Comparative study of the properties of three types of land use belonging to the hydromorphic soil class of the corridors of the Benoue National Park

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Abstract

Soil, with its multiple ecological services is a natural resource. The objective of the study is to assess the level of soil degradation in the seven corridors (GalerieForestière, Buffle, Girafe, Hippotrague, Eland de derby, Cob Défassa and Cob de Buffon) of Benoue National Park (BNP), the present study was carried out from March to July 2016. "*In situ*" (soil pit) and "*ex situ*" (laboratory analysis) evaluation methods were used. Evaluation of physical properties of corridors soil showed the existence of different textures depending on the type of soil occupation, ranging from sandy, loamy to sandy-silt texture. Values of bulk density ($\chi^2 = 0.16$, ddl = 12, P = 1), negatively correlated with the total porosity ($\chi^2 = 2.54$, ddl = 12, P = 1) in each case, indicating the low state of soil compaction. Analysis of chemical parameters of soil based on the determination of pH, electrical conductivity, organic matter, potassium, nitrogen, and phosphorus contents, emphasized the negative effect of chemical pesticide residues on the environment. These different methods have highlighted the impact of cropping systems on soil degradation. It is therefore urgent to undertake methods of restoring these soils in order to preserve BNP from degradation.

1. Introduction

Soil is a living environment resulting from the physical and chemical alteration of the mother rock under the action of climatic (temperature, precipitation, humidity...) and biological agents [1-2]. It provides several ecological functions [3]: biological function, food function, storage and support function, socio-cultural function [4] and regulator function [5]. Unfortunately, this multi-service structure, formed over several millennia, is easily degraded and non-renewable on a human scale [6].

However the human action on the ground through his activities (agriculture, gold planning)considerably altered these properties and may lead to so called degradation phenomenon. Soil degradation is a process of reducing or losing its productivity and its biological and / or economic complexity; it is also an alteration of its physical, biological and chemical properties [7-8].

In Northern Cameroon, humans and their activities associated with irregular rainfall and very high annual average temperature are the engines of acceleration of this phenomenon [9-10-11].

This region has three protected areas (about 44% of its surface area) communicating with one another through the corridors belonging to the Benoue National Park (BNP) [12]. These protected areas have the role of conserving biodiversity and natural resources such as soils. With the population growth in the neighborhood of the BNP, the populations invaded the corridors for the practice of their activities the example agriculture as an important soil degradation factor and an impediment to wild life migration via corridors[12-13].

In the Northern Region, few studies have being focused on soil management and conservation strategies, mainly in the BNP and its corridors where the most recent soil work dates back to 1974. It is in this context that

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the present study aims to assess the level of physical and chemical properties of BNP corridors soils, with a view to promote a better management of its resources and to optimize of the plan of restoration of degraded soils.

It is the same for three types of soils of Saïs in Morocco whose physico-chemical characterization is rarely discussed in detail [14].

