Effects of agroecological practices on the fertility of hydromorphic soils of the Tiebele plain under sweet potato(*Ipomoea batatas (L.)* Lam) cultivationin the South Sudanian zone of Burkina Faso

ABSTRACT

Aims: Thissutyd aims is to assess the effects of agroecological practices on soil chemical parameters in the irrigated area of the Tiébélé plain.

Studydesign: The cropping systems used can contribute to significant changes in the physical and biochemical properties of the soil. This study combined data collection on a developed plain and laboratory analyses.

Place an duration: The data was collected from producers' plots in the dry season (months of March-April) of the year 2022.

Methodology: A sample of 24 farms was monitored during the cropping season 2021-2022, based on the existing practices: crop rotation on upland areas; vegetable growing - irrigated rice rotation; potato - irrigated rice rotation; irrigated rice - fallow rotation; short fallow; long fallow. In each plot, soil samples were taken from a depth of 0-20 cm for laboratory analysis.

results: The results show that the sweet potato - irrigated rice rotation leads to an increase in total carbon of 22.5% and 48.5% compared to the fallow - irrigated rice and vegetable - irrigated rice systems, respectively. This practice resulted in a 12.5% increase in total nitrogen compared to the irrigated rice - vegetable rotation. Compared to the irrigated rice - sweet potato rotation, the irrigated rice - vegetable rotation resulted in a 16% increase in pH. The vegetable - irrigated rice system resulted in a 269.05% increase in available phosphorus compared to the fallow - irrigated rice system. Compared to the sweet potato - irrigated rice rotation, the vegetable - irrigated rice rotation resulted in a 17.63% increase in cation exchange capacity and a 24.7% increase in the sum of exchangeable bases.

Conclusion:The adoption of agroecological practices based on crop rotation improves soil fertility in irrigated rice production.

Key words : *Fertility, soil, rotation, rice, agroecology.*

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1. INTRODUCTION

In Burkina Faso, rice is the fourth most widely grown cereal crop, both in terms of area and in terms of production. Rice is grown in three ecologies (irrigated, lowland and rainfed) in Burkina Faso [1]. There is a abundant literature on cereal fertilization and the value of crop rotation in Burkina Faso [2]. Rice is a cereal grown as a staple by farmers in small inland valleys or as a cash crop in many irrigated areas. As a result, cropping systems are increasingly intensified and, where possible, rice is grown twice a year (during the rainy season and the hot and dry seasons). Long-term intensive rice cultivation with periodic flooding can affect the dynamics of soil organic carbon (SOC), pH, CEC and nutrient use efficiency [3].work by Haefele *et al.* (2004) [4] showed a non-significant decrease in SOC in irrigated rice systems. The work of[5] concluded that double cropping of irrigated rice does not reduce COS. Other studies[6] have shown that tillage practices affect soil physical and chemical properties and crop productivity in the wheat-mung bean - rice cropping system under subtropical climatic conditions in Bangladesh. Therefore, to maintain soil quality, studies [7] recommend the adoption of a cropping system with at least one upland crop in rotation with irrigated rice. The introduction of crop rotation therefore seems to be an alternative to improve soil fertility performance. Research [8] has shown that the rice - wheat cropping system can be profitably intensified and diversified with rice - potato or rice - cabbage - fodder cowpea. In West Africa, many studies have investigated the effect of organic and organo-mineral fertilization on the agro-morphological parameters of sweet potato[9]. However, research on the effect of soil fertility is rare. In other geographical areas where crop rotation is practiced, the fundamental research question is whether intensive rice production integrated with vegetable growing in irrigated perimeters is sustainable in the long term in terms of soil fertility in Burkina Faso.

The present study was initiated to answer this question. The general objective is to assess the effects of agroecological practices on soil chemical parameters in the irrigated perimeter of the Tiébélé hydro-agricultural development in the South Sudanian zone of Burkina Faso.

