical, physical, and biological properties of the soil (Hien, 2004). These dysfunctions are also exacerbated by the impact of global climate change (Jauffret, 2009), whose predictive models agree on a likely increase in the instability of climatic conditions across the world, with catastrophic droughts or floods. In addition to the impact of climate change and human activity on continental biogeosystems, it is important to consider the unique characteristics of tropical environments. These environments are often characterised by fragile soils and intense climates, which can further compound the effects of these disturbances. As a landlocked and ecologically fragile country, Burkina Faso is unfortunately not immune to this general trend in the agricultural world of the Sahel. It is even more exposed because its economy is structured primarily around its "land and/or natural resources" capital. Unfortunately, under the combined effects of climate and anthropogenic activity, this "land and/or natural resources" capital is undergoing a worrying degradation, jeopardizing the country's socioeconomic development. Indeed, some studies (Gomgnimbou et al., 2010; Ouédraogo et al., 2019, Sanou et al. 2025) have shown that the degradation of terrestrial ecosystems and the environment in Burkina Faso in general is linked to anthropogenic factors, particularly agricultural activities. In addition, the slopes present a morpho-pedological heterogeneity from upstream to downstream, often marked by the presence of a shell or armor which limits the useful depth of the soil (80 and 100 cm maximum). The presence of this shallow shell or armor on nearly two-thirds of the glacis imposes, among other things, constraints on water management and plant growth, as well as the susceptibility of soils to runoff, regardless of their texture. According to an assessment by INERA in 2010, about 24% of Burkina Faso's farmland is severely degraded. This poses a threat to the quality of the natural environment and the country's food security in the medium and long term.

Added to this is the fact that the country's soils are characterized by their nutrient deficiency, particularly nitrogen and phosphorus (Dembélé and Somé, 1991). They are also rich in silt and fine sand with poor structural stability, low clay content, and low organic matter content (less than 3% under vegetation and 0.7% under crops) (Pieri, 1989).

To address these realities, scientific agronomic work combined with traditional peasant knowledge has helped to identify and reveal innovative agroecological technical solutions. Technically based on the measured use of local resources, agroecology aims to integrate into its practice all the parameters of ecological management of cultivated areas, making it possible to reconcile productivity, sustainable management of natural resources, food security and human development while preserving the health of populations (Altieri, 2002; De Schutter, 2010; Dufumier, 2010; Van Walsum, et al., 2014; Francis et al., 2003). These advantages are therefore the foundations for building a more resilient agriculture (USAID, 2012). Stone bunds are, in this context, a promoted technique whose effects on soils and crop yields have been evaluated in the western, northern, and eastern regions of the country (Coulibaly et al., 2018; Yaméogo et al., 2011; Sawadogo et al., 2008, Douamba et al., 2011). However, few research has been conducted into the effectiveness of the technique when the spacing between stone-rows varies.

Hence the interest of this study in this agroecological zone after several years of promoting stone-rows. It consisted of evaluating the impact of spacing between stone-rows on the chemical and microbiological characteristics of soils, but also to determine the optimal spacing between the stone-rows.

2. material and methods

**2.1 Site description**

The study was conducted in the eastern Burkina Faso in the village of Sampieri about 150 km east of Fada N'Gourma city and 20 km west of the commune of Kantchari (border Burkina-Niger). The climate in this area is Northern-Sudanian an mean annual precipitation and temperature are 687 mm and 29 °C respectively. Geologicaly, Sampiéri is on a basement resulting from the alternation between birrimian furrows and granitic terrains (Sattran and Wenmenga, 2002). Soil from granitic level was subsequently altered leading to the formation of plinthite or petro-plinthite layer. The main soils inventoried in the village are lixisols (WRB, 2014) from little leached to leached on sandy, sandy-clayey and clayey-sandy and poorly evolved. They are mainly characterized by low levels of nitrogen and phosphorus. Basic soil data for the Sampieri village are given in Table 1. Agriculture (sorghum, millet, maize system) is the main activity and is family-based with a set of small plots (about 3 ha) per farmer. Production is predominantly subsistence, but in recent years cash crops have also been developed, especially cotton and sesame. The fields concerned by our study have been cultivated for years (sorghum, millet, maize) before being gradually developed into stone-rows and then amended in compost since 2006.

