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Chemical Fertility of a Ferralitic Soil in a Cropping System Based on Cereals (Fonio and Sorghum) and Legumes (Soya and Mung Bean) on an Experimental Station in Burkina Faso

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Abstract

In Burkina Faso, the low nutrient content of the country's soils has a direct impact on crop yields. The objective of this study is to evaluate the effects of applying organic matter (compost, poultry manure.), and mineral fertilizer Nitrogen-Phosphorus-Potassium (N:14% P:23% K:14%), urea (43% nitrogen) and Burkina Phosphate (BP) on soil fertility in a legume/cereal cropping system. The study was conducted at the INERA Farako-Bâ experimental station from 2018 to 2021. The experimental design was a 4x4 factorial, corresponding to four rotations and four manures, respectively, used as the first and second factors. A split-plot design with three replications was employed. The results obtained indicated that, in comparison to the initial soil, there was an increase of 33% in soil organic carbon and 36% in total nitrogen in the plots where soya and fonio were cultivated in rotation. In comparison to the plots with fonio-sorghum rotation, the plots with mung bean-sorghum and soya-fonio rotations demonstrated increase in assimilable phosphorus of 17% and 15%, respectively. Furthermore, the fertilizer combining compost and poultry manure resulted in a 300% increase in assimilable phosphorus and 28% increase in available potassium compared to the soil without fertilizer inputs and uncultivated for years. Additionally, the fertilizers of compost combined with poultry manure and compost combined with poultry manure and BP resulted in increases in assimilable phosphorus of 131.78% and 116%, respectively. The positive effects obtained on the chemical parameters (phosphorus, potassium and carbon) provide the potential for sustainable soil fertilization in cropping systems, while also valorizing local organic fertilizer.

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Introduction

Agriculture and cattle breeding represent the primary sources of livelihood for the populations of the West African Sahel. The challenges associated with these farming systems include low soil fertility, low soil organic carbon and clay content, limited resources for investment in fertilizers, erosion, soil acidity, export of crop residues for livestock and household needs, erratic rainfall and frequent droughts.[1] In Burkina Faso, as in most West African countries, several fertility management methods have been developed including the introduction of legumes into cropping systems.[2,3,4] It is well established that nitrogen-fixing legumes can enhance soil fertility in cropping systems, thereby facilitating the supply of mineral nitrogen by legumes.[5] Studies have demonstrated that crop rotation, as a nature-based solution, affects the decomposition and transformation of soil organic carbon due to the contribution of root residues and the release of root exudates.[6,7] This process improves soil organic carbon pools and optimizes the structure and diversity of the soil microbial community. In north-eastern Benin same research, showed that intercropping, crop rotation, crop residue management, the use of inoculum and non-removal of soya plants are the practices most perceived by soya farmers as contributing to sustainable land management.[8]

For sustainable land use, the application of organic or organo-mineral fertilizers represents a strategic option. Indeed, several studies have shown that the use of organo-mineral fertilizers contributes to significant improvements in crop yields, chemical and biological soil parameters.[9,10] In addition, according to a study, using organic inputs such as manure, compost, or municipal waste increases soil carbon.[11] Similarly,[12] have shown that the combination of organic and mineral fertilizers in the rotation of millet with legumes allows a significant improvement in cereal yields, better mobilization of soil nitrogen and efficient use of nitrogen fertilizer.

Furthermore, the work[13] evaluated the effects of adding three doses of manure to five levels of NPK applied in micro-doses on fonio biomass and soil chemical properties. The results of these experiments indicate that the combined use of legumes and poultry manure to enhance soil fertility under the condition of fonio and sorghum-based crop rotation is worthy of particular attention in Burkina Faso. This study participates in this dynamic process and it was initiated to answer the following research questions: What are the combined effects of legumes (mung bean and soya) and poultry manure on soil chemical properties? In particular, what are the effects of cereal/legume rotations on soil fertility? What are the effects of organo-mineral fertilizers on soil chemical fertility under cereal-based cropping systems (fonio and sorghum)? Does the interaction between cereal/legume rotation and organo-mineral fertilizers influence soil chemical parameters?

The research hypothesis is that cereal/legume rotation improves soil pH, organic carbon and total nitrogen.

The overall aim of this work is to increase agricultural production by intensifying cropping system practices through the use of manures and rotations with nitrogen-fixing legumes.

Materials and Methods

Study Site

The study was conducted at the Farako-Bâ experimental station of the *Institute for Environment and Agricultural Research* (INERA) situated approximately ten kilometers south of Bobo-Dioulasso, on the Bobo Dioulasso-Banfora road. The site is situated at an altitude of 505 meters, at longitude 04°20' West and latitude 1° North.

The *climate* of the area is of the South Sudanian type, with two alternating seasons: A rainy season spanning 5 to 6 months (May-October), with rainfall varying between 900 and 1000 mm, and a dry season (November to April). The average temperature is 25°C. The majority of precipitation occurs between June and September, with 50 to 70 days of rain.[13]

The *soils* of Farako-Bâ are predominantly leached tropical ferruginous.