2. MATERIALS AND METHODS

2.1. Study site

The study was conducted in the rice-growing plain of Tiébélé, 200 km south of Ouagadougou, in the Nahouri province of Burkina Faso. The area has a South Sudanian climate. It is characterized by an alternating rainy season from May to October and a dry season from November to April. Rainfall averages 933.5 mm and is generally unevenly distributed in time and space. The average annual temperature in Tiébélé is 28.1°C. The geographical coordinates of Tiebele are 11°10' north latitude and 0°57' west longitude, with an altitude of 268 m.

2.2. Data collection methods

*Selection of farmers :*The units of observation for the study were rice and vegetable farmers in general, and specifically those who had used soil fertility management practices (crop rotation and monoculture) on at least one plot during the 2021-2022 season. After a summary census of all vegetable growers, a representative sample of vegetable farms was created. Twenty-four (24) farms

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were selected. Soil samples were collected from each plot to form composite samples. At each research site, vegetable growers were selected on a simple random basis.

*Selection of soil fertility management practices :*The selected soil fertility management practices are shown in Table 1.

Table 1. List of selectedtreatments

Treatments	**Description**
HT	upland (crops grown: potato, pepper and maize)
MR	vegetable – irrigatedrice
PR	potato – irrigatedrice
JR	fallow – irrigatedrice
J5	short fallow (duration of fallow ≤ 5 years)
J6	long fallow (fallow duration ≥ 6 years)

2.3. Soil sampling and laboratory analysis

Soil chemical parameter data were collected. Soil samples were taken from the soil fertility management plots at a depth of 0-20 cm. Measurements were made for pH-water, organic carbon, total nitrogen, total phosphorus, total potassium, assimilable phosphorus, available potassium, cation exchange capacity (CEC) and sum of exchangeable bases (SEB).

These analyses were carried out at the Soil-Water-Plant Laboratory of the INERA (Environmental and Agricultural ReserchInsititute) in Burkina using the following methods: pH-water was measured using an electronic pH meter in a suspension of the sample in distilled water. Total carbon was determined by the [10]. Total nitrogen was determined after mineralization using the Kjeldahl method [11]. After mineralization, the aqueous solution obtained was diluted 10 times with distilled water and then passed through a flame photometer to determine total potassium. Total phosphorus was determined by the method of [12].

2.4. analysis

The collected data were entered using Microsoft Office Excel 2016 and then subjected to an analysis of variance (ANOVA) using XLSTAT software version 2018.6.53463. The means were separated using the Fisher test at the 5% threshold. In addition, relationships between soil chemical parameters and agroecological practices were established. Nine (9) soil parameters were considered. They are introduced in the PCA as active or explanatory variables. They are: pH = pH of water, C.org = total soil organic carbon (in %), N.tot = total soil nitrogen (in %), P.tot = total soil phosphorus (in mg.kg^{-1} soil), Pass = assimilable phosphorus (in mg. kg^{-1} soil), K_tot = total potassium (in mg.kg^{-1} soil), K_disp = available potassium (in mg.kg^{-1} soil), SEB = sum of exchangeable bases (in c.mol.kg^{-1} soil), CEC = cation exchange capacity (in c.mol.kg-1 soil). Six (6) treatment parameters are considered and included in the PCA as additional variables: HT: upland (crops grown: potato, pepper and corn); MR:

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vegetable - rice=1,2 and 3; PR: potato - rice=1,2 and 3; JR: fallow - cice=1,2 and 3; J5: short fallow (fallow duration ≤ 5 years); J6: long fallow (fallow duration ≥ 6 years).

3. RESULTS

3.1. Relationships between soil chemical parameters and agroecological practices

Fig. 1 shows the relationship between soil chemical parameters and agroecological practices. Examination of the circle of correlations between variables (soil chemical parameters) and individuals (treatments) in the main plane 1-2 (Fig. 1) reveals the relationships between the different chemical parameters and agroecological practices. Axis 1 is characterized by K_tot, P_tot, N_tot, CEC and C_org. It can be considered as the "organic matter" axis. Axis 2 is characterized by K-disposable and SBE. It can be considered as the "absorbent complex" axis. Axes 1 and 2 can be considered as axes expressing soil fertility. Some relationships are close. This is the case between treatments "J6", "J5", "PR" which are related to total nitrogen, organic carbon, total phosphorus, total potassium, CEC and SEB. Treatments "HT" and "MR" are strongly related and weakly related to treatment "JR" and are quite close to the parameters pH, K_availaible, P_bray and C:N. There is a close relationship between these treatments and the assimilable phosphorus.