**Table 1 : Basic soil properties of Sampieri soil (Bunasols, 2008)**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter | Clay | Sand | Silt | C | N | C/N ratio | Pa | pH |
| Unit | % | % | % | mg.g-1 | mg.g-1 | - | ppm | - |
| Value  | 8-10 | 37-51 | 39-55 | 4.5 | 0.4 | 10-13 | 1.4 | 6-6.6 |

**2.2 Methods**

Stone-rows are obstacles along a contour that cut down run-off speed. The implementing of this structure allowed the sedimentation of soil particles (sands, organic matter, ….). According to the farmer's organization, the plots arranged in stone-rows on the average slope glacis are subdivided into three plots P1, P2 and P3 (Fig. 1). Plots P1, P2 and P3 correspond respectively to plots of size 15.5; 18.5 and 22 m. Within each plot, soil samples are taken at regular distances ranging from 0 to 15 meters initially for all three plots. In a second step, an additional sample is taken within plots P2 and P3 to the end of the plot. These samples are taken in the 0-10 and 10-20 cm layers. A total of 120 soil samples were taken within the plots delimited by the stone barriers, i.e. 36 samples for plot P1 and 42 for plots P2 and P3. Composite soil samples were then taken with these elementary samples according to the sampling distance to obtain a total of 40 samples. The soil samples thus constituted were dried, sieved to 2 mm, then preserved for physical, chemical and microbiological analyses.



Fig 1 : Plots arranged in stone ridges and sampling plan

The experimental texture kit named Soil Texture Unit (code 1067) developed by LaMotte company (USA) was used for the determination of the various particles size fractions of the soils after sieving at 2 mm. This test was designed to separate fine earth into three basic mineral fractions independently of coarse elements greater than 2 mm: sand from 2 mm to 50 μm, silt from 50 μm to 2 μm and clay less than 2 μm. Determination of total nitrogen content was realized using an elemental flash pyrolyser analyser (Flash 2000, Thermo Fischer Scientific). For this purpose, soil samples were finely ground (diameter less than 160 μm) and then placed in a tin capsule and introduced into a high-temperature furnace (900 °C) crossed by a current of helium, an oxygen supply causing total combustion. The respective contents of nitrogen (N) are quantified by gas chromatography. Total organic carbon content was determined by the Rock-Eval method (Disnar et al., 2003) using a Rock-Eval 6 Turbo (Vinci Technologies, France). It consists in heating successively between 300 and 650 °C (pyrolysis) and 300 and 850 °C (oxidation) 100 mg of soil sample finely ground beforehand. Microbial communities’ characterization was carried out by the MicroRespTM technique (Campbell et al., 2003), which allows the study of the functional diversity of a soil in its entirety without the cultivation of the microorganisms present with the risk of selection phenomena. The MicroRespTM technique is a measurement soil respiration through the quantification of the CO2 emitted. The principle is based on the capture of CO2 released by the soils incubated in deep well plates (96 wells) by cresol red placed in detection plates. Soil samples (approximately 0.4 g of soil per well) placed in these wells were previously moistened to about 60% of their maximum water retention capacity. In addition to blank (distilled water), 25 μL of the following 15 carbon substrates added at 30 mg C g-1 soil water were used to enrich the incubated soils: glucose, galactose, mannose, fructose, trehalose, sucrose, maltose, mannitol, sorbitol, inositol, glycine, proline, arginine, citrate and malate. Substrates were chosen based on their complexity (i. e. length of the C chain) and diversity concerning their role in the metabolism. Moreover, theses substrates are representative of low molecular weight organic compounds released during the decomposition of plant residues and released in root exudates (Campbell et al., 2003). All the C sources were obtained from Sigma-Aldrich (Saint-Quentin Fallavier, France). CO2 released by the soil, after six hours incubation in the dark at 25 °C was captured by the gel. A chemical reaction takes place between the CO2 formed and the HCO3- ion to give, inter alia, H+; the medium thus sees its pH decreasing causing a change of color of the indicator in the detection plate. The change from pink to yellow was measured before adding substrates and following the 6 hour incubation, using a spectrophotometer at the wavelength of 570 nm (Bio-Tek Instrument, Inc., µQuant – MQX 200). This will make it possible to estimate the rate of respiration of each well. The rate of CO2 respiration expressed per gram of soil per well was calculated using the formula provided in the MicroResp™ manual (Macaulay Scientific Consulting, UK). The amount of CO2 produced from the water addition wells was subtracted from the respiration in the substrate wells to accurately calculate the substrate induced response (SIR). The determination of the basal respiration (BR) was calculated from data obtained after soil incubation with water added. Results were expressed in μg C-CO2 g-1 soil h-1. The microbial biomass (MB) was calculated from respiration produced from the glucose amended wells using the equation from Anderson and Domsch (1978). The metabolic quotient (qCO2) was calculated according to the equation (Anderson and Domsch, 1993): qCO2: basal respiration / microbial biomass. Higher qCO2 indicated stress or exogenous disturbance (Anderson and Domsch, 1993). Shannon-Weaver index (H') and equitability index (E) were calculated to subsequently characterize the microbial community. All measurements were done in 6 technical replicates.

