EFFECTS OF LEGUMES CROPPING WITH *ANDROPOGON GAYANUS KUNTH.* SHORT-TERM FALLOWING ROTATION ON THE SOIL FERTILITY IN WEST CENTRAL REGION OF BURKINA FASO, KOUDOUGOU

ABSTRACT

The low productivity of land in Burkina Faso is one of the major threats of the agricultural sector. In order to propose means of recovery, a test was set up in Péyiri from the center-west of the country and focused on the comparative study of the effects of land management options and microtopography on physico-chemical characteristics of degraded soils. A completely randomized block of plots was installed on two spaces of a transect comprising two geomorphological units (UG) called UGI and UGII, respectively. On each UG there were three repetitions of elementary plots under continuous legume cultivation (MC) and three repetitions of elementary plots under short-term fallow (03 years) with *Andropogon gayanus* (MA) installed following legume cultivation. The results obtained revealed that the MA treatment increased the contents of N, C, S_{ech}, 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 NO_3^- by 5% compared to MA. The slope of 1.35% observed between UGI and UGII caused a deterioration of the organic status, physicochemical parameters and major nutrients on the UGII. Thus, the study shows that on small family farms systems in Burkina Faso, crop rotation which integrate *Andropogon gayanus* under short-term fallow constitutes a means of agricultural intensification and sustainable land management.

Keywords: *Land management, short fallow, physicochemical characteristics, Burkina Faso*

INTRODUCTION

Burkina Faso, like other West African countries, is an essentially agricultural country whose state of natural resources is highly dependent on climatic hazards and anthropogenic activities (MEDD, 2014). The agricultural sector employs nearly 70% of the active population and contributes nearly by 35% to GDP (Souratié *et al.* 2019). More than 60% of agricultural household's incomes come from this sector (SCADD, 2013) and is therefore a strategic sector for the development of the country. However, Burkina Faso agriculture faces numerous difficulties that hinder its development, one of which is the low productivity of agricultural land (Ministry of Agriculture, 2002).

This low land productivity finds its origin in environmental degradation and poor agricultural practices like 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; Pieri, 1991; Zoungrana, 1993; Hien *et al*. 1993). But the demographic increase in recent years, i.e. approximately 20,505,155 inhabitants with a growth rate of 2.94% in 2019 (INSD, 2022), 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). Other authors assessed the potential of short-term fallow to restore degraded land (Tassambedo, 2001; Bassonon, 2002 and Somé *et al.* 2004). These works, which focused on fallows of three (03), five (05) and seven (07) years, used Andropogon gayanus in a cereal cropping/fallow or cotton cropping/fallow rotation system.

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). However, in our study area and according to our knowledge, no study has yet evaluated the effects of 05 years of legumes cropping with 03 years short-term *Andropogon gayanus* fallowing rotation, compared to the continuous cultivation of legume on a degraded environment for 08 years, while taking into account the influence of microtopography. However, 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*.

Our study is part of the same research dynamic on the means of recovering degraded soils, the general objective being to study the effects of some land management methods and microtopography on the organic status, the physicochemical characteristics and major nutrient elements of some types of degraded soils in West-Central region of Burkina Faso (Koudougou). Specifically, it involves to:

- Compare the effects induced by legumes continuous cropping with the practice of legumes cropping and Andropogon gayanus fallowing short-term rotation systems;
- Evaluate the influence of microtopography on the evolution of degraded soils properties under legumes cropping and Andropogon gayanus short-term fallowing.

To evaluate the achievement of the objectives set in this study, the following hypotheses were made:

- On degraded lands, the continuous cultivation of legumes and the practice of fallowing with *Andropogon gayanus* in “legumes cropping/fallow” rotation system, influence differently the organic status, physicochemical characteristics and major nutrients of degraded soils;
- Microtopography can also influence the biophysical properties of degraded soils.

MATERIAL AND METHODS

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 located 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. Annual maxima of 39°C are observed from March to May and annual minima of 18°C are between December and January (Météo Burkina, 2023). 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.

