Journal of Experimental Agriculture International

Volume 46, Issue 12, Page 493-506, 2024; Article no.JEAI.128212
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Short Term Impact of *Andropogon gayanus* Kunth. on Soil Fertility and Legume Crop Rotation in West Central Region of Koudougou, Burkina Faso

Boussa Tockville Josue Mare [a*], Yiénibirma Josias Lankoande [b], Issaka Senou [b], Salifou Traore [a] and Waldemar Spychalski [c]

[a] Joseph Ki-Zerbo University (UJKZ), Training and Research Unit in Life and Earth Sciences (UFR/SVT), 03 BP-7021 Ouagadougou 03, Burkina Faso.
[b] University of Dédougou, Institute of Environmental Sciences and Rural Development (ISEDR) BP-176 Dédougou, Burkina Faso.
[c] Department of Soil Science and Land Protection, Poznań University of Life Sciences, Poland.

Authors' contributions

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

Article Information

DOI: https://doi.org/10.9734/jeai/2024/v46i123155

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/128212

Original Research Article

Received: 14/10/2024
Accepted: 20/12/2024
Published: 24/12/2024

**Corresponding author: E-mail: mare_josi@yahoo.fr;*

Cite as: *Mare, Boussa Tockville Josue, Yiénibirma Josias Lankoande, Issaka Senou, Salifou Traore, and Waldemar Spychalski. 2024. "Short Term Impact of Andropogon Gayanus Kunth. on Soil Fertility and Legume Crop Rotation in West Central Region of Koudougou, Burkina Faso". Journal of Experimental Agriculture International 46 (12):493-506. https://doi.org/10.9734/jeai/2024/v46i123155.*

ABSTRACT

The low productivity of land in Burkina Faso is one of the major threats of the agricultural sector. This study aims to evaluate the short-term legume crop impact in a sequence with a short term Andropogon gayanus fallow rotation in order to propose means of degraded lands recovery and their sustainable management. To achieve this goal, a test was set up in Péyiri village in West-Central region of Burkina Faso. The test which is made up of a completely randomized block of three plots, was installed on two area of a transect taking into account the microtopography (1.35%) effects. The first area which is called geomorphological unit I (UGI) consisted of a block of three replications plots and this area was used for legume crop (MC) during five (05) years. The legume crop was followed in rotation with a short-term Andropogon gayanus fallow (MA) for three (03) years. Following the micro-slope (1.35%), the same test was repeated on the second area of the transect called geomorphological unit II (UGII). On each plot of each UG, three (03) replications soil samples were collected on 0-20 cm soil layer at the end of legume crop and at the end of Andropogon gayanus short-term fallow for the soil physico-chemical properties assessment. The results obtained revealed that the MA treatment increased the contents of N, C, Sech, CEC, V, pH, NH_4^+, P, K, Mg, Ca respectively by 33%, 51.72%, 20.55%, 16.43%, 3%, 7%, 192.71%, 18.61%, 98.68%, 1095.8% and 353% on UGI except NO_3^- compared to the MC treatment results which increased the content of NO3- by 5% compared to MA. The slope of 1.35% observed between UGI and UGII caused a deterioration of the organic status, physicochemical properties and major nutrients on the UGII. These results suggest that even for small slopes, soil conservation measures are still necessary. In conclusion, the study showed that on small family farms systems in Burkina Faso, legume crop rotation with *Andropogon gayanus* short-term fallow constitutes a means of agricultural lands sustainable management.

Keywords: Land management; short fallow; physicochemical characteristics; Burkina Faso.

1. INTRODUCTION

Burkina Faso, a West Africa's country, primarily relies on agriculture to drive its economic growth (Zanré et al., 2024). The agricultural sector employs nearly 70% of the active population and contributes nearly by 35% to GDP (Souratié et al. 2019). This agricultural sector is therefore strategic for the development of the country. However, poor farming practices have contributed to the degradation of the majority of soils in Burkina Faso leading in some time to the formation of bare soils and new clearings (Dabre et al., 2024).

Poor agricultural practices can be export of crop debris, overgrazing and bush fires (Koudougou *et al*. 2017). These inappropriate agricultural practices make fields more vulnerable to erosion which causes the stripping of fine elements towards lowland areas, leading to decline in soil productivity and sometimes to extreme denudation of the soil. In the municipality of Koudougou, Central West region of Burkina Faso, deep, medium-deep and leached tropical ferruginous soils with stains and concretions are among the most vulnerable to erosion (Salawu, 2009). Indeed, in this region, the total soil loss is estimated at 392,379.82 t/year (with an average rate of 1.22 t/ha/year) including a representation of 79% for cultivation areas and 8.51% for plant formations (Yaméogo et al. 2021).

Faced with this challenge of soil degradation, Burkinabè agricultural producers in general placed emphasis on the one hand on the extension of cultivated areas with a view to increasing agricultural yields and on the other hand on the fallowing of agricultural land for several years because long-term fallowing (20 to 30 years) has indeed shown its capacity to restore soil fertility (Sédogo, 1981; Piéri, 1991; Zoungrana, 1993; Hien et al. 1993; Assede et al., 2023). But the demographic increase in recent years, i.e. approximately 20,505,155 inhabitants with a growth rate of 2.94% in 2019 (INSD, 2024), has led to an increase in food demand and strong pressure on agricultural land, inducing the shortening of fallow periods. This situation has encouraged numerous works relating to this type of fallow in order to propose alternatives to long-term fallow. Some authors have emphasized that recourse to the practice of short-term fallow could ensure the viability of agrosystems (Hien et al. 1993; Floret et al. 1994; Somé et al. 2004). The increased grain yields are frequently also obtained when a cereal follows a grain legume in sequence compared with a cereal-cereal rotation (Smith et al., 2020). These lands management systems focused on *Andropogon gayanus* in a sequence with cereal, or a cereal-cereal, or cereal-cotton rotation system (Blair and Crocker, 2000; Benincasa et al., 2017; Blair et al., 2006).

Studies have also underlined that legumes cultivation can not only enrich the soil with organic matter but above all with nitrogen through symbiotic fixation of atmospheric nitrogen (Dugje *et al.* 2009). Others authors even stressed the conditions for good symbiotic nitrogen fixation (Adam et al., 2023; Li et al., 2023; Zhou et al., 2024; Dollete et al., 2024). Then the combination of crops, ranging from simplest forms to complex multi-stage associations, such as agroforests, have allowed many populations to maintain their production conditions (Valet et al., 2014).

In drylands ecosystems with an increased rate of degraded soils also du to the negative effects of climate change, our study aims to evaluate the impact of a sequence of short-term legume crop with a short term *Andropogon gayanus* fallow rotation. The results of this study could not only help low-income family farms in the sustainable management of agricultural land, but also allow them to further integrate livestock breeding with the production of fodder *by Adropogon gayanus*.