**2.3 Statistical analysis**

The data was collected into Excel spreadsheet and then analyzed using ANOVA variance of XLSTAT 7.5 software. Means were separated according to the Tukey test at the 5% threshold. For the MicroResp data, principal component analysis (PCA) using a correlation similarity matrix was used to identify separate groups according to different soils treatments applying the XLSTAT 7.5 software. For soil microbial diversity, two indices cited above were calculated. The functional diversity as measured by Shannon-Weaver index (H’) was calculated using the equation: H’= ∑Pi(lnPi), where Pi was the ratio of the utilization rate of each C source to the sum of the utilization rate of all C source for each soil sample (Zak et al., 1994). Evenness (E) or Pielou index was calculated based on the equation of E = H’/H’max=H’/lnS, where Hmax was the largest H’ within a specific sample (Zhou et al., 2012) and S total number of species, represented here total number of substrates tested.

3. results and discussion

3.1. Results

**3.1.1. Effects of spacing between stone-row lines on soil chemical** **characteristics**

The analysis of the Table below shows a variation in pH depending on the types of plots (Table 2). Thus, we note high values at the level of plots P1 (6.63) and P2 (6.89) unlike plot P3 where the pH is 6 for the 0-10 cm layer. As for the 10-20 cm layer we have the same trend as that of the 0-10 cm layer with 5.87 for P1 and 6.16 for P2 which are clearly higher than that of P3 (5.2). As for the pH-KCl, it follows the same trend as the pH water both on the surface and in depth. We can note in the 0-10 cm layer 5.98 for P1, 6.02 for P2 and 5.12 for P3. In the 10-20 cm layer the values are 5.67; 5.95 and 4.46 respectively for P1, P2, and P3. It can also be noted that the pH and pH-KCl of plot P2 are higher than those of plot P1. Furthermore, there are significant differences between these treatments regardless of the layer at the 5% threshold according to the Tukeys test (Table 2).

For electrical conductivity, in the 0-10 cm layer, the electrical conductivity values are 247.47 µS/cm for P2, 175.66 µS/cm for P3, and 163.78 µS/cm for P1. In the 10-20 cm layer, the variation is the same, with 147 µS/cm for P2, 78.86 µS/cm for P3, and 74.83 µS/cm for P1. There is no significant difference between the treatments in the 0-10 cm layer. On the other hand, in the 10-20 cm layer there is a significant difference between plot P2 and the other treatments (Table 2).