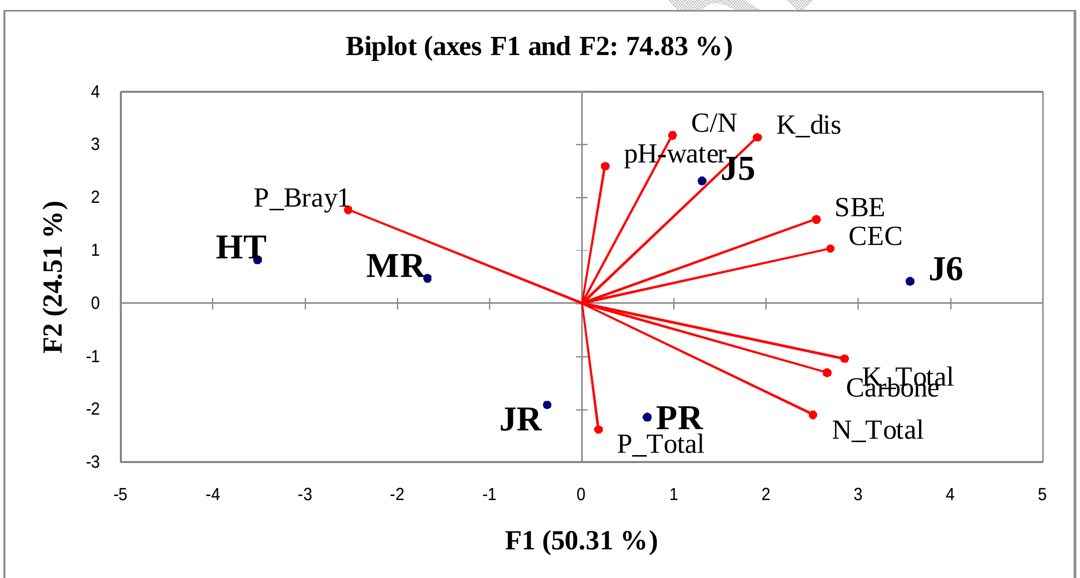

Fig. 1. Relationships between soil chemical parameters and agroecological practices

HT : upland (crops grown : potato, pepper and corn) ; MR: vegetable – rice=1,2 and 3 ; PR : potato - rice=1,2 and 3 ; JR : fallow - rice =1,2 and 3 ; J5 : short fallow (duration of fallow ≤ 5 years)= 1,2 and 3 ; J6 : long fallow (fallow duration ≥ 6 years)= 1,2 and 3

3.2. Effect of agroecological practices on C org, N_Total, P_Total and K_Total

Table 2 shows the effects of agroecological farming practices on soil chemical fertility. Carbon content follows the same trends as total nitrogen, P_total and K_total content. The results show a highly significant difference between systems for soil carbon. There was also a significant difference between systems for nitrogen, but for P_total and K_total there were no differences between cropping systems. The best carbon contents were obtained on plots under long-term fallow and sweet potato-rice rotation. Compared to the fallow-rice (C=0.8%) and vegetable-rice systems (C=0.68%), the sweet potato – rice rotation has a carbon rate of 0.98%, which is equivalent to increases in carbon from 22.5% to 48.5% respectively.Long fallow had the highest nitrogen levels. This practice is followed by sweet potato-rice rotation and fallow-rice rotation.