2. MATERIALS AND METHODS

2.1 Description of the Study Site

Our trial was set up on a site of approximately 11ha located in the village of Péyiri in the municipality of Koudougou, West-Central region of Burkina Faso. This area belongs to “the NGO-D Le Soleil dans la main”, an associative structure of which base is in Luxembourg and therefore operates in Burkina Faso in different development sectors.

The climate is North Sudanese, hot and dry, characterized by a rainy season from May to September and a dry season from October to April. The average rainfall varies between 600 and 1000 mm per year. The annual evolution of cumulative water levels from 2013 to 2022 shows that on average, a quantity of 821.03 mm of water has been recorded over the last 10 years. The lowest rainfall was observed in 2013 with an amount of 608 mm spread over 48 rainy days. The highest rainfall was recorded in 2016 with an amount of 1034 mm spread over 54 rainy days. In addition to the significant variation in rainfall, the stormy and violent nature of the precipitation leads to significant runoff which causes soil erosion. The average annual temperature is 28.1°C. According to climate data obtained from the National Meteorology Agency of Burkina Faso (ANAM-BF), the annual maxima of 39°C are observed from March to May and annual minima of 18°C are between December and January. Soils that are denuded due to climatic hazards, bush fires and other anthropogenic practices become also susceptible to wind and water erosion. There are three main types of soil (Bunasol, 2001):

- Lithosols on cuirasse found at the tops of hills and on gently slopes;
- Hydromorphic soils encountered throughout rivers and lowlands. They are more often sandy-loamy or clayey-sandy associated with ferruginous;
- Leached tropical ferruginous soils, often made up of gravel materials, represent a high proportion, poor in organic matter, nitrogen, phosphorus and potassium with a low exchange capacity.

2.2 Materials

The technical equipment is mainly composed of agricultural tools, measuring, mapping and packaging instruments. The list of materials used is made up of:

- Pickaxes and shovels used to open the pits in order to describe the pedomorphological properties and soil samples collection;
- GPS used to take the coordinates of the site;
- The Qgis software was used to create the map of the study area;
- Plastic bags were used to package the samples collected;
- An electronic balance was used to weigh the mass of raw soil;
- A mortar and pestle were used to break up the clods;
- A sieve with a mesh size equal to 2 mm was used to sieve the samples.

2.3 Methodology, Experimental Design and Soil Sampling

In general, the methodology of the study followed the following scheme:

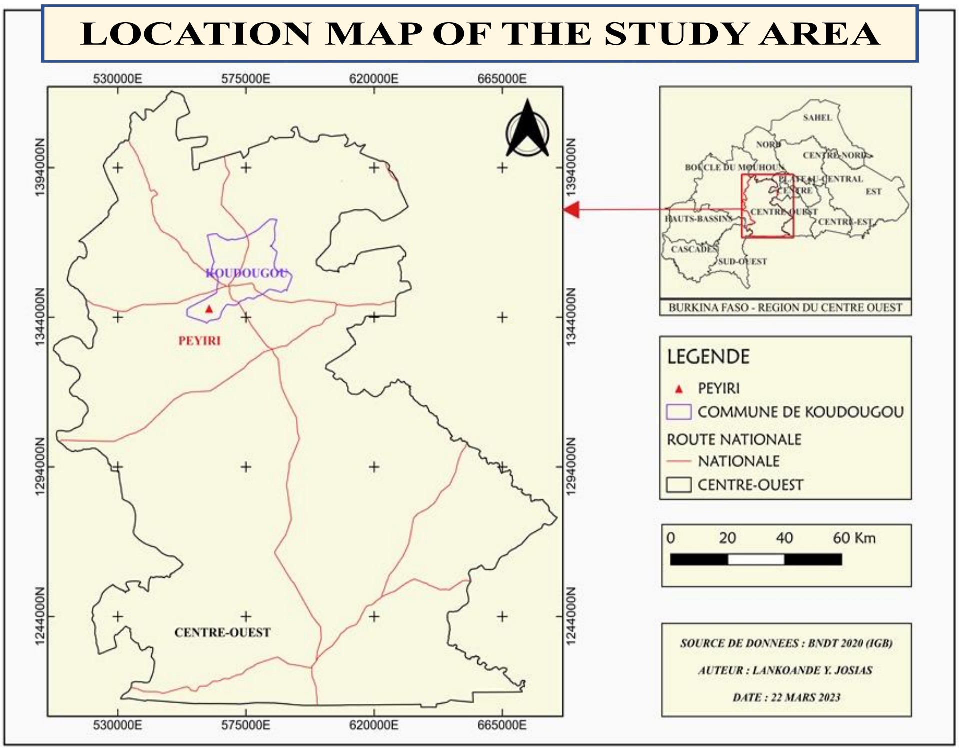

Fig. 1. Map of the study area

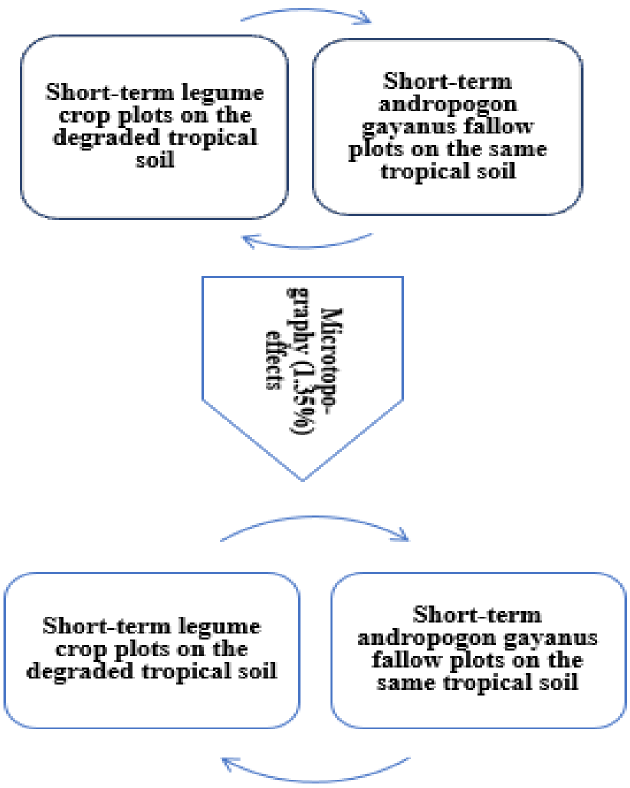

Fig. 2. Workflow showing the steps of the methodology

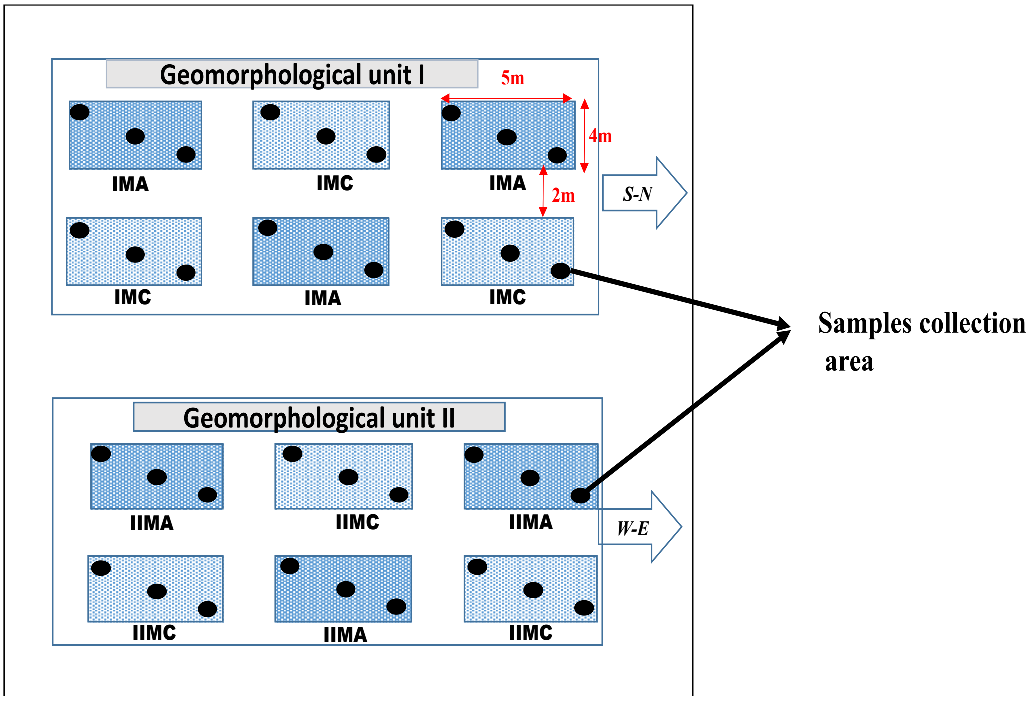

Fig. 3. Experimental design and soil sampling

Following the objectives of our study, a first block of three elementary plots is installed on a tropical degraded soil called "geomorphological unit I" (UGI). On this area, a a short-term legume crop plots were set up in rotation with a short-term andropogon gayanus fallow. The main factor is the mode of land management with two modalities which are (i) short-term legume crop and (ii) short-term andropogon gayanus fallow. The second block of which composition was identical to that of the first block, was installed on the same degraded type of soil called geomorphological unit II (UGII) with variation of the microtopography. At the end of each experimentation process, soil samples in three replications per plot, were collected from 0-20 cm soil layer and analysed to assess the induced effects. The Fig. 3 gives the details on the experimental design.

2.4 Soil Samples Analysis

A total of 36 samples were collected, packaged in labeled plastic bags and transported to Poznan life sciences University laboratory (Poland). Before the analysis, the samples were air-dried at room temperature and screened through a 2 mm mesh. After this operation, soil pH_{kcl} is potentiometrically measured in the supernatant suspension of a 1:2.5 soil: liquid mixture. The texture was determined by the pipette method after dispersion of the sample with a sodium hexametaphosphate solution (Gee and Bauder, 1986). The organic C (C_{org}) and total nitrogen (N) were determined by dry combustion (Thermo Scientific Lab EA-1110) on carbonate-C free samples. The concentration of soluble elements (Ca, Mg, K, Na etc.) was measured by ICP-OES in a 1:2.5 soil to deionised water suspension, after centrifugation and filtration of the water extracts (Van Reeuwijk, 2002). The exchangeable bases extraction (TEB) was done using the ammonium acetate (pH 7) method and the cation exchangeable capacity (CEC) were determined by ICP-OES after exchange with 0.05 N cobaltihexamine chloride solution (Orsini and Remy, 1976, modified by Ciesielski and Sterckeman, 1997). Phosphorus concentration in the obtained extracts was marked with a colorimetric method with blue-staining ammonium molybdate and ascorbic acid and potassium antimonyl tartrate (Murphy and Riley, 1962). Reading was done on Cary 60 apparatus. The concentration of NO_3^- and NH_4^+ ions was measured using the colorimetric method on the Cary 60 apparatus.

2.5 Slope Calculation

The slope was determined according to the slope percentage calculation model of Baden-Powell (2014) of which formula is:

Slope = Elevation/Length traveled
Elevation = total height between the arrival and the starting point.

2.6 Statistical Analysis

The data collected were entered using an Excel 2013 spreadsheet. The data were then subjected to an analysis of variance (ANOVA) to compare the means of the variables at the 5% significance level ($P<0.05$) and the test of Tukey was used for mean separation. The results are presented in table form. The ANOVA was performed using IBM SPSS Statistics software version 22.0.

3. RESULTS AND DISCUSSION

3.1 Effects of Short-Term Fallowing and Legume Cropping on C_{org}, total N of Degraded Soils

The short-term fallow with Andropogon gayanus (IMA) presented the highest contents of C (0.88%) and N (0.043%) compared to the results obtained in C (0.58%) and N (0.03%) on legume plots (Table 1). The values on the relative percentages on C_{org} and total N are reported in the table. The trend on the C/N ratio showed a predominance of the value obtained on IMC (24.64) compared to IMA (21.25). Analysis of variance between IMA and IMC revealed a significant difference on C (p=0.022).

The *Andropogon gayanus* fallow environment of geomorphological unit II (IIMA) also presented the highest contents in C (0.6%), N (0.03%) and C/N (20.0) compared to IIMC of which values are 0.33% for C, 0.02% for N and 17.27 for the C/N ratio (Table 2). The values on the relative percentages on C_{org} and total N are reported in the table. Analysis of variance between IIMA and IIMC revealed a significant difference on C/N (p=0.022).

3.2 Effects of Short-Term Fallowing and Legume Cropping on the Texture of Degraded Soils

On geomorphological unit I, the plots under legume cropping (IMC) had a loamy-clay-sandy (LAS) to loamy (L) texture and presented the

Table 1. Effects of short-term fallowing and legume cropping on C_{org}, total N of UGI

Medium	N_%	C_%	C/N	N relative %	C_{org} relative %
IMC	0.026	0.58 a	24.64	38	40
IMA	0.043	0.88 b	21.25	62	60
P-value	0.152	0.022	0.088		
Significance	ns	*	Ns		

Legend: IMC= Environment under legume cropping of geomorphological unit I; IMA= Environment under fallow with Andropogon gayanus of geomorphological unit I; P-value = Probability of significance at the 5% threshold (Tukey test); ns = Not significant; (*) = significant.