**Table 2 : pH; pH-KCl and electrical conductivity of the different plots**

|  |  |  |  |
| --- | --- | --- | --- |
| **Plots** | **pH** | **pH-KCl** | **EC** |
| **0-10 cm** | **10-20 cm** | **0-10 cm** | **10-20 cm** | **0-10 cm** | **10-20 cm** |
| **P1** | 6.63 a | 5.87 a | 5.98 a | 5.67 a | 163.78 a | 74.83 b |
| **P2** | 6.89 a | 6.16 a  | 6.02 a | 5.95 a | 247.47 a | 147.00 a |
| **P3** | 6.00 b | 5.20 b | 5.12 b | 4.46 b | 175.66 a | 78.86 b |

The carbon content of Plot P3 is low compared to that of Plots P2 and P1, regardless of the sampling layer (Fig. 2). It varies for Plot P3 from 4.23 mg g-1 in the 0-10 cm horizon to 4.10 mg g-1 in the 10-20 cm layer. For Plots P1 and P2, the 0-10 cm layer contains 9.18 mg g-1 and 8.28 mg g-1, respectively. In the 10-20 cm layer, it decreases for these two plots but remains higher than that of P3, at around 8.38 mg g-1 for P1 and 6.82 mg g-1 for P2. Analysis of variance shows significant differences between Plots P1 and P2 and P3, regardless of the layer (Table 3).

**Figure 2 : Organic carbon content of different plots**

Nitrogen contents are increasing and evolve from 0.48 mg g-1 for P3; 0.54 mg g-1 for P2 and 0.56 mg g-1 for P1 for the 0-10 cm layer (Fig. 3). In the 10-20 cm layer they are also increasing. We note 0.18 mg g-1 for P3, 0.49 mg g-1 for P1 and 0.50 mg g-1 for P2. The analysis of variance shows no significant difference between plots P1 and P2 regardless of the sampling layer. On the other hand, there are significant differences between plots P1, P2 and P3 on the two sampling layers (Table 3).



**Figure 3 : Total nitrogen content of the different plots**

The available phosphorus levels in the plots are generally low (Fig. 4). In the 0-10 cm layer, values of 0.04 mg g-1 were recorded for P1, 0.08 mg g-1 for P2 and 0.02 mg g-1 for P3. These values increase to 0.01 mg g-1 for P1, 0.03 mg g-1 for P2 and 0.01 mg g-1 for P3 in the 10-20 cm layer. There are also significant differences between P2 and the other treatments at the 5% threshold according to Tukey, regardless of the layer (Table 3).



**Figure 4 : Content of assimilable posphorus of the different plots**

**Table 3: Comparison of average C, N, and Pa contents**

|  |  |  |  |
| --- | --- | --- | --- |
| **Plots** | **N (mg.g-1)** | **C (mg.g-1)** | **Pa (mg.g-1)** |
| **0-10 cm** | **10-20 cm** | **0-10 cm** | **10-20 cm** | **0-10 cm** | **10-20 cm** |
| **P1** | 0.56 a | 0.49 a | 9.18 a | 8.38 a | 0.04 ab | 0.01 b |
| **P2** | 0.54 a | 0.50 a | 8.28 a | 6.82 a | 0.08 a | 0.03 a |
| **P3** | 0.48 b | 0.18 b | 4.23 b | 4.10 b | 0.02 b | 0.01 b |

For Na+ and Mg2+, there were no significant differences between the plots regardless of the sampling layer (Table 4). For K+, there was a significant difference between P1 and the other plots at the 5% threshold for both sampling layers. For Ca2+, only plot P2 differed significantly from the other treatments. Regarding cation exchange capacity, in both layers, high values were noted for P1 and P2 compared to P3. Significant differences were recorded between P1, P2, and P3 in the 0-10 cm layer at the 5% threshold (Table 4). In the 10-20 cm layer, however, only treatment P2 was significantly different from treatment P3.