The vegetation is characterized by grassy to wooded savannah, which is relatively dense in certain locations. The species present are: *Gmelina arborea Roxb*., *Parkia biglobosa* Benth, *Adansonia digitata* L., *Mangifera indica* L., *Vitellaria paradoxa* Gaerth, *Khaya senegalensis* (Desr.) A.Juss. There are also grassy species such as: *Andropogon gayanus* Kunth, *Brachariasp*, *Cynodondactylon* (L.) Persda, *Digita riahorizontalis* Wild.[14]

Experimental Setup

The work was carried out using a split-plot design with 4 main treatments corresponding to the different rotations and 4 secondary treatments (manure level) repeated three (3) times, resulting in a total of 16 elementary plots per block (48 plots in all for the 3 replications). The treatments are shown in the table.

The main plots are 89.25 m^2, spaced one meter apart. The subplots, which received the treatment, are 20 m^2 each, spaced 0.5 m apart. The total area of the experiment is 1237.5 m^2.

Rotations of four (4) species (fonio, soya, mung bean and sorghum) were conducted over a period of 2 years.

R1: fonio/sorghum; R2: Soya/Fonio; R3: Sorghum/ Mung bean; R4: Mung bean/Fonio.

The main treatments (Table 1) were randomized in each block. Secondary treatments (Table 2) were also randomized in each subplot.

Table 1: List of main treatments (rotations)

Rotations	Years			
	2018	**2019**	**2020**	**2021**
R1	Fonio	Sorghum	Fonio	Sorghum
R2	Soya	Fonio	Soya	Fonio
R3	Sorghum	Mung bean	Sorghum	Mung bean
R4	Mung bean	Fonio	Mung bean	Fonio

Table 2: List of secondary treatments

Treatments	Description
T0	Control(No fertilizer)
T1	Compost + NPK (150 kg ha^{-1}) + Vulgarized urea (100 kg ha^{-1})
T2	Compost + Poultry manure (7.5 t ha^{-1})
T3	Compost + Poultry manure (7.5 t ha^{-1}) + BP (500 kg ha^{-1})

BP : *Burkina Phosphate*

The present study participates in the effort to improve soil fertility in a sustainable manner through the combined effect of cropping systems and local organic matter. The rational for this approach is that intensifying soil productivity can be achieved through the use of fertilizers and rotations with nitrogen-fixing legumes.[15] This is exemplified by rotations between cereals (R2=Soya/Fonio; R3=Sorgho/Mung bean and R4=Mung bean/Sorgho). Specifically, the objective of the study is to achieve optimal, sustainable soil fertility management in cropping systems based on cereals (fonio and sorghum) and legumes. Regarding the cereal/cereal rotation (R1=Fonio/Sorgho), its introduction was motivated by the observation that producers engage in this rotation for various reasons (lack of legumes).

Given the high cost of chemical fertilizers, this study aims to evaluate the performance of local fertilizers and soil improvers (poultry manure, compost and Burkina phosphate), which are readily available to farmers at lower cost.

In addition, the study seeks to show the influence of crop rotation on soil chemical parameters in a cropping system.

Fertilizers used and Soil Type

Poultry manure (7.5 t ha^{-1}) was applied in two phases, with 2/3 or 5 t ha^{-1} being applied before planting and the remaining 1/3 (2.5 t ha-1) applied 45 days later.

NPK mineral fertiliser with the formulation 14-23-14 (150 kg ha^{-1}) and urea at a dose of 46% N (100 kg ha^{-1}) were used. The chemical composition of Burkina phosphate (500 kg ha-1) is : P2O = 25.38%; CaO = 34.45%; MgO = 0.27%; Ferral = 6.5%; $Si0_2$= 26.24%; Fluor = 2.5%; K_20 = 0.25%.

The complex fertilizer NPK, poultry manure and Burkina Phosphate were applied 5 days before planting. Urea was used only on sorghum and fonio as a second application (40 days after planting) to match the nitrogen doses recommended for these crops. The mineral fertilizers NPK, formulated 14-23-14 (150 kg ha^{-1}) and urea at 46% N (100 kg ha-1) were used. The chemical composition of Burkina Phosphate (500 kg ha^{-1}) is: P2O= 25.38%; CaO = 34.45%; MgO = 0.27%; Ferral = 6.5%; Si02= 26.24%; Fluor = 2.5%; K20= 0.25%.

With regard to the chemical characteristics of the soils prior to the implementation of the agronomic trial, they were found to be highly acidic (pH = 5.5) and significantly deficient in organic matter and nitrogen. The soils of the experimental site are of the tropical ferruginous type with a sandy-loamy texture and clay content of 17.65%, silt content of (19.6%) and sand content of (62.75%).