Table 2. Effects of short-term fallowing and legume cropping on Corg, total N of UGII

Medium	N_%	C_%	C/N	N relative %	C_{org} relative %
IIMC	0.02	0.327	17.27 a	40	35
IIMA	0.03	0.597	20.01 b	60	65
P-value	0.158	0.068	0.042		
Significance	ns	ns	*		

Legend: IIMC= Environment under legume cropping of geomorphological unit II; IIMA= Environment under fallow with Andropogon gayanus of geomorphological unit II; P-value = Probability of significance at the 5% threshold (Tukey test); ns = Not significant; (*) = significant.

Table 3. Effects of short-term fallowing and legume cropping on the texture of UGI

Medium	Particle size distribution (%)				Texture
	Sand	Silt	Clay	El. Gr	
IMC	49.41	32.45	18.2	7.54	LAS to L
IMA	46.96	38.89	14.2	9.39	LS to L
P-value	0.587	0.150	0.253	0.373	
Significance	ns	Ns	ns	ns	

El. Gr= Coarse elements; LS=Silty-sandy; LAS=Silty-clay-sandy; L= Loamy highest values of sand (49.41%), clay (18.22%) compared to the results obtained in sand (46.96%), clay (14.22%) on the short-term fallow with Andropogon gayanus (IMA) of which soils have loamy-sandy textures (LS) to loamy (L). IMA showed the highest values in silt (38.89%), coarse elements (9.39%) compared to the results in silt (32.45%), coarse elements (7.54%) obtained by IMC (Table 3).

The plots under legume cropping and those under short-term fallow with *Andropogon gayanus* of geomorphological unit II were all a loamy-sandy texture (LS). IIMC presented the highest values in sand (60.92%), clay (5.44%) and coarse elements (6.53%) compared to the results obtained in sand (56.55%), clay (5. 34%) and coarse elements (4%) on IIMA (Table 4). The trend on silt showed a predominance of the value obtained on IIMA (38.17%) compared to IIMC (33.67%). The analysis of variance revealed between IIMA and IIMC a significant difference in the percentage of coarse elements (p=0.020).

3.3 Effects of Short-Term Fallowing and Legume Cropping on Some Chemical Index of Degraded Soils

The short-term fallow with *Andropogon gayanus* (IMA) presented the highest values of $S_{écha}$ (4.4767 cmol(+)/kg), CEC (6.0933 cmol(+)/kg), V (73, 4%), pH (5.44) and Cdt (222.533 µs/cm) compared to the values in S_{echa} (3.7133 cmol(+)/kg), CEC (5.2333 cmol(+)/kg), V (70.94%), pH (5.05) and Cdt (62.8333 Us/cm) obtained on IMC (Table 5). Analysis of variance on chemical characteristics between IMA and IMC revealed a highly significant difference on Cdt (p=0.004).

On geomorphological unit II, the short-term fallow with *Andropogon gayanus* (IIMA) presented also the highest values of $S_{échan}$ (2.0233 cmol(+)/kg), CEC (3.7311 cmol(+)/ kg), pH (5.16) and Cdt (101.523 Us/cm) compared to the values in $S_{échan}$ (1.4633 cmol(+)/kg), CEC (2.6022 cmol(+)/kg), pH (4.48) and Cdt (65.38 µS/cm) obtained by IIMC (Table 6). However, IIMC presented the highest value in V (55.71%) compared to V (53.16%) obtained by IIMA. Analysis of variance of chemical characteristics between IIMA and IIMC revealed a significant difference on CEC (p=0.044).

3.4 Effects of Short-Term Fallowing and Legume Cropping on Major Nutrients of Degraded Soils

On geomorphological unit I, the short-term fallow with Andropogon gayanus (IMA) presented the highest contents of NH_4^+ (2.6733 mg/l), Pt (87.3533 mg/kg), K (5.5433 mg /l), Mg (6.6167 mg/l) and Ca (13.7333 mg/l) compared to the results obtained in NH_4^+ (0.9133 mg/l), Pt (73.65 mg/kg), K (2.79 mg/l), Mg (0.5533 mg/l) and Ca (3.0267 mg/l) on legume plots (IMC) (Table 7). The trend on NO_3^- showed a predominance of the value obtained on IMC (11 mg/l) compared to IMA (1.1833 mg/l). Analysis of variance of major nutrients between IMA and IMC revealed differences, very highly significant

Table 4. Effects of short-term fallowing and legume cropping on the texture of UGII

Medium	Particle size distribution (%)				Texture
	Sand	Silt	Clay	El. Gr	
IIMC	60.92	33.67	5.44	6.53 a	LS
IIMA	56.55	38.17	5.34	4 b	LS
P-value	0.188	0.154	1.000	0.020	
Signification	Ns	Ns	ns	*	

Table 5. Effects of short-term fallowing and legume cropping on the chemical index of UGI

Medium	$S_{échan}$_cmol(+)/kg	CEC_ cmol(+)/kg	V (%)	pH_1 mol KCl	Cdt Us/cm
IMC	3.7133	5.2333	70.94	5.05	62.83 a
IMA	4.4767	6.0633	73.4	5.44	222.53 b
P-value	0.133	0.158	0.435	0.90	0.004
Significance	ns	ns	ns	ns	**

$S_{échan}$= Sum of exchangeable bases cations; CEC= Cation exchange capacity; pH= Hydrogen potential; Cdt= Conductivity; V= Saturation rate.

Table 6. Effects of short-term fallowing and legume cropping on the chemical index of UGII

Medium	$S_{échan}$_cmol(+)/kg	CEC_cmol (+)/kg	V (%)	$pH_{\_ KCl}$	Cdt µS/cm
IIMC	1.463	2.6022 a	55.71	4.84	65.38
IIMA	2.023	3.7311 b	53.16	5.16	101.523
P-value	0.273	0.044	0.752	0.214	0.425
Significance	ns	*	ns	Ns	ns

Table 7. Effects of short-term fallowing and legume cropping on major nutrients of UGI

Medium	NO_3^-_mg/l	NH_4^+_mg/l	P_mg/kg	K_mg/l	Mg_mg/l	Ca_mg/l
IMC	11	0.9133 a	73.65	2.79 a	0.5533 a	3.027 a
IMA	1.183	2.6733 b	87.353	5.543 b	6.6167 b	13.73 b
P-value	0.28	0.005	0.145	0.044	0.001	0.005
Significance	ns	**	ns	*	***	**

Table 8. Effects of short-term fallowing and legume cropping on major nutrients of UGII

Medium	NO_3^-_mg/l	NH_4^+_mg/l	P_mg/kg	K_mg/l	Mg_mg/l	Ca_mg/l
IIMC	10.937	1.89	57.657	7.543	0.387	1.447
IIMA	3.57	4.297	65.063	10.787	2.407	6.123
P-value	0.127	0.103	0.25	0.209	0.119	0.106
Significance	ns	ns	ns	ns	ns	ns

on Mg (p=0.001), highly significant on Ca and NH_4^+ (p=0.005), significant on K (p=0.044) and no significant difference on NO_3^- and P (p>0.05).