**Table 4 : Exchangeable cations and cation exchange capacity of different plots**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Exchangeable cations** | **Sampling depth** | **P1** | **P2** | **P3** |
| ***Na+ (meq/100g)*** | **0-10 cm** | 1.100 a | 0.296 a | 0.751 a |
| **10-20 cm** | 0.313 a | 0.893 a | 0.407 a |
| ***Mg2+ (meq/100g)*** | **0-10 cm** | 3.000 a | 1.972 a | 2.138 a |
| **10-20 cm** | 3.740 a | 2.929 a | 2.783 a |
| ***K+ (meq/100g)*** | **0-10 cm** | 1.860 a | 0.879 b | 0.565 b |
| **10-20 cm** | 1.224 a | 0.627 b | 0.279 b |
| ***Ca2+ (meq/100g)*** | **0-10 cm** | 17.226 b | 22.130 a | 12.532 b |
| **10-20 cm** | 18.991 ab | 29.784 a | 18.054 b |
| ***Sum des EC*** | **0-10 cm** | 23.186 a | 25.277 a | 15.986 b |
| **10-20 cm** | 24.268 ab | 34.233 a | 21.524 b |
| ***CEC (meq/100g))*** | **0-10 cm** | 15.450 a | 19.908 a | 8.117 b |
| **10-20 cm** | 24.353 ab | 29.412 a | 16.187 b |

**3.1.2. Effects of spacing between stone-row lines on soil microflora**

For plots P1, P2 and P3, the Basal Respiration (BR) values were 0.194µg C-CO2 g-1 h-1, 0.250µg C-CO2 g-1 h-1 and 0.122µg C-CO2 g-1 h-1 respectively. For microbial biomass (MB), a high value is noted for plot P2 (16.071 µg biomass-C g-1), which is higher than that of treatments P1 (5.595 µg biomass-C g-1) and P2 (6.324 µg biomass-C g-1). The metabolic quotient ranges from 0.031 µgC-CO2biomass-C g-1 h-1 for P3 to 0.071 µgC-CO2biomass-C g-1 h-1 for P1. For diversity index H', the lowest value is observed at plot P2 (2.144). Plots P1 and P3 have diversity indices of 2.362 and 2.196, respectively. However, statistical analysis does not reveal any significant difference between treatments at the 5% threshold according to the Tukey test. Similar to the diversity index H', the equitability index is highest in P1, then P3, and the lowest value is recorded in P2. However, despite the differences and improvements observed for all of these microflora parameters, statistical analysis shows that there is no difference between these treatments at the 5% threshold according to the Tukey test.

**3.1.3. Fertility Gradient with Slope**

Following the initial results on plot sizes, we deemed it important to verify whether there was a soil fertility gradient depending on the position within the plots. Tables 5 and 6 give the values of the various soil fertility parameters at the different sampling points. It should be noted that there is no order of magnitude depending on the distance from the stone bund lines.

**Table 5: pH and electrical conductivity**

|  |  |  |  |
| --- | --- | --- | --- |
| **Distance to the stone-row line** | **pH** | **pHKCl** | **EC** |
| **0-10 cm** | **10-20 cm** | **0-10 cm** | **10-20 cm** | **0-10 cm** | **10-20 cm** |
| **0** | 6.12 | 5.68 | 5.63 | 5.04 | 276.77 | 92.33 |
| **0.5** | 6.64 | 5.99 | 5.74 | 6.05 | 188.06 | 143.38 |
| **1** | 6.47 | 5.60 | 5.49 | 5.38 | 225.94 | 132.97 |
| **2** | 6.68 | 6.04 | 5.65 | 5.59 | 186.70 | 131.09 |
| **5** | 6.65 | 5.51 | 5.93 | 4.90 | 134.45 | 58.50 |
| **15** | 6.49 | 5.66 | 5.81 | 5.18 | 161.90 | 65.15 |

**Table 6 : Carbon, nitrogen and avalaible phosphorus content**

|  |  |  |  |
| --- | --- | --- | --- |
| **Distance to the** **stone-row line** | **N (mg.g-1)** | **C(mg.g-1)** | **Pa (mg.g-1)** |
| **0-10 cm** | **10-20 cm** | **0-10 cm** | **10-20 cm** | **0-10 cm** | **10-20 cm** |
| 0 | 0,505 | 0,384 | 7,67 | 5,83 | 0,034 | 0,017 |
| 0.5 | 0,523 | 0,400 | 6,83 | 7,17 | 0,055 | 0,015 |
| 1 | 0,557 | 0,377 | 7,37 | 6,90 | 0,051 | 0,030 |
| 2 | 0,552 | 0,383 | 7,03 | 5,87 | 0,052 | 0,019 |
| 5 | 0,515 | 0,386 | 7,40 | 6,67 | 0,025 | 0,010 |
| 15 | 0,535 | 0,415 | 7,10 | 6,17 | 0,045 | 0,010 |

Furthermore, like figure 5 for pH, le results show that there is no strong correlation between carbon, nitrogen, Pa contents and sampling distances regardless of the sampling layer.