The characteristics of the soil, the fertilizers and the dosages of nutrients are presented in Tables 3, 4 and 5, respectively.

Table 3: Chemical characteristics of the soil before the trial was set up

Parameters		Soil
pH water		5.43
Organic matter (%)		0.95
N%		0.05
C:N		10.36
Total P	mg.kg^{-1}	95.6
Assimilable P		2.54
Total K		937.81
Available K		47.8
CEC	Cmol.kg^{-1}	1.72
SEB		1.01
Saturation rate (%)		59.03

Table 4: Chemical characteristics of the compost and poultry manure used

Nature	pH_H_2O	C (%)	Total N (%)	C:N	Total P (mg kg^{-1})	Total K (mg kg^{-1})
Poultrymanure	7.04	32.05	2.128	15	9688.53	14684.65
Compost	7.5	15.06	0.887	16	6543.86	7738.80
Initial soil	5.5	0.3	0.025	2.35	54.3	5.5

Table 5: Nutrient doses provided by mineral fertilizers, depending on crops

Crop	Nutrients (kg ha^{-1})				
	N	P	K	S	Mg
Sorghum	67.01	252.3	15.08	265	2.7
Fonio	67.01	252.3	15.08	265	2.7
Soya	14.01	241	1.08	265	2.7
Mung Bean	14.01	241	1.08	265	2.7

Cultivation

The rotation consists of a legume crop and a cereal crop grown consecutively for two years without interruption. Cereal and legume crops are then alternated for an effective rotation.

Fonio was planted in continuous rows with a spacing of 0.80 m between rows. Sorghum was also planted with a spacing of 0.80 m between rows and 0.40 m between clusters. Soya and mung beans were planted with a spacing of 0.4 m between rows and 0.4 m between clusters.

Statistical Analysis

All the data collected were entered into EXCEL version 2018. The measured parameters were subjected to analysis of variance (ANOVA) to compare the means of soil chemical parameters (i) under the four rotations (R1, R2, R3 and R4) and (ii) under the four manures. In addition, the combined effect of rotations and fertilizers on soil chemical parameters was measured. The Student-Newman-Keuls (SNK) test was performed at the 5% threshold using XLSTAT 2016.02.27444 software.

Multivariate statistical analyses were carried out to detect any possible or close relationships between soil chemical parameters, crop rotations and fertilizers applied. The multidimensional statistical method used was Principal Component Analysis (PCA) with XLSTAT 2016.02.27444 software on centred-reduced data.

Results

Interaction between Rotation System and Manure

The results presented in Table 5 show that the interactions between rotation and fertilization are highly significant for the assimilable phosphorus and total nitrogen treatments. Nevertheless, no significant differences were observed between rotation and manure interactions for pH, carbon and available potassium. The interaction between the sorghum/mung bean cropping system and poultry manure exhibited the highest levels of total nitrogen and available phosphorus, with values of 0.35% and 28.868 mg kg^{-1} respectively.

Effect of Rotations on Soil Chemical Properties

The effects of rotations on soil chemical properties are presented in Table 5. The soya/fonio rotation exhibited the highest total nitrogen content, enhanced total soil carbon and facilitated phosphorus and potassium availability. The utilization of this rotation led to a 454% increase in available phosphorus and an 80% increase in available potassium in comparison to the initial soil. In comparison to the fonio/sorghum rotation, the mung bean/sorghum and soya/fonio rotations resulted in increases in total phosphorus of 17% and 15%, respectively. However, the use of these cropping systems resulted in a 4.26% reduction in soil organic carbon compared to the initial soil. In comparison to the Sorghum/Fonio system, the Soya/Fonio rotation resulted in a 1.52% increase in organic carbon.

Effect of Fertilization on Soil Chemical Properties

Table 6 presents the effect of manure on soil chemical parameters. The statistical analysis revealed no significant differences between treatments with regard to total carbon and total nitrogen. The application of the manures increased soil pH by more than 4% compared to the initial soil. In comparison to the initial soil pH, the Compost+PM+BP and Compost+PM treatments resulted in soil pH increases of 0.3 and 0.28 pH units respectively. In comparison to the control, the Compost+PM treatment increased assimilable phosphorus and available potassium by 300% and 28%, respectively. In comparison to the Compost+NPK+Urea treatment, Compost+PM and Compost+PM+BP resulted in increases in assimilable phosphorus of 131.78% and 116%, respectively.

Relationship between Soil-Rotation Parameters and Fertilizers

The examination of the correlation circle between variables (soil chemical parameters) and individuals (treatments) in the main plane 1-2 (Figure 1) reveals relationships between the different soil chemical parameters and cropping system and fertilizer combinations. Some relationships are close. This is the case for treatments R2T3 and R1T2, which are related to pH, organic carbon and total nitrogen. The R1T3 and R2T2 treatments are quite similar and are related to the assimilable phosphorus and available potassium parameters. Treatments R4T2, R4T1 and R4T3 are strongly related and weakly related to treatments R1T3 and R2T2. No parameters are related to treatments R4T0, R3T0, R3T1 and R3T3. These treatments are strongly opposed to R4T2, R4T1, R1T3 and R2T2.