On geomorphological unit II, the short-term fallow with Andropogon gayanus (IIMA) presented the highest contents of NH_4^+(4.2967 mg/l), Pt (65.0633 mg/kg), K (10.7867 mg/l), Mg (2.4067 mg/l) and Ca (6.1233 mg/l) compared to the results obtained in NH_4^+ (1.89 mg/l), Pt (57.6567 mg/kg), K (7.5433 mg/l), Mg (0.3867 mg/l) and Ca (1.4467 mg/l) on legume plots (IIMC) (Table 8). The trend on NO_3^- showed a predominance of the value obtained on IIMC (10.9367 mg/l) compared to IIMA (3.57 mg/l). Analysis of variance of major nutrients between IIMA and IIMC revealed no significant differences on NO_3^-, $NH_4^{+,}$ Pt, K, Mg and Ca (p>0.05).

3.5 Influence of the Microtopography on C_{org}, Total N of Degraded Soils

The short-term fallow with Andropogon gayanus on geomorphological unit I (IMA) presented the highest contents of C (0.88%), N (0.04%) and C/N (21.25) compared to the results obtained in C (0.6%), N (0.03%) and C/N (20.01) on geomorphological unit II (IIMA) (Table 9). Analysis of variance on organic status revealed a significant difference on C/N (p=0.04).

On the environment under legumes cropping, geomorphological unit I (IMC) presented the highest contents of C (0.58%), N (0.03%) and C/N (24.64) compared to the results obtained in C (0.34%), N (0.02%) and C/N (17.27) on geomorphological unit II (IIMC) (Table 10). Analysis of variance revealed a highly significant difference between IMC and IIMC on C (p=0.003), a significant difference on C/N (p=0.13) and no significant difference on N (p>0.05).

3.6 Influence of the Microtopography on the Physical Properties of Degraded Soils

On geomorphological unit I (UGI), the short-term fallow plots of *Andropogon gayanus* (IMA) have a loamy-sandy (LS) to loamy (L) texture and on geomorphological unit II (IIMA), they have a loamy-sandy texture (LS). IMA presented the highest values in silt (38.89%), clay (14.2%) and coarse elements (9.39%) compared to the results obtained in silt (38.17%), clay (5. 34%) and coarse elements (4%) on IIMA (Table 11). The trend on the percentage of sand showed a predominance of the value obtained on IIMA (56.55%) compared to IMA (46.96%). The analysis of variance revealed differences between IMA and IIMA, significant on the percentage of clay (p=0.015), highly significant on the percentage of coarse elements

Table 9. Effects of microtopography on C_{org}, total N of degraded soils (IMA, IIMA)

Medium	N_%	C_%	C: N
IMA	0.043	0.883	21.25 a
IIMA	0.03	0.597	20.01 b
P-value	0.205	0.095	0.044
Significance	ns	ns	*

Table 10. Effects of microtopography on C_{org}, total N of degraded soils (IMC, IIMC)

Medium	N_%	C_%	C:N
IMC	0.027	0.58 a	24.64 a
IIMC	0.02	0.327 b	17.27 b
P-value	0.374	0.003	0.013
Significance	ns	**	*

Table 11. Effects of microtopography on physical properties of degraded soils (IMA, IIMA)

Medium	Particle size distribution (%)				Texture
	Sand	Silt	Clay	El. Gr	
IMA	46.96	38.89	14.2 a	9.39 a	LS to L
IIMA	56.55	38.17	5.34 b	4 b	LS
P-value	0.193	0.865	0.015	0.008	
Significance	ns	ns	*	**	

Table 12. Effects of microtopography on physical properties of degraded soils (IMC, IIMC)

Medium	Particle size distribution (%)				Texture
	Sand	Silt	Clay	El. Gr	
IMC	49.41 a	32.45	18.2 a	7.54	LAS to L
IIMC	60.92 b	33.67	5.44 b	6.53	LS
P-value	0.011	0.328	0.004	0.510	
Signification	*	ns	**	ns	

Table 13. Effects of microtopography on chemical index of degraded soils (IMA, IIMA)

Medium	$S_{échan}$_cmol (+)/kg	CEC_cmol(+)/kg	V (%)	pH_1 mol KCl	Cdt Us/cm
IMA	4.477 a	6.093 a	73.4 a	5.44	222.53
IIMA	2.023 b	3.7311 b	53.16 b	5.16	101.523
P-value	0.012	0.017	0.028	0.62	0.057
Significance	*	*	*	ns	ns

(p=0.008) and no significant difference on the percentages of sand and silt (p>0.05).

On UGI, the plots under legume cropping (IMC) had a loamy-clay-sandy (LAS) to loamy (L) texture and on UGII (IIMC), they were loamy-sandy (LS). IMC presented the highest values in clay (18.2%), coarse elements (7.54%) compared to the results obtained in clay (5.44%) and coarse elements (6.53%) on IIMC (Table 12). However, IIMC presented the highest contents of sand (60.92%), silt (33.67%) compared to the results obtained in sand (49.41%), silt (32.45%) on IMC. The analysis of variance revealed differences between IMC and IIMC, significant on the percentage of sand (p=0.011), highly significant on the percentage of clay (p=0.004) and no significant difference on the percentages of silt and coarse elements (p>0.05).

3.7 Influence of the Microtopography on the Chemical Index of Degraded Soils

The short-term fallow with *Andropogon gayanus* (IMA) presented the highest values $S_{échan}$ (4.4767 cmol(+)/kg, CEC (6.0933 cmol(+)/kg, V

(73.4%), pH (5.44) and Cdt (222.533 µS/cm) compared to the values in $S_{échan}$ (2.0233 cmol(+)/kg, CEC (3.7311cmol(+)/kg),V (53.16%), pH (5.16) and Cdt (101.523 µS/cm obtained on IIMA (Table 13). The analysis of variance on chemical characteristics revealed a significant difference between UGI and UGII on $S_{échan}$, CEC, V (respectively p=0.012; p=0.017; p=0.028) and a non-significant difference on pH, Cdt (p>0.05).

The legumes cropping on geomorphological unit I (IMC) presented the highest values of $S_{échan}$ (3.7133 cmol(+)/kg, CEC (5.2333 cmol(+)/kg, V (70.94%) and pH (5.05) compared to the values in Sec (1.4633 cmol(+)/kg, CEC (2.6022 cmol cmol(+)/kg, V (55. 71%) and pH (4.84) obtained on IIMC (Table 14). The trend showed a predominance of the value obtained on IIMC in Cdt (65.38 Us/cm) compared to the value in Cdt (62.8333 Us/cm) obtained on IMC. Analysis of variance of chemical characteristics revealed differences between IMC and IIMC, very highly significant on $S_{échan}$, CEC (p=0.001), significant on V (p=0.048) and not significant on pH and Cdt (p>0.05).