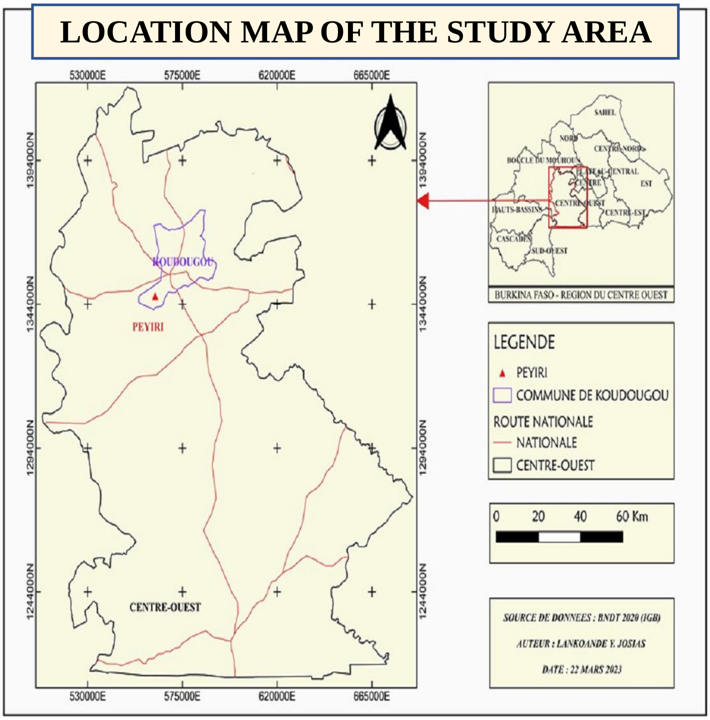

Fig. 1*: Map of the study area*

Experimental design and soil sampling

Experimental design (Figure 2), made up is a set of twelve (12) elementary plots, completely randomized with two factors, namely the management option (continuous cultivation of legumes for 08 years and short-term fallow with Andropogon gayanus of 03 years) and the slope. The twelve elementary plots were grouped into two blocks based on the microtopography. A block made up of six elementary plots installed in an area called 'geomorphological unit I' (UGI), included three repetitions of elementary plots with Andropogon gayanus (IMA) and three repetitions of elementary plots delimited on the legume cropping medium (IMC). The second block of which composition was identical to that of the first block, was installed in an environment called geomorphological unit II (UGII) with variation in the microtopography. On each elementary plot, three samples were collected from the 0-20 cm soil layer following it diagonal.

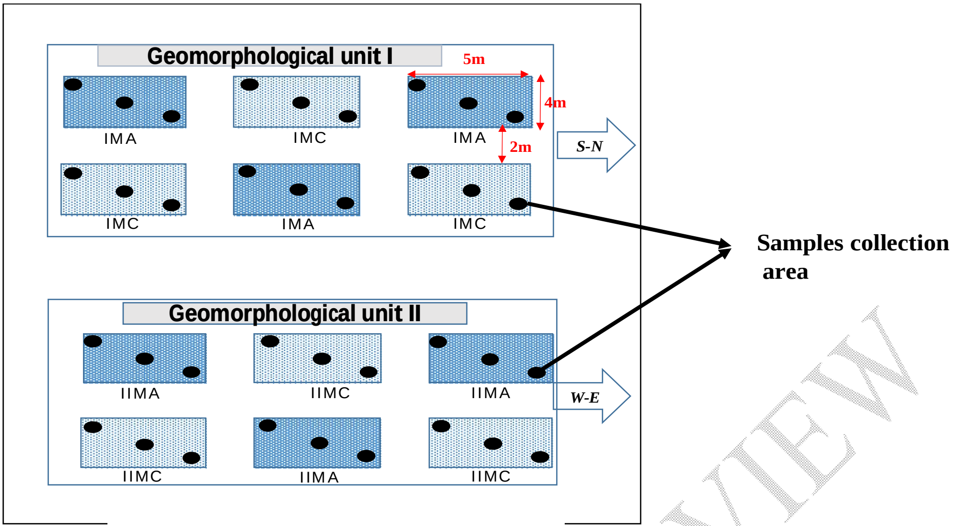

Fig. 2: *Experimental design and soil sampling*

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 Rèmy, 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, according to Murphy's and Riley's method. 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.

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.

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.

RESULTS AND DISCUSSION

RESULTS

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 I). 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 ($p=0.022$).

Table I: 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.

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 II). 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 ($p=0.022$).

Table III: 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.

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 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 III).

Table IIIII: 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;

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 IV). 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).

Table IVV: 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	*	

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 V). Analysis of variance on chemical characteristics between IMA and IMC revealed a highly significant difference on Cdt (p=0.004).

Table V: 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.

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 VI). 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).

Table VI: 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*

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 VII). 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 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).

Table VII: 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*	***	*****	****

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 VIII). 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).

Table VIII: 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*

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 IX). Analysis of variance on organic status revealed a significant difference on C/N (p=0.04).

Table IX: 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*	***

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 X). 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).

Table X: 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*	****	*

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

Table XI: 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***	*****	******	

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 XII). 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).

Table XII: 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***	

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 XIII). 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).

Table XIII: 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*

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 XIV). 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)

Table XIV: 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*

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 XV). 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).

Table XV: 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*

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 XVI). 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).

Table XVI: 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*	***

DISCUSSION

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.

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.

CONCLUSIONS

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.

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