Table 6: Effects of cropping systems on soil, after three years of cultivation (2019-2021).

Treatments		pH_water	C(%)	Total N (%)	Ass_P (mg kg-1)	Aiv_K (mg kg-1)
	Soya/Fonio	5.871±0.13[a]	0.399[a]	0.034±0.01[a]	13.370±13[a]	83.767±21[a]
Rotation	Sorghum/Fonio	5.921±0.27[a]	0.393[a]	0.034±0.01[ab]	13.843±13[a]	81.149±18[b]
	Mung-bean/Fonio	5.609±0.22[b]	0.379[ab]	0.033±0.01[ab]	11.562±10[b]	78.862±18[a]
	Mung-Bean/ Sorghum	5.611±0.14[b]	0.358[ab]	0.031±0.01[ab]	13.360±12[a]	78.533±18[a]
Pr > F		**	**	**	****	***
Manures	Cpost +PM+BP	5.808±0.46	0.395±0.1	0.034±0.008	18.684±14[a]	84.658±14[ab]
	Cpost +PM	5.799±0.42	0.391±0.06	0.034±0.005	20.054±12[a]	88.331±18[a]
	Cpost+NPK+ Urea	5.710±0.43	0.379±0.07	0.033±0.007	8.652±8[b]	80.588±15[ab]
	Positive control	5.694±0.42	0.364±0.07	0.032±0.006	4.746±2[b]	68.733±20[bc]
Pr > F		*	*	*	****	***
Rotation*Manure		*	*	***	***	*

PM : poultry manure, BP : Burkina Phosphate, Total N: Total nitrogen ; Ass_P: assimilable phosphorus ; Avai_ K: available potassium. Cpost : Compost
Treatments with the same letter in the same column are not significantly different.
Not significant (*); ** significant (**); highly significant (***)

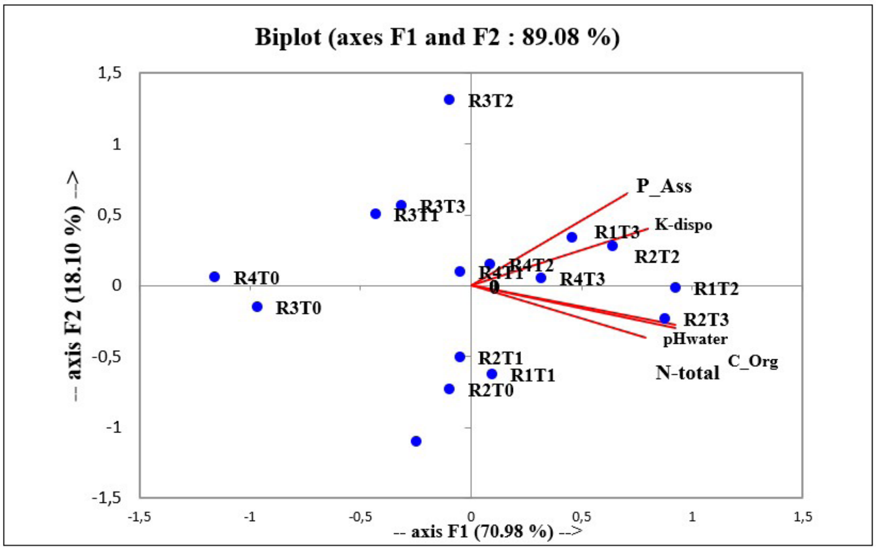

Fig. 1: Circle of correlations between parameters - soils - cropping systems interaction and fertilizers in the main plane.

C: Carbon, N-**Total:** Total nitrogen ;**P_ass :**assimilableP ; **K-dispo :** Potassium available.
R1: Sorghum/Fonio; R2: Soya/Fonio; R3: Mung bean/Sorghum; R4: Mung bean/Fonio.T0: Control, T1: Compost+NPK+Urea, T3: Compost+Poultry Manure, T4: Compost+Poultry Manure+Burkina Phosphate.