3.8 Influence of the Microtopography on the Major Nutrients of Degraded Soils

The short-term fallow with *Andropogon gayanus* of geomorphological unit I (IMA) presented the highest contents of Pt (87.3533 mg/kg), Mg (6.6167 mg/l) and Ca (13.7333 mg /l) compared to the results obtained in Pt (65.0633 mg/kg), Mg (2.4067 mg/l) and Ca (6.1233 mg/l) by the short-term fallow of Andropogon gayanus of the geomorphological unit II (IIMA). The trends show a predominance of the values obtained on IIMA in NO_3^- (3.57 mg/l), NH_4^+ (4.2967 mg/l), K (10.7867 mg/l) compared to the results obtained on IMA in NO_3^- (1.1833 mg/l), NH_4^+ (2.6733 mg/l) and K (5.5433 mg/l) (Table 15). Analysis of variance of major nutrients revealed a significant difference between UGI and UGII on K and Mg (p=0.041 and p=0.028 respectively).

The legume cropping of geomorphological unit I (IMC) presented the highest contents in Ca (3.0267 mg/l), Mg (0.5233 mg/l), NO_3^- (11 mg/l) and Pt (73.65 mg/kg) compared to the results obtained in Ca (1.4467 mg/l), Mg (0.3867 mg/l), NO_3^- (10.9367 mg/l) and Pt (57.6567 mg/kg) on the short-term fallow with *Andropogon gayanus* of geomorphological unit II (IIMA) (Table 16). The trends showed a predominance of the values obtained on IIMC in K (7.5433 mg/l) and NH_4^+ (1.89 mg/l) compared to the results obtained on IMC in K (2.79 mg/l) and NH_4^+ (0.9133 mg/l). Analysis of variance of major nutrients revealed a significant difference between IMC and IIMC on K and Pt (p=0.040 and p=0.012 respectively).

On UGI, the nitrogen (N) rate representing 62% on IMA compared to N (38%) of IMC shows a continuous enrichment in N of the environment which would be linked to the quantity and quality of biomass produced by the *Andropogon gayanus.* Considering the abiotic and biotic environmental factors, this study reveals that the biomass from *Andropogon gayanus* would have a rate of soil organic matter mineralization which makes it possible to reconstitute an increasing stock of N. These results are similar to those of some others authors (Bassonon, 2002; Somé *et al*. 2004) who showed a N gain in a short fallow with *Andropogon gayanus* compared to a control plot with continuous cereal cropping. According to soil organic carbon, the higher content obtained by MA (60-65%) compared to MC confirms a relative biomass abundance of *Andropogon gayanus.* In other way, this study shows that the organic matter from *Andropogon gayanus* in the soil is more stable than the legumes's organic matter. These results are also in the same trend with some authors who found, compared to a control like continuous cereal cropping, a gain in carbon with *Andropogon gayanus* of 43.31% (Tassambedo, 2001; Bassonon, 2002; Somé *et al.* 2004). Our study highlights that by *Andropogon gayanus* short-term fallow rotation with legumes, we make a gain of at least 20% of soil organic matter sequestration compared to cereals rotation with Andropogon short fallow. The study also reveals that the slope of 1.35% induced a variation of 2% in N on MC and on MA but in the opposite direction depending on the cultural speculation. We also found the same trend with soil organic carbon variation with the slope until 5%. These results suggest that farming in the vulnerable soils, the type and cropping system influence C and N behavior more than the microtopography.

The higher percentage of clay on legume cropping soil (IMC, IIMC) compared to the short-term fallow with *Andropogon gayanus* (IMA, IIMA) could be explained by good ground plant cover with MC which would have helped to reduce the splash effect of the rains, decreasing the runoff intensity. These results are similar to those who showed (Roose,1967) that soil stripping can be done diffusely over the entire unprotected surface and results in the concentration of stones on the surface by preferential erosion.

Table 14. Effects of microtopography on chemical index of degraded soils (IMC, IIMC)

Medium	Séch_cmol	CEC_ cmol/kg	V (%)	pH_1 mol KCl	Cdt Us/cm
IMC	3.713 a	5.2333 a	70.94 a	5.05	62.833
IIMC	1.463 b	2.6022 b	55.71 b	4.84	65.38
P-value	0.0006	0.001	0.048	0.462	0.89
Significance	***	***	*	ns	ns

Table 15. Effects of microtopography on major nutrients of degraded soils (IMA, IIMA)

Medium	NO_3^-_mg/l	NH_4^+_mg/l	P_mg/kg	K_mg/l	Mg_mg/l	Ca_mg/l
IMA	1.183	2.673a	87.353a	5.543	6.617	13.73
IIMA	3.57	4.297b	65.063b	10.787	2.407	6.123
P-value	0.075	0.222	0.061	0.041	0.028	0.056
Significance	ns	*	*	ns	ns	ns

Table 16. Effects of microtopography on major nutrients of degraded soils (IMC, IIMC)

Medium	NO_3^-_mg/l	NH_4^+_mg/l	P_mg/kg	K_mg/l	Mg_mg/l	Ca_mg/l
IMC	11	0.913a	73.65	2.79	0.523	3.027a
IIMC	10.937	1.89b	57.657	7.543	0.387	1.447b
P-value	0.995	0.066	0.0121	0.040	0.362	0.122
Significance	ns	*	ns	Ns	ns	*

The higher sum of exchangeable bases ($S_{échan}$) presented by MA compared to MC, could be explained by the higher rate of organic matter reported on MA. This result confirms that soils poor in organic matter are also the most acidic and the least saturated in bases (Roose, 1980 and Carrier, 2003). The amount value of cation exchange capacity obtained by MA (IMA, IIMA) compared to those obtained by MC (IMC, IIMC) could be explained by the higher organic matter rate on MA. In effect the CEC depends on the type of clay, the content of fine mineral elements as well as the content of organic matter (Dabin, 1970; Alexandre *et al.* 2012; Koull *et al*. 2016).