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Table 2. Effect of agroecological cropping practices on chemical fertility

Treatments	C (%)	N_total (%)	P_Total (mg/kg)	K_Total (mg/kg)
J6	1.38 ± 0.30^{a}	0.11 ± 0.35^{a}	174.18±522.55	1810.53 ± 426.59^{a}
J5	0.66 ± 0.07^{cd}	0.06 ± 0.18^{c}	186.96±560.87	1174.39 ± 933.58^{ab}
JR	0.80 ± 0.23^{bc}	0.08 ± 0.35^{bc}	191.71±575.15	1027.59 ± 661.95^{ab}
PR	0.98 ± 0.13^{b}	0.09 ± 0.29^{ab}	243.66±658.12	1516.93 ± 882.15^{b}
MR	0.68 ± 0.09^{bcd}	0.06 ± 0.20^{c}	219.37±658.12	521.95 ± 101.86^{b}
HT	0.40 ± 0.01^{d}	0.03 ± 0.11^{d}	163.32±489.98	456.71 ± 149.49^{b}
Probability	***0.0001***	***0.001***	***0.44***	***0.117***

***HT** : upland (crops grown : Potato, pepper and corn) ; **MR**: vegetable –rice=1,2 and 3 ; **PR** : potato - rice=1,2 and 3 ; **JR** : fallow – rice =1,2 and 3 ; **J5** : short fallow (duration of fallow ≤ 5 years); **J6** : long fallow (duration of fallow ≥ 6 years).*

3.3. Effect of agro-ecological practices on pH, CEC, SBE, K-disp and C/N parameters

The effects of agroecological practices on chemical fertility are shown in Table 3. The results show a highly significant difference between systems for pH and a significant difference for CEC, with pH ranging from 5 to 8. The use of fallow land leads to alkalinity, while the rice - vegetable system has a neutral soil. The other systems have soil acidity below neutral. Compared to the sweet potato - rice system, the vegetable - rice rotation results in an increase in pH of one unit, or 16%. Long-term fallow had the highest available potassium. The vegetable - rice rotation also improved available potassium with an increase of 44.35%. Compared to the sweet potato - rice rotation, the vegetable - rice rotation increased CEC by 17.63% and SEB by 24.7%. Compared to the short 6-year fallow, the sweet potato - rice and vegetable - rice rotations resulted in a reduction of 45.55% and 33.71%, respectively.

Table 3. Effect of agroecological practices on chemical fertility

Treatments	pH_water	SEB (c.molckg^{-1})	CEC (c.molckg^{-1})	K_dis	C :N
J6	8.78 ± 0.05^{a}	10.22 ± 1.98^{a}	10.44 ± 1.7^{a}	65.77 ± 1.44^{ab}	11.76±0.88
J5	5.09 ± 0.14^{d}	8.27 ± 1.44^{ab}	9.36 ± 1.52^{ab}	57.22 ± 1.98^{b}	11.03±0.73
JR	5.21 ± 0.55^{cd}	5.52 ± 3^{bc}	6.63 ± 3.45^{bc}	31.89 ± 1.20^{bc}	10.15±1.57
PR	6.05 ± 0.27^{c}	4.82 ± 1.20^{cd}	5.67 ± 1.69^{cd}	41.76 ± 10.82^{bc}	10.80±2.46
MR	7.01 ± 0.52^{b}	5.55 ± 0.80^{bc}	6.92 ± 0.70^{bc}	28.93 ± 16.34^{c}	9.29±1.54
HT	5.30 ± 0.83^{cd}	2.13 ± 0.58^{d}	2.64 ± 0.6^{d}	39.46 ± 1.7^{bc}	10.93±0.51
Probability	***< 0.0001***	***0.001***	***0.004***	***0.017***	***0.44***

***HT** : upland (crops grown : potato, pepper and corn) ; **MR**: vegetable growing –rice=1,2 and 3 ; **PR** : potato - rice=1,2 and 3 ; **JR** : rice - fallow=1,2 and 3 ; **J5** : short fallow (duration of fallow ≤ 5 years) ; **J6** : long fallow (duration of fallow ≥ 6 years).*

3.4. Distribution of assimilable phosphorus depending on agroecological practices

Fig. 2 shows the assimilable phosphorus depending on agroecological practices. It can be seen that the vegetable - rice rotation (MR) improves the assimilable phosphorus. This rotation system is statistically equivalent to the upland cropping system (HT). With this system, there is a 269.05%

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increase in P_bray compared to the fallow - rice system. The fallow - rice rotation systems produced statistically the same amount of assimilable phosphorus.