Discussion

Effect of Rotations on Soil Chemical Properties

The results of the study showed that, in general, legume rotation (mung bean and soya) improved soil fertility to a lesser extent with respect to the parameters studied. These two legumes have the potential to restore soil fertility. Indeed, the *Fabaceae* and *Mimosaceae* families of these legumes are known for their high production of plant biomass, which, when buried in the soil, produces organic matter. Following a three-year cultivation period, the soil in the Soya/Fonio system exhibited an organic carbon content of over 1.52% higher than that observed in the Fonio-Sorghum system. Thus, the organic matter provided by the plant biomass plays a role in the nitrogen release mechanisms. This availability of nutrients may be due to the accelerated decomposition of the lignin contained in the litter of herbaceous legumes, due to their very low C/N ratio. According to,[16] these legumes are better able to maintain organic carbon status. The buried plant biomass (mung bean and soya) is a reservoir of a wide range of mineral elements for the subsequent crop. This could explain the effect of legumes on potassium (K) and phosphorus (P). In fact, the root exudates of these legumes are capable of solubilizing calcium and occluded phosphorus, thereby increasing the availability of assimilable phosphorus and its absorption by the main crop.[17] Organic carbon decrease following tillage is a commonly observed phenomenon. On the contrary, the results of short-term experiments show that legumes do not prevent either organic carbon or total soil nitrogen from decreasing. This could be explained by the presence of crop residues in the plots, which certainly helped to limit soil carbon decrease. The present study confirms that of,[4] who observed that the increase of vegetation cover on the Sahel soils is associated with an increase in total soil carbon, with this trend being more pronounced on sandy soils. It has been shown that agricultural activity without restitution generally leads to a decrease in organic carbon.[1] Several authors[18] have demonstrated that environmental perturbations cause the system to evolve towards a new equilibrium, resulting in a decrease in organic matter relative to the stock. The results of this study are not consistent with the aforementioned findings. The observed decrease in soil carbon is likely to depends on the type of legume and the duration of the cropping system. The decrease may also be related to the type of interaction (fertilizer and cropping system) employed. This discrepancy in results may be explained by the fact that the work of,[16] for example, did not focus on a specific soil type and diversified legume type, and only used crop residues and nitrogen fertilizers. The results show a slightly significant contribution of cropping systems to soil carbon accumulation. The presence of a cropping system effect could be explained by the short duration of the system and the use of organic resources in these cropping systems, which contribute to soil organic carbon enhancement. These results are consistent with those of,[19] who showed that over time, winter cropping increased soil organic carbon by 21% and total soil nitrogen by 7% compared to winter fallow. According to,[20] the elimination of ploughing contributes to slowing the mineralization of organic matter, resulting in the redistribution of carbon and thus increasing soil carbon stocks. This is made possible by the large amount of crop residues returned and the cover crops.

Effect of Fertilization on Soil Chemical Properties

The results on soil fertility indicated that there was an increase in the pH value of water, carbon organic and total nitrogen. The Ca content of poultry manure, compost and Burkina phosphate is probably responsible for the increase in pH in soils fertilized with compost and chicken manure.[21,22] Poultry are generally fed with dietary supplements such as limestone, mineral salts and trace elements which results in poultry manures having a high calcium bicarbonate content. Same study[23] demonstrated that poultry manure contains a higher concentration of nutrients, including basic cations (Ca, Mg and Na). The mineralization of compost and manure by micro-organisms firstly increased the amount of humus in the soil, and secondly increased the number of cations (Ca^{2+} and M^{g+}) on the CEC, thereby raising the pH from its initial state. Some authors have concluded that poultry manure is a potential alternative for correcting soil acidity for small-scale, resource-limited farmers who are unable to afford lime due to its high cost.

The application of organic fertilizers, such as poultry manure, has helped to improve total soil nitrogen. Poultry manure is recognized as the most remarkable natural fertilizer due to its high nitrogen content. According to,[24] this fertilizer contains nitrogen in two main forms: ammoniacal nitrogen, which functions similarly to a conventional mineral fertilizer, and organic nitrogen, which must be degraded by soil microorganisms in order to be mineralized.

These results confirm those of other authors,[25,26] who showed that organo-mineral fertilization with poultry manure leads to an increase in pH and improves soil nitrogen. According to other studies,[27,28] the high organic matter and magnesium content and the pH (acidic) are favorable for the solubilization of natural phosphates. The acidic nature of the soil at the site certainly favoured the solubilization of Burkina phosphate. Those authors[29,30] showed that treatments combining half doses of chemical fertilizers with poultry manure led to an increase in assimilable phosphorus due to an increase in biological activity. This may explain the solubilization of rock phosphate under the conditions of the present experiment. It should be noted that the poultry manure applied had a moderately acid pH and a high organic matter content. The agronomic efficacy of mineral fertilizers used alone has shown their positive short-term effect, but also their negative long-term effect on soil chemical degradation (lower pH and higher exchangeable Al in particular), leading to a reduction in yield.[12,25] These results demonstrate that carbon content can be maintained in a sustainable manner through the use of organic inputs. According to,[31] in tropical soils with high carbon saturation deficits, the quality and quantity of applied organic inputs influence soil carbon accumulation.

Interaction between Cropping Systems and Fertilization

Given the limited effects of organic and mineral fertilizers applied separately, it is more appropriate to combine them in order to improve soil fertility.