The amount value of K, Mg and Ca obtained by the short-term fallow soil (IMA, IIMA) compared to the legume cropping area (MC) could be explained in the one hand by the relative higher content of organic matter on MA. This biomass after decomposition would have released nutrients for the plant. It could also be explained by leaching of nutrients on MC caused by erosion due to the fact that the legume cropping is rainfed and does not cover the soil all year round. This result is similar to those of others authors (Abbadie 1995; Somé *et al.* 2000; Vécchia *et al*. 2001), who showed that by humifying, organic matter combines with mineral matter to form the clay-humic complex having the property of retaining cations. Nitrates (NO_3^-) and ammonium (NH_4^+) are the main forms of mineral (inorganic) nitrogen directly used by plants for their nutrition. The higher NO_3^- content obtained by MC compared to MA could be explained by the fact that the legume fixed atmospheric nitrogen and stored it in the soil and that on MA, the Andropogon gayanus passed directly nitrogen from dead roots to living roots, without having to pass through the humic stock of the soil. The Andropogoneae, thanks to the spatial structure of their underground apparatus, have the capacity to organize a short circuit in the nitrogen cycle allowing the direct passage of nitrogen from dead roots to the living roots, without having to pass through the humic stock of the soil (Abbadie *et al*. 2000). Also, the cowpea enriches the soil with nitrogen by biological fixation of atmospheric nitrogen. The significant difference observed with NH_4^+ and its higher content on MA compared to MC could be due to the fixation of NH_4^+ on the adsorbent complex due to the greater quantity of organic matter observed on MA. These results are similar to those of others authors who showed that Andropogoneae have the advantage of avoiding the leaching of mineral nitrogen by the fixation of ammonium ions on the clay-humic complex (Abbadie *et al.* 2000) due to the fact that they preferentially use ammonium ions (NH_4^+) instead of and place of nitrates (NO_3^-) used by other taxa for their nutrition.

4. CONCLUSION

The activities carried out during this study concerned the means of recovering degraded soils. We aimed to study the effects of land management methods and microtopography on the organic status, physicochemical characteristics and major nutrient elements of the degraded soils. The specific objective was to compare the effects induced by the legumes cropping and the short-term fallow with Andropogon gayanus rotation taking into account the effect of the microtopography. The short-term fallow period of 3 years with *Andropogon gayanus* improved the organic status, the chemical characteristics (exchangeable bases, saturation rate, cation exchange capacity, pH) and soil major nutrients except NO_3^- compared to the legume continuous cropping. Legume cropping increased the soil NO_3^- stock and ensured better soil coverage preventing the loss of fine fraction through erosion compared to short-term fallow.

For the modest-income family farms, the results of our study sufficiently show that in a context of climate change and population growth, cropping systems that integrate the legumes cropping in rotation with *Andropogon gayanus* short-term fallows, constitutes a viable model for sustainable management of agricultural ecosystems.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Abbadie, L. (1995). Organic matter and nutrient dynamics in wet savanna of Côte d'Ivoire: Facts and hypothesis. In D. Bellan, G. Bonin, & C. Emig (Eds.), *Functioning and dynamics of natural and perturbed ecosystems* (pp. 197–203). Paris: Lavoisier.

Abbadie, L., Lata, J. C., & Tavernier, V. (2000). Impact of perennial grasses on a rare resource: Nitrogen. In C. Floret & R. Pontanier (Eds.), *Fallow in tropical Africa. Roles, developments, alternatives* (Vol. I, pp. 189–193). Proceedings of the international seminar, Dakar, 13–16 April 1999. John Libbey-Eurotext-IRD-CORAF.

Adam, M. B., & Ulas, A. (2023). Vigorous rootstocks improve nitrogen efficiency of tomato by inducing morphological, physiological, and biochemical responses. *Gesunde Pflanzen, 75*, 565–575. https://doi.org/10.1007/s10343-022-00819-8.

Alexandre, M., Hansrudolf, O., Raphaël, C., Vincent, B., & Sokrat, S. (2012). Long-term effect of organic fertilizers on soil properties. *Rech. Agron. Switzerland, 3*(3), 148–155.

Assede, E.S.P., Orou, H., Biaou, S.S.H. et al. Understanding Drivers of Land Use and Land Cover Change in Africa: A Review. Curr Landscape Ecol Rep 8, 62–72 (2023). https://doi.org/10.1007/s40823-023-00087-w.

Baden, P. (2014). Calculation of the percentage (%) of slope. *Topography*. Available: http://www.toujourspret.com/techniques/orientation/topographie/calcul_du_pourcentage_d%27une_pente.php (Accessed on April 13, 2023).

Bassonon, B.S., 2002. Impacts of natural or improved short Andropogon gayanus Kunth. fallows on the organic, biological and microbiological status of soils in the Sudanian zone of Burkina Faso. Master dissertation in Burkina Faso: IDR, Polytechnic University of Bobo-Dioulasso, 58 p.

Benincasa, P., Tosti, G., Guiducci, M., Farneselli, M., & Tei, F. (2017). Crop rotation as a system approach for soil fertility management in vegetables. In *Advances in Research on Fertilization Management of Vegetable Crops* (pp. 115–148).

Blair, N., & Crocker, G. J. (2000). Crop rotation effects on soil carbon and physical fertility of two Australian soils. *Soil Research, 38*(1), 71–84.

Blair, N., Faulkner, R. D., Till, A. R., & Crocker, G. J. (2006). Long-term management impacts on soil C, N, and physical fertility: Part III: Tamworth crop rotation experiment. *Soil and Tillage Research, 91*(1-2), 48–56.

Bunasols. (2001). Morphological study report on soils in the provinces of Sissili and Ziro. (83 p.)

Ciesielski, H., & Sterckeman, T. (1997). Determination of cation exchange capacity and exchangeable cations in soils by means of cobalt heamine trichloride. Effects of experimental conditions.

Agronomie, 17, 1–7.

Dabin, B. (1970). Chemical factors of soil fertility. In *Rural Techniques in Africa, Pedology and Development*. ORSTOM and BDPA, Paris, 278 p.

Dabre, A., Savadogo, P., Sanou, L., et al. (2024). Sorghum yield using rectangular versus spherical zaï pits and integrated soil fertility management in the Sahelian and Sudano-Sahelian zones of Burkina Faso. *Agricultural Research, 13*, 253–265. https://doi.org/10.1007/s40003-023-00690-7.

Dollete, D., Lumactud, R.A., Carlyle, C.N. et al. Effect of drought stress on symbiotic nitrogen fixation, soil nitrogen availability and soil microbial diversity in forage legumes. Plant Soil 495, 445–467 (2024). https://doi.org/10.1007/s11104-023-06348-1.

Dugje, Y. I., Omoigui, O. L., Ekelem, F., Kamara, Y. A., & Ajeigbe, H. (2009). Cowpea production in West Africa: A farmer's guide. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 20 p.

Floret, C., & Pontanier, R. (1994). Research on fallow in tropical Africa. In C. Floret, R. Pontanier, & G. Serpantié (Eds.), *Fallow in tropical Africa* (MAB File 16, pp. 11–54).

Gee, G.W. and Bauder, J.W. (1986) Particle-Size Analysis. In: Klute, A., Ed., Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods, Agronomy Monograph No. 9, 2nd Edition, American Society of Agronomy/Soil Science Society of America, Madison, WI, 383-411.