2. Material and methods

2.1. Study site

The study was carried out in the seven corridors of the Benoue National Park (BNP). These corridors bear the names of some emblematic animals found there. These corridors were located in three of the eight Areas of Interest (ZIC 1, 2, 3, 4, 5, 7, 9 and 15) surrounding the BNP (Figure 1)[10]: ZIC N ° 1 known as *Sakdjé* (39,552 ha) which includes the corridors *Galerie Forestière*(0,5 km), *Buffle* (3 km) and *Girafe* (8 km); ZIC No. 4, known as *Bel Eland* (40.64 ha) with corridors *Hippotrague* (5.2 km), *Eland de derby* (7 km) and *Cob Défassa* (2 km) and ZIC N ° 15 known as *Faro Coron* (76.128 ha) with a unique *Cob de Buffon* corridor (4.6 km) [13-15], (Figure 1).
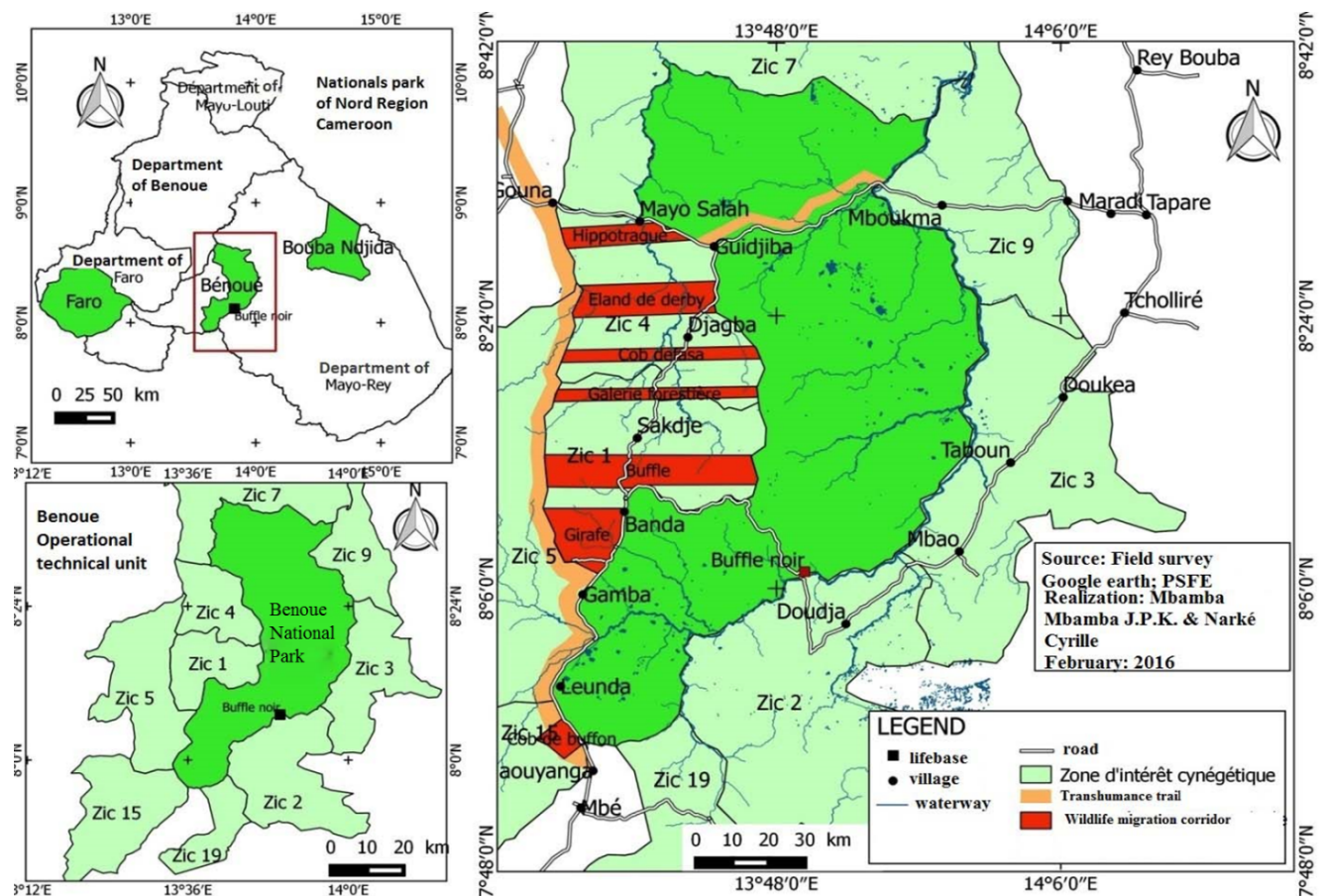
Figure 1: Presentation of the study area

2.2. Methods for assessing the soil properties of corridors in the Benoue National Park

The evaluation methods were used "*in situ*" and "*ex situ*" (in the laboratory) on field soils (FS), fallow (control soil, T1 means not Exploited by man) and permanently naked (control soil, T2). These soils were selected based on vegetation cover during the rainy season.

The methods for evaluating these properties were carried out on uniform plots of 400 m^2. The pitch between the plots was one kilometer and three repetitions were made by land-use and corridor types.

2.2.1.In situ evaluation of soils in park corridors

Soils physical properties were evaluated "*in situ*" on samples obtained from soil pits [16-17]. The soil pit was excavated to a 30 cm depth and provided information on the state of water saturation, porosity, color, presence of herbaceous roots and root hairs. The state of water saturation was determined by touch and physical observations were made to determine whether the soil is dry or moist. The porosity was determined from the

observation of the pores on the clods. The color was evaluated with the Munsell soil color charts. The study of roots was based on a physical description of the shape and abundance of roots in the soil.

2.2.2. Ex situ evaluation of soils in park corridors

Laboratory evaluation revealed the physical and chemical properties of 63 soil samples taken from different corridors. Each sample was composed of five subsamples packaged, labeled and stored in plastic bags. These samples were taken between 0-30 cm depth. In the laboratory, samples were stripped and dried in the open air before sieving with a 2 mm mesh screen [18] and stored for further analysis.

2.2.2.1. Physical properties

The following parameters: texture, bulk density and total porosity, allowed for the evaluation of physical properties of the soils samples.
The texture was determined at the end of the granulometric analysis by sieving the samples with different mesh sieves. The bulk density (da, $g.cm^{-3}$) is the mass of a unit volume of soil dried at 105° C for 2 h. This volume was measured by the cylinder method. The porosity expressed as a percentage (%) was determined by the equation below:

$$\text{Total Porosity} = (1 - \frac{\text{Bulk density}}{\text{Actual Density}}) * 100,$$

which the actual density egals to 2.65 g/cm^3[18].