The results showed relationships between treatments R2T3, R1T2 which are related to pH, organic carbon and total nitrogen. This shows that Soya/Fonio rotation and Poultry Manure +BP interactions provide more carbon and improve total soil nitrogen. This leads to an increase in soil pH. The advantage of this system is that it reduces acidity and promotes nutrient mobilization by the plant.[9] Furthermore, the interactions between "R1T3" and "R2T2" result in phosphorus release and potassium availability. This shows that under Sorghum/Fonio rotation conditions with the application of compost + poultry manure and Burkina Phosphate, there is a high probability of enhancing the soil in assimilable phosphorus and available potassium. According to,[1,12] in cropping systems, legume residues enrich the soil in nitrogen. The interactions observed here between mineral fertilizers and organic matter were not statistically significant for pH, organic carbon and total nitrogen, indicating that these factors influence these parameters in a similar manner. However, there was a significant increase in pH with the poultry manure and legume combinations. An increase in pHwater of about 4.69% was obtained with the combination of residues (legumes/cereals) and poultry manure, but this increase was less significant than that obtained with the combination of Sorghum/Fonio rotation or poultry manure. The increase in soil water-holding capacity with poultry manure and legumes contributed to improved nutrient availability.[3,32,33] In fact, the joint application of mineral fertilizer and organic amendments often results in synergistic effects that increase the long-term nutrient holding capacity of the soil and, in some cases, the recovery rate of mineral fertilizer.[31] It should be noted that nitrogen is a highly mobile element with complex dynamics. The measurement of total nitrogen in the soil at a given time cannot account for the availability of this element in the soil. In line with these results and those obtained in other studies,[34,35] mineral nitrogen is a very good indicator for assessing the nitrogen contribution of legumes.

In fact, the positive correlation between carbon and pH and nitrogen indicates a certain relationship between these parameters. This shows that soil carbon levels are among the soil variables that best explain the increase in total nitrogen and the improvement in pH. This is probably a consequence of the mineralization of legume residues coupled with that of organic matter from poultry manure, since the interactions of legumes and poultry manure systems are the best suppliers of total nitrogen.

Conclusion

This study relates to the issue of the sustainable management of soil fertility through the combined use of cropping systems and poultry manure on acid pH soils with low organic matter content in Burkina

Faso. In a context where the cost of mineral fertilizers is too high, this study makes sense in the search for palliative solutions. The results of this study show that the mung bean/fonio and Soya/Fonio rotations resulted in a greater increase in assimilable phosphorus and total nitrogen. The results also show that the Compost+PM+BP and Compost+PM manures improved soil pH and increased available phosphorus and potassium in the cropping system. The present results confirm the role of legumes and poultry manure in improving soil chemical parameters. The Soya/Fonio-Compost-poultry manure rotation combination improved soil pH, organic carbon, total nitrogen, available phosphorus, and potassium.

The results obtained can be used to draw agronomic conclusions. Legume/cereal rotations should be encouraged and even promoted in the country's agricultural systems. Similarly, the use of organic fertilizers should be popularized and integrated into soil fertilization programs in order to maintain the sustainability of farms.

To consolidate these initial results, it is necessary to continue research in the long term to gain a better understanding of the effects of combinations of cropping systems and organic or organo-mineral fertilizers on mineral nitrogen. This will provide guidelines for optimizing the productivity of cereal-based cropping systems, especially fonio and sorghum.

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Conflict of Interest

The authors do not have any conflict of interest.

Data Availability Statement

The data supporting this review are derived from various sources and are comprehensively cited within the tables presented in this manuscript. All referenced tables, containing the relevant data points, are available within the main body of the text. Readers are encouraged to consult these tables for detailed information on the sources and data discussed in this review. Additional inquiries regarding specific data points can be directed to the corresponding author.

Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Author Contributions

- **Gomgnimbou Alain Peoule Kouhouyiwo, Sanon Abdramane:** literature review, methodology development.
- **Sanon Abdramane, Sanou Wilfried, Fofana Sékou :** draft manuscript preparation.
- **Sanon Abdramane:**: Table, graph and figure creation.
- **Nacro Bismarck Hassan:** Final manuscript editing, coordination among authors, and overall supervisionof the review process.

References

1. Bado B.V., Bationo A. Integrated management of soil fertility and land resources in Sub-Saharan Africa: involving local communities. *Adv. Agron.*2018; 150 : 1-33.
2. Coulibaly K., Traore M., Gomgnimbou A.P.K., Yameogo L.P., Bacye B., Nacro H.B. Effets de différents modes de gestion de la fertilité du sol sur les performances du niébé (*Vignaunguiculata*) et de l'Ambérique (*Vignaradiata*) à l'Ouest du Burkina Faso. Int. *J. Biol. Chem. Sci.*2023; 17(1): 267-280
3. Bado B.V., Whitbread A., Manzo M.L.S. Improving agricultural productivity using agroforestry systems: Performance of millet, cowpea, and ziziphus-based cropping systems in West Africa Sahel.*Agric., Ecosyst. Environ.*2021; 335 (107992):1-13.
4. Bayala J., Sanou J. H., Bazié R., Coe R., Kalinganire A., Sinclair F.L. Regenerated trees in farmers' fields increase soil carbon

across the Sahel. *Agrofor System.* 2020; 94 : 401-415.