Hien, V., Sédogo, P. M., & Lompo, F. (1993). Study of the effects of short-term fallows on production and soil evolution in different cropping systems in Burkina Faso. In C. Floret & G. Serpantié (Eds.), *Fallow in West Africa* (pp. 221–232). Paris, France: ORSTOM, Colloques et séminaires.

Koudougou, S., & Stiem, L. (2017). Sustainable land management in Burkina Faso: An analysis of project experience in Houet, Tuy, and Loba. *Summary report*. Institute for Advanced Sustainability Studies (IASS), 31 p.

Koull, N., & Halilat, M. T. (2016). Effects of organic matter on the physical and chemical properties of sandy soils in the Ouargla region (Algeria). *Et. Gest. Sols, 23*(1), 9–19.

Li, X., & Li, Z. (2023). What determines symbiotic nitrogen fixation efficiency in rhizobium: Recent insights into *Rhizobium leguminosarum*. *Archives of Microbiology, 205*, 300. https://doi.org/10.1007/s00203-023-03640-7.

Murphy, J. and Riley, J.P. (1962) A Modified Single Solution Method for the Determination of Phosphate in Natural Waters. Analytica Chimica Acta, 27, 31-36. http://dx.doi.org/10.1016/S0003-2670(00)88444-5.

National Institute of Statistics and Demography (INSD). (2024). 5th population census report. Available: https://www.insd.bf

Orsini, L. and Remy, J.C. (1976) Use of cobaltihexammine chloride for the simultaneous determination of the exchange capacity and exchangeable bases of soils. AFES Bulletin Soil Science, 4, 269-275.

Piéri, C. (1991). The agronomic bases for improving and maintaining the fertility of savannah lands south of the Sahara. In *Savanes d'Afrique, Terres Fertiles* (pp. 43–52). Proceedings of international meetings. Ministry of Cooperation and Development, CIRAD.

Roose, E. J. (1967). Some examples of the effects of water erosion on crops. Communication project at the Tananarive Congress of November 1967. ORSTOM, Adiopodoumé Center, Pedology Laboratory, 18 p.

Roose, E. J. (1980). Capacity of fallows to restore the fertility of poor soils in the Sudano-Sahelian zone of West Africa. Director of Pedologist Research. ORSTOM - 911, av. d'Agropolis, BP: 5045, 34032 Montpellier CEDEX 1, 12 p.

Salawu, A. (2009). Influence of soil fertility management methods on microbial activity in a long-term crop system in Burkina Faso. State doctorate in natural sciences Option: Plant production systems. Polytechnic University of Bobo Dioulasso, Burkina Faso, 215 p.

Sédogo MP., 1981. Contribution to the valorization of crop residues in ferruginous soil and in a semi-arid tropical climate (Soil organic matter and nitrogen nutrition of crops). Doctoral thesis. Nancy, France: ENSAIA, 198 p.

Smith, C. J., & Chalk, P. M. (2020). Grain legumes in crop rotations under low and variable rainfall: Are observed short-term N benefits sustainable? *Plant and Soil, 453*(1), 271–279. Available:

https://link.springer.com/article/10.1007/s11104-020-04578-1

Somé, N. A., Hien, V., & Alexandre, D. Y. (2000). Comparative dynamics of soil organic matter in Sudanese fallows under the influence of annual herbaceous plants and perennials. In C. Floret & R. Pontanier (Eds.), *Fallow in tropical Africa. Roles, Developments, Alternatives* (Vol. I, pp. 212–222). Proceedings of the international seminar, Dakar, April 13–16, 1999. Paris, France: CIRAD.

Somé, N. A., Traoré, K., Traoré, O., & Tassembedo, M. (2004). Potential of artificial fallows with *Andropogon spp.* in improving the chemical and biological properties of soils in the Sudanian zone (Burkina Faso). *Biotechnology, Agronomy, Society and Environment*, 245–252.

Souratié, W., Koinda, F., Decaluwé, B., & Samandoulougou, R. (2019). Agricultural policies, employment, and income of women in Burkina Faso. *Journal of Development Economics*. Available: https://www.cairn.info/revue-d-economie-du-developpement-2019-3-page-101.htm (Accessed on August 10, 2023), 101–127.

Tassambedo, M.A., 2001. Improvement of the fertility of soils under cover with Andropogon gayanus and Andropogon ascinodis: effects on the shortening of fallow on a ferruginous leached tropical soil of Sobaka (Sudanian Zone of Burkina Faso). Monitoring sptio-temporal structures of plant communities in short-term fallows. Master dissertation, IDR, Water and Forests Option: Polytechnic University Bobo Dioulasso, 89p.

Valet, S., & Ozier-Lafontaine, H. (2014). Ecosystem services of multispecific and multistratified cropping systems. In H. Ozier-Lafontaine & M. Lesueur-Jannoyer (Eds.), *Sustainable Agriculture Reviews* (Vol. 14, pp. 155–178). Springer, Cham. https://doi.org/10.1007/978-3-319-06016-3_7.

Van Reeuwijk, L. P. (2002). Procedures for soil analysis. *Technical Paper n. 9*. International Soil Reference and Information Centre, Wageningen, 11–1.

Vécchia, D. A., Koné, B., Bakary, D., Moussa, L., Tarchiani, V., Tiziana De Filippis, D. T., Paganini, M., & Vignarol, P. (2001). Agricultural and pastoral soil suitability in CILSS countries. *Early Warning and Forecasting of Agricultural Production (AP3A) Project*, 173 p.

Yaméogo, A., Somé, Y. S. C., Palé, S., Sirima, B. A., & Da, D. E. C. (2021). Application of GIS/RUSLE to the estimation of sheet runoff erosion in the upper Sissili watershed (Burkina Faso). *Geo-Eco-Trop, 45*(2), 299–310. Available: http://www.geoecotrop.be (Accessed on March 5, 2023).

Zanré, K. P., & Combary, O. S. (2024). The heterogeneous effects of climate variability on cotton farming productivity in Burkina Faso. *Environmental Development and Sustainability, 26*, 12707–12735. https://doi.org/10.1007/s10668-023-03988-2

Zhou, M., Li, Y., Yao, X. L., et al. (2024). Inorganic nitrogen inhibits symbiotic nitrogen fixation through blocking NRAMP2-mediated iron delivery in soybean nodules. *Nature Communications, 15*, 8946. https://doi.org/10.1038/s41467-024-53325-y.

Zoungrana, I. (1993). North Sudanese fallows: Diversity, stability, and evolution of plant communities. In C. Floret & G. Serpantié (Eds.), *Fallow in West Africa* (pp. 359–366). Paris, France: ORSTOM, Colloquia and seminars.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/128212