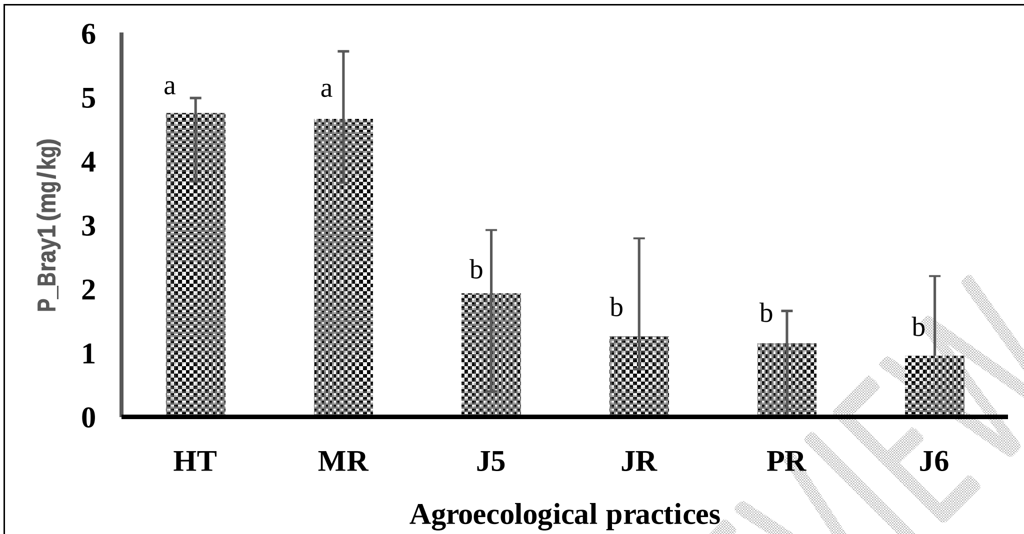

Fig. 2. Assimilable phosphorus depending on agroecological practices.

***HT** : upland (crops grown : potato, pepper and corn) ; **MR**: vegetable growing –rice=1,2 and 3 ; **PR** : potato - rice=1,2 and 3 ; **JR** : rice - falow=1,2 and 3 ; **J5** : short fallow (duration of fallow ≤ 5 years) ; **J6** : long fallow (duration of fallow ≥ 6 years).*

4. DISCUSSION

Agro-ecological practices affect the fertility of irrigated perimeter soils in Tiébélé in different ways. Long fallow, sweet potato - rice rotation and vegetable - rice rotation increase soil carbon, cation exchange capacity (CEC) and sum of exchangeable bases (SEB). In the soil, CEC can be seen as a reservoir capable of storing fertilizing elements. A soil rich in clay and humus is characteristic of a soil with a high CEC. The use of agroecological practices such as sweet potato rice - rotation and vegetable - rice rotation has probably improved soil fertility. This explains the close relationship between CEC, agroecological practices and sweet potato - rice rotation. The decrease in CEC in the rice - sweet potato and rice - vegetable rotations compared to the rice - fallow rotations reflects a reduction in the capacity to retain nutrients, leading to acidification of these soils. However, the supply of organic matter from harvest residues (leaves, roots, stems, etc.) from sweet potato and vegetable crops helps to recycle this organic matter and prevent the loss of exchangeable cations[13]. This situation probably explains the close relationship between total soil carbon, short and long fallow practices. The recycling of nutrients after a few years of fallow makes the soil less sensitive to soil degradation, while preventing the loss of soil fertility in irrigated rice cultivation. Our results confirm those of [5]. This situation of increased soil carbon under fallow or sweet potato - rice rotation could be explained by the recycling of crop residues and root stumps under irrigated conditions. According to several authors, residue decomposition is much slower in flooded soils than in aerated soils [14]. The recycling of sweet potato harvest residues and roots from subsequent crops is a continuous source of carbon that has certainly incorporated the organic matter fraction of the hydromorphic soils of the Tiébélé plain. [15] found in the semi-arid zone of Morocco that a continuous fallow – wheat - barley rotation improved soil structural facets and allowed organic matter accumulation compared to

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rotations including fallow. The results of[16] show that cropping systems with legumes and green manure improve the microbial environment in the soil. This contributes to an increased diversity of soil flora and fauna, leading to a greater stability of the overall soil life.