**Figure 5: Relationship between sampling distance and soil pH**

The biological parameters measured were basal respiration, microbial biomass, metabolic quotient, H' diversity and E equitability indices. These biological parameters show a large variability depending on the sampling distances. This is valid for all the measured parameters; if we consider, for example, microbial biomass, we note an increase from 0 to 1 m; then a decrease for 2 m and then a considerable increase for 5 m and a drastic decrease for 15 m. It is therefore not clearly established that there is a fertility gradient depending on the soil sampling distance.

3.2 Discussion

Although very little work has been done exclusively on the effects of spacing between stone bunds, contrary to our expectations, we were unable to establish a soil fertility gradient from the top to the bottom of the plots in the direction of the slope, regardless of the parameters measured. This could be explained by the non-uniform distribution of organic matter inputs on these plots. Zougmoré et al. (2004) had effectively proven the role of organic matter in the success of CES-DRS techniques. Indeed, the mature compost is first deposited in piles in the fields before being spread and buried by surface plowing. This process may explain the differences observed within the same plot. This is all the more true since, at the scale of individual plots, we note differences between treatments P1, P2 and P3 for physical and chemical parameters. We note a clear improvement in the effect of inputs on plots P1 and P2 compared to plot P3, which is larger. We could therefore say that the smaller the plot, the more controlled the inputs are and the more the effects are felt on the soil characteristics. But the fact that there is no significant difference between P1 and P2 shows that there is a reasonable threshold (profitability threshold of approximately 18.5 meters) beyond which the induced effect is no longer significant. But for the biological parameters there is no difference between plots P1, P2 and P3. In other circumstances Ballo et al., (1994) already drew the attention of agronomists to the dimensions to be given to agricultural plots. Contrary to our results Kima et al., (2012) had shown that the positive effect induced by stone barriers is observable over a distance of 20 m. Similar studies have shown the beneficial effect of reducing the distance between stone bund lines on runoff and agricultural production (Zougmoré et al., 2000) and on the physical, chemical and biological characteristics of soils (Zougmoré et al., 2002). Like Zougmoré et al. (2000), Sanou in 2014 worked on spacings of 33 m and showed clear improvements in soil characteristics thanks to stone-rows.

As for the second part of this work, it should be noted that no prior work has been conducted on the subject. But like the internal work on the spacing of stone lines, it can be said that fertility is uniform in the space between the lines of stones.

4. Conclusion

We can note that very little research has been devoted exclusively to investigating the effect of spacing between stone bunds on soil fertility parameters. However, our results have shown that the smaller the distance between rows, the more significant the effect on soil chemical parameters up to a spacing of 18.5 m between rows. This leads us to believe that this distance is the reasonable threshold for their implementation in this area. Also, the results of the fertility gradient test confirm this view. Conversely, this is not the case for microbiological parameters, hence the need to further explore this work in this direction.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

References

Altieri, M. A., (2002). Agroecology: The science of natural resource management for poor farmers in marginal environments. Agriculture, Ecosystems and Environment, 93, 1-24.

Anderson, T.H., & Domsch, K.H., (1993). The metabolic quotient for CO2 (qCO2) as a specific activity parameter to assess the effects of environmental conditions, such as pH, on the microbial biomass of forest soils. Soil Biol. & Biochemi., 25, 393-395.

Ballo, K., Quencez, P., Ouattara, S., Tailliez, B., & Rey, H., (1994). Edge effects in a control plot of a potassium fertilization trial on depleted soils in Côte d'Ivoire. Oléagineux, 49(4), 137-143.

National Soil Office (Bunasols). (2008). Morphopedological study of the province of Tapao. Bunasols, technical report n°143, 119 p.