5. Traoré A., Traoré K., Bado B.V., Traoré O., Nacro H.B., Sedogo M.P. Effet des précédents culturaux et de différents niveaux d'azote sur la productivité du riz pluvial strict sur sols ferrugineux tropicaux de la zone sud soudanienne du Burkina Faso. *Int. J. Biol. Chem. Sci.* 2015; 9 (6): 2847-2858.
6. Vukicevich E., Lowery T., Bowen P., Urbez-Torres J.R., Hart M. Cover crops to increase soil microbial diversity and mitigate decline in perennial agriculture. *A review, Agron. Sustain.* Dev. 2016; 36(48):1-14, https://doi.org/10.1007/s13593-016-0385-7.
7. Frasier I., Noellemeyer E., Figuerola E., Erijman L., Permingeat H., Quiroga A. High quality residues from cover crops favor changes in microbial community and enhance C and N sequestration. *Glob. Ecol. Conserv.*2016; 6 242-256.
8. Yarou S. B.M., Hougni A., Yessoufou D.O.A., Yabi J.A. Déterminants de La perception des producteurs de soja du Nord-Est du Benin face aux pratiques de gestion durable des terres. *Agron.Afr.*2023 ; 35 (1) : 75 - 89.
9. Sanon A., Gomgnimbou A.P.K., Zongo K.F., Coulibaly K., Fofana S., Sanon W., Nacro H.B. Propriétés chimiques d'un lixisol sous application de fumure organique et minérale en culture continue de riz pluvial strict. *IJCR.*2021;13 (08): 18527-18532. https://doi.org/10.24941/ijcr.41739.08.2021
10. Lamichhane S., Babu B.R.K., Jaishi A., Bhatta S., Gautam R., Shrestha J. Effect of integrateduse of farmyardmanure and chemicalfertilizers on soil properties and productivity of rice in Chitwan. *Agron JN.* 2022; 6(1):200-212.https://doi.org/10.3126/ajn.v6i1.47994
11. Razafimbelo T.M., Andriamananjara A., Rafolisy T., Razakamanarivo H., Masse D., Blanchart E., Falinirina M.V., Bernard L., Ravonjiarison N., Albrecht A. Impact de l'agriculture climato-intelligente sur les stocks de carbone organique du sol à Madagascar. *Cah. Agric.* 2022; 27 : 35001.https://doi.org/10.1051/cagri/2018017
12. Zeinabou H., Mahamane S., Nacro H.B., Bado B.V., Lompo F., Bationo A. Effet de la combinaison des fumures organo-minérales et de la rotation niébé-mil sur la nutrition azotée et les rendements du mil au sahel.Int. *J. Biol. Chem. Sci.*2014; 8 (4): 1620-1632.
13. Coulibaly K., Gomgnimbou A.P.K., Traoré M., Nacro B.H. Effets des associations maïs-légumineuses sur le rendement du maïs (*Zeamays*L.) et la fertilité d'un sol ferrugineux tropical à l'Ouest du Burkina Faso. AS.2017; 13 (6) : 226-235.
14. Guinko S. Caractéristiques de la végétation du Burkina Faso et leurs impacts sur les sols. Tour B7 du 16è Congrès Mondial de science du sol. Ouagadougou, Burkina Faso, 1998. 13 p
15. Bado V., Bationo A., Whitbread A., Tabo R., Manzo M.L.S.Improving the productivity of millet-based cropping systems in the West African Sahel: Experiences from a long-term experiment in Niger. *Agric., Ecosyst. Environ*.2022; 335 : 107992.
16. Tian G., Stefan H., Koutika L.S., Fusako I., Chianu N. Pueraria cover crop Fallow systems: benefits and applicability. In Sustaining soil fertility in West Africa. Warren A, Jerry L., David M. (ed). *The Soil Science Society of America and the American Society of Agronomy Minneapolis: Minnesota* (USA); 2001; pp137-155.
17. Alvey S., Bagayoko M., Newmann G., Buerkert A. Cereal/Legume rotation affect chemical properties and biological activities in two west African soils. *Plant and Soil.*2001; 231 (1) : 45-54.
18. Fauck R., Moureaux C., Thomman C. Bilan de l'évolution des sols de Séfa (Dasmance, Sénégal) après 15 années de culture continue. *Agron Trop*.1969; 24: 263- 301.
19. Zhou Q., Zhang P., Wang Z., Wang L., Wang S., Wenting Y., Yang B., Huang G. Winter crop rotation intensification to increase rice yield, soil carbon, and microbial diversity.*Heliyon.* 2023; 9-1-13.https://doi.org/10.1016/j.heliyon.2023.e12903.
20. Powlson D.S., Stirling C.M., Jat M.L., Gerard B.G., Palm C.A., Sanchez P.A. Limited potential of no-till agriculture for climate change mitigation. *Nat. Clim. Change*.2014; 4: 678-683. DOI: 10.1038/nclimate2292.
21. Sedat C., Sahriye S. Effects of chemical fertilizer and different organic manures application on soil pH, EC and organic matter

content. *J. Food, Agric. Environ.*2011 ;9 (4): 739-741.