The C :N ratio is lowest in the vegetable - rice and sweet potato - rice rotation plots, reflecting strong carbon mineralization. This situation leads to an increase in assimilable phosphorus in the vegetable - rice plots. The assimilable phosphorus (4.65±1.53 mg/kg) recorded in the rice - vegetable rotation plots is higher than the assimilable phosphorus value (4.43 mg/kg) observed by[17] on West African rice soils. However, the total phosphorus levels in the vegetable - rice and sweet potato - rice rotation plots at Tiébélé in the South Sudanian zone of Burkina Faso are average and lower than the phosphorus levels observed in most irrigated rice soils in West Africa. This confirms the conclusions of[17] that phosphorus is generally deficient in West African rice soils. The improvement in total nitrogen, total phosphorus and total potassium in the sweet potato - rice rotation plots compared to the upland soil of the Tiébélé zone may be due to the lower C:N ratio in the sweet potato - rice plots. This situation also explains the close relationship between sweet potato - rice rotation and total nitrogen, total phosphorus and total potassium on the one hand, and between vegetables - rice and assimilable phosphorus on the other hand. The use of mineral fertilizers in sweet potato and rice crops promotes the mineralization of soil carbon, as indicated by the C:N ratio between 9 and 10, which indicates a good decomposition of organic matter. This shows that by using the agroecological practice of sweet potato - rice rotation, it is possible to improve the total nitrogen, total phosphorus and total potassium content of the soil. The total nitrogen values were quite high in the plots of the vegetable - rice and sweet potato-rice rotations. The increase in total nitrogen levels in the sweet potato - rice and vegetable - rice rotation plots could be attributed to microbial activity, which could have led to increased decomposition of organic forms of N from the fraction of organic matter incorporated during the recycling of sweet potato and other vegetable crop residues, resulting in increased release of total nitrogen.

According to several sources, most of the irrigated valleys in the Sahelian-Sudanian savannah have significant potassium reserves in the soil [4]. This situation probably explains the high total potassium content of the hydromorphic soils of the Tiébélé plain. The best available potassium levels are found in long fallow and sweet potato - rice rotation.

The soil acidification observed in sweet potato - rice rotation plots is probably explained by the physiological processes of P absorption. This situation leads to the mobilization of phosphorus through the release of elements such as organic acid anions or phosphatases that mineralize organic P [18]. On the other hand, alkalinity in rice - cropping rotation plots is certainly related to the accumulation of weak bases after heavy evaporation. These weak bases are certainly introduced by irrigation water. The work of [19] has shown that the change in the chemical composition of this water due to evaporation is at the origin of their accumulation. Covering the soil with sweet potato plants certainly prevents this evaporation, which probably explains the difference in pH between these two types of agroecological practices.

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5. CONCLUSION

At the end of this study, it was found that agroecological practices had positive effects on soil fertility. Systems based on vegetable growing (tomato, onion) made phosphorus available and improved CEC and SEB. These results confirm the need to extend these agroecological practices to rice cultivation systems, given the diversity of their effects on soil fertility. The agroecological practice of sweet potato - rice rotation, with its high carbon and nitrogen content, can contribute to carbon and nitrogen sequestration in lowland soils, with a view to preserving the environment.

In a context of insufficient developed areas for rice cultivation, agroecological practices such as sweet potato - orange pulp rice and vegetable - rice could be options for improving irrigated rice production in the South Sudanian zone of Burkina Faso.

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