Campbell, C. D., Chapman, S. J., Cameron, C. M., Davidson, M. S., & Potts, J. M., (2003). A rapid microtiter plate method to measure carbon dioxide evolved from carbon substrate amendments so as to determine the physiological profiles of soil microbial communities by using whole soil. Appl, and Environ, Microbiol, 69, 3593-3599.

Coulibaly, A., Hien, E., Motelica-Heino, M., & Bourgerie, S., (2018). Effect of agroecological practices on cultivated lixisol fertility in Eastern Burkina Faso. International Journal of Biological and Chemical Sciences, 12 (5), 1976-1992. https://dx.doi.org/10.4314/ijbcs.v12i5.2

Coulibaly, A., Motelica-Heino, M. & Hien, E. (2019). Determinants of Agroecological Practices Adoption in the Sudano-Sahelian Zone. Journal of Environmental Protection, 10, 900-918. https://doi.org/10.4236/jep.2019.107053

DE SCHUTTER, O. (2011). Agroecology and the Right to Food. Report presented at the 16th Session of the UN Human Rights Council. New York, USA, UN, 23 pp.

Dembele, Y., & Somé, L. (1991). Hydrodynamic Properties of the Main Soil Types of Burkina Faso. Soil Water Balance. In Vie Sudano-Sahdian Zone (Proceedings of the Niamey Workshop, February 1991), IAHS Publ, 199, 217-227.

Disnar, J.-R., Guillet, B., Keravis, D., Di-Giovanni, C., & Sebag, D., (2003). Soil organic matter (SOM) characterization by rock eval pyrolysis: scope and limitations. Org. Geochem., 34, 327-343.

Doamba, S.M.F., Nacro, H. B., Sanon, A., & Sedogo, M., (2011). Effect of stone bunds on the biological activity of a leached tropical ferruginous soil (Kouritenga Province, Burkina Faso). International Journal of Biological and Chemical Sciences, 5, 304-313.

Dufumier, M., (2010). AGROECOLOGY AND SUSTAINABLE DEVELOPMENT. Emilie COUDEL, Hubert DEVAUTOUR, Christophe-Toussaint SOULARD, Bernard HUBERT. ISDA 2010, June 2010, Montpellier, France. CIRAD-INRA-SupAgro, 20 p. <hal-00521817>

Francis, C., Lieblein, G., Gliessman, S., Breland, T. A., Creamer, N., Harwood, R., et al. (2003). Agroecology: The Ecology of Food Systems. Journal of Sustainable Agriculture, 22(3), 99-118. http://dx.doi.org/10.1300/J064v22n03\_10.

Goita, M., (2014). The Challenges of Agricultural Development in Africa and the Choice of Model: Green Revolution or Agroecology? SOS FAIM, No. 10, 39p.

Gomiero, T., Pimentel, D., & Paoletti, M. G., (2011). Is There a Need for a More Sustainable Agriculture? Critical Reviews in Plant Sciences, 30(1-2), 6-23.

Gomgnimbou, A. P.K., Savadogo, P. W., Nianogo, A. J., & Millogo-Rasolodimby, J., (2010). Agricultural Practices and Farmer Perceptions of the Environmental Impacts of Cotton Farming in Kompienga Province (Burkina Faso). Sciences & Nature 7(2), 165–175.

Hien, E., (2004). Carbon dynamics in a ferric acrisol from central-western Burkina Faso: influence of cultural practices on the stock and quality of organic matter. Doctoral thesis from the Ecole Nationale Supérieure Agronomique de Mompellier, France 138p.

INERA. (2010). Component 2: Literature Review on Land Use in the Burkinabe Sahel. LaSyRe-Sahel Project. Report, 198 pages.

Jauffret, S., Briki, M., Dorsouma, Al H., Khatra, N. B., Baubion, C., & Issa A., (2009). Ecological Indicators of Roselt/OSS, Desertification and Biodiversity of Circum-Saharan Ecosystems. Introductory Note No. 4, 52 p.

Kiema, A., Nacro, H. B., & Nianogo A.J., (2012). Effects of Stone Lines and Scarification on the Physical and Chemical Characteristics of the Soil of a Glacis Pasture in Burkina Faso. Rev. CAMES-Series A, 13 (Suppl 2), 94-97.