22. Bhatt M.K., Raverkar K.P., Labanya R., Bhatt C.K.Effects of long-term balanced and imbalanced use of inorganic fertilizers and organic manure(FYM) on soil chemical properties and yield of rice under rice-wheat cropping system. *J. Pharmacogn. Phytochem*.2018;7(3):703-708
23. Kiba D.I, Zongo N.A., Youssouf O., Traoré A., Louré M., Barry H., Sanon S., Bassirou S., Gnankambary Z., Ouandaogo N., Lompo F., Sedogo M.P.Poultry farming practices affect the chemical composition of poultry manure and its C and N mineralization in a ferric acrisol. *J. Agric. Sci.*2020; 12, (3): 95-104.
24. Benouadah S., Oulbachir K., Benaichata, L., Miara, M.D., Labdelli, F., Rezzoug, W. Impact of organic amendments on soil physical properties under semi-arid climate (Tiaret, Algeria). *J. Fundam. Appl. Sci.*2020;12(3): 1386-1403. DOI: http://dx.doi.org/10.4314/jfas.v12i3.25
25. Sanon A., Gomgnimbou A.P.K., Zongo K.F., Coulibaly K., Fofana S., Sanon W., Nacro H.B. Propriétés chimiques d'un lixisol sous application de fumure organique et minérale en culture continue de riz pluvial strict. *IJCR*.2021; 13 (08): 18527-18532. https://doi.org/10.24941/ijcr.41739.08.2021
26. Bacye B., Kambire H.S., Some A.S.Effets des pratiques paysannes de fertilisation sur les caractéristiques chimiques d'un sol ferrugineux tropical lessivé en zone cotonnière à l'Ouest du Burkina Faso. *Int. J. Biol. Chem. Sci.*2019; 13 (6): 2930-2941.
27. Lompo F., Bonzi M., Bado B.V., Gnankambary Z., Ouandaogo N., Sedogo M.P., Yao-Kouame A.Effets des modes de gestion de la fertilité sur la solubilisation des phosphates naturels dans un lixisol en zone nord soudanienne du Burkina Faso. Science et technique, *Sciences naturelles et agronomie.* 2007; 29 (1 et 2) : 37-55.
28. Ranoarisoa M.P., Blanchart E., Vom Brocke K., Ramanantsoanirina A., Sester M., Plassard C., Cournac L., Trap J. Attractancy of bacterivorous nematodes to root-adhering soils differs according to rice cultivars. *Rhizosphere.* 2017; 3: 128-131.
29. Akanza P., Sanogo S. Effets des fumures sur la fertilité, les composantes de rendement et diagnostic des carences du sol sous culture de riz sur les ferralsols en Côte d'Ivoire. *J. Soc. Ouest-Afr. Chim.*2017; 43 : 1-10.
30. Biaou O.D.B., Saidou A., Bachabi F.X., Padonou G.E., Balogoun I. Effet de l'apport de différents types d'engrais organiques sur la fertilité du sol et la production de la carotte Daucus carota L. sur sol ferralitique au sud Bénin.*Int. J. Biol. Chem. Sci.* 2017; 115: 2315-2326.
31. Fujisaki K., Chevalliern T., Chapuis-Lardyn L., Albrecht A., Razafimbelo T., Masse D. Soil carbon stock changes in tropical croplands are mainly driven by carbon inputs: a synthesis. *Agrofor System.* 2018 ; 259 : 147-158.
32. Ndoli A., Baudron F., Schut A.G.T., Mukuralind A., Giller K.E. Disentangling the positive and negative effects of trees on maize performance in smallholdings of Northern Rwanda. *Field Crop Res.* 2017;213: 1-11.
33. Haque M.M., Biswas J.C., Islam M.R., Islam A. & Kabir M.S. Effect of long-term chemical and organic fertilization on rice productivity, nutrient use-efficiency, and balance under a rice-fallow-rice system. *J. Plant Nutr.*2019; 42(20) : 2901-2914 https://doi.org/10.1080/01904167.2019.1659338
34. Bationo A., Ntare B.R. Rotation and nitrogen fertilizer effects on pearl millet, cowpea and groundnut yield and soil chemical properties in a sandy soil in the semi-arid tropics, West Africa. *Journal of agricultural Science.*2020; 134: 277-284.
35. Bagayoko M., Buerkert A., Lung G., Bationo A., Römheld V. Cereal/legume rotation effects on cereal growth in Sudano-Sahelian West Africa: soil mineral nitrogen, mycorrhizae and nematodes. *Plant and soil.*2000; 218: 103-116.