Mazoyer, M. & Roudart, L. (2002). History of World Agriculture: From the Neolithic to the Contemporary Crisis. Paris, Éd. du Seuil. 705 p.

Ouédraogo, B., Kaboré, O., & Kaboré, M. (2019). Quantitative Mapping of Soil Erosion Using a GIS/RUSLE Approach in the Municipality of Karangasso Vigué (Burkina Faso). International Journal of Biological and Chemical Sciences, 13(3), 1638-1653. DOI: https://dx.doi.org/10.4314/ijbcs.v13i3.35

Pieri, C. (1989). Fertility of Savannah Lands: A Review of Thirty Years of Agricultural Research and Development South of the Sahara. Ministry of Cooperation, France, 444 p.

Sainju, U.M., Terrill, T.H., Gelaye, S., & Singh B.P., (2003). Soil aggregation and carbon and nitrogen pools under peanut rhizoma and perennial weeds. Soil Science Society of America Journal, 67, 146–155.

Sanou, B.C., Guébré, D. & Hien, E. (2025). Effects of soil diversity and topographic level on microbial activity and carbon cycling in the South Sudanese lowlands of Burkina Faso. European Scientific Journal, ESJ, 21 (21), 153. https://doi.org/10.19044/esj.2025.v21n21p153

Sattran, V., Wenmenga, U., (2002). Geology of Burkina Faso. Czech Geological Survey.

Sawadogo, H., Bock L., Lacroix D. & Zombré N. P., (2008). Restoring the Potential of Degraded Soils Using Zaï and Compost in Yatenga (Burkina Faso). Biotechnol. Agron. Soc. Environ., 12(3), 279-290.

Sanon, A., (2014). Impacts of Vegetated Stone Barrier on Vegetation and Soil Physicochemical Properties. MASTER'S THESIS, Institute of Rural Development/Polytechnic University of Bobob Dioulasso, Burkina Faso. 58 p.

Soule, B. G. & Gansari S., (2010). The Dynamics of Regional Cereal Trade in West Africa. Study Report 2010, 111 p.

USAID, (2012). Building resilience to recurrent crises: USAID policy and program guidance, Washington DC: U.S. Agency for International Development, 25 p.

Van Walsum, E., van den Berg, L., Bruil J., and Gubbels, P. (2014). From vulnerability to resilience: agroecology for sustainable dryland management. In: PlanetRisk, 2(1), Special Issue on Desertification: 62-69, Davos: Global Risk Forum GRF Davos.

WRB, (2015). World reference base for soil resources 2014. World Soil Resources Reports No. 106, FAO, Rome.

Yaméogo, J.T., Somé, A.N., Mette Lykke, A., Hien, M., & Nacro, H.B. (2013). Restoring the potential of degraded soils using zaï and stone barriers in western Burkina Faso. TROPICULTURA, 31 (4), 224-230.

Zak, J.C., Willig, M.R., Moorhead, D.L., & Wildman, H.G., (1994). Functional diversity of microbial communities: a quantitative approach. Soil. Biol. Biochem., 26, 1101–1108.

Zhou, X., Wu, H., Koetz, E., Xu, Z. & Chen, C., (2012). Soil labile carbon and nitrogen pools and microbial metabolic diversity under winter crops in an arid environment. Appl. Soil. Ecol., 53, 49-55.

Zougmore, R., Guillobez, S., Kambou, N.F., & Son, G., (2000). Runoff and sorghum performance as affected by the spacing of stone lines in the semiarid Sahelian zone, Soil & Tillage Research, 56, 175-183.

Zougmore, R., Gankambary, Z., Guillobez, S., Stroosnijder, L., (2002). Effect of stone lines on chemical characteristics under continuous sorghum cropping in semiarid Burkina Faso, Soil & Tillage Research, 66, 47-53.

Zougmoré, R., Ouattara, K., Mando, A., & Ouattara, B., (2004). Role of nutrients in the success of water and soil conservation techniques (stone bunds, grass strips, zaï and half-moons) in Burkina Faso. Secher., 15, 41-48.