2.2.2.2. Chemical properties

Evaluation of chemical properties concerned soil organic matter, pH, total phosphorus (P_2O_5), potassium (K_2O), nitrogen, carbon and electrical conductivity.
Organic matter content expressed in g.kg-1 (1% = 10 g.kg-1) was determined according to the following equation after loss of the dry matter (organic fraction) of the samples in a temperature oven equal to 500 ° C. for two hours [19];

$$\% \text{ MO} = \frac{(P1 - P0) - (P2 - P0)}{(P1 - P0)} * 100$$

P0 = weight of empty crucible; P1 = final weight = weight of crucible with sample before calcination; P2 = crucible weight + sample after calcination.

The total carbon was deduced from the conventional formula below, where, 1.72 is the average proportion of carbon in the organic matter [20].

$$\text{MO} = \text{C} * 1,72 \rightarrow \text{C} = \frac{\text{MO}}{1,72}$$

pH value was determined at ambient temperature from a glass electrode pH meter on diluted suspension (20 g of sol in 200 ml of distilled water) and homogenized with an electric stirrer [21].

Electrical conductivity was measured by using an electrode conductivity meter on an aqueous extract (20 g of soil diluted in 200 ml of distilled water) homogenized using an electric stirrer [21].

P_2O_5, K_2O and nitrogen content were determined by assay in these soil samples using the "Nice soil testing kit" revised on July 1, 2007 (ISO 9001). These contents were determined colorimetrically according to well-known stallion games.

2.3. Statistical analysis

Different measurements were analyzed using the Microsoft Excel 2010 and XLSTAT 2016 software were used for calculations (average, standard deviations and chi 2).

3. Results and discussion

3.1. Properties of soils in the corridors of the Benoue National Park

3.1.1. Physical properties

3.1.1.1. In situ assessment of soils in the corridors of the Benoue National Park

The study of the soil pit show a variation of the soil parameters studied according to the activities carried out there in layers or horizons (Table 1). In the superficial horizon (0-15 cm), the soils of the fields had a gray (10 YR 5/1) loose structure, somewhat porous, some roots devoid of absorbent hairs. Fallow soils have a gray (10 YR 3/1), lumpy structure with many roots and absorbent hairs. In permanently bare soils, the structure was particulate, gray (10 YR 5/1), non-porous and not rooted (Table 1). The lumpy structure and the black gray color are indicative of the good functioning of a soil provided with microorganisms and of organic matter (fallow soils) compared to gray-colored loose and soils in particles. The absence of roots other than crops can be

explained by the use of selective plant herbicides in agriculture. These results compared with those of [18] are different at some points but similar in others. In the fields they had the following characteristics: moist soil, brown to mottled brown (2.5 YR 4/3 to 7.5 YR 3/4), with low humus penetration and a lumpy structure with some roots. In fallow soils, moisture varies from medium to low, the coloring is either brown dark brown, red or brown (2.5 YR to 7.5 YR) and spotted (2.5 YR / 4/3), Humeral penetration varies from low to medium, with rather remarkable presence of roots. In this study, regardless of soil types, the soil structure did not vary as a function of depth, while the color varied for the brown yellow on the horizon 15 - 30 cm same as the porosity. In addition, the occurrence of roots was a function of the type of land use. The variation in porosity reflects a negative change in the physical properties of the soil which is correlated with the decrease or absence of roots in some layers.

The presence of roots in the fields was low because of the action of herbicides compared to the abundance of roots in fallow soils.

Table 1: Physical properties of soils in the corridors of Benoue National Park

Parameters studied	Land use					
	Field soil		Fallow land		Floor permanently naked	
Depth(cm)	0 - 15	15 - 30	0 - 15	15 - 30	0 - 15	15 - 30
Soil Condition	wet	Wet	wet	wet	Wet	wet
Erosion	yes++	No	yes+	no	yes+++	no
Color	10 YR 5/1	10 YR 5/4	10 YR 3/1	10 YR 5/1	Gray	10 YR 5/1
Live roots	yes+	No	yes +++	yes++	No	no
Absorbent hair	no	No	yes +++	yes++	No	no
Porosity	yes+	No	yes+++	yes+	No	no
Structure	soft	soft	Grumpy	Grumpy	Particulate	Particulate

Legend : Black gray: (10 YR 3/1) ; yellow brown: (10 YR 5/4) ; gray : (10 YR 5/1) ; + : poor ; ++ : important ; +++ : most important.

In the view of the results of the field evaluation, fallow soils have good physical properties, unlike field soils and permanently naked soils; this difference materializes the state of degradation of agricultural soils whose properties are similar tothose of permanently naked soils but are not sufficient to conclude on the condition of soils that require in-depth laboratory analysis.

3.1.1.2. Ex situ assessment of soils in the corridors of the Benoue National Park

- Texture

In all, the permanently naked soils have poor textural properties as well as the fields and fallow soils of the "Galerie Forestière", "Buffle and Hippotrague". Only "Cob de Buffon", "Cob Défassa", "Eland de Derby" and the fallow fields in "Hippotrague", "Eland de Derby", "Cob Défassa", "Girafe" and "Cob de Buffon" have good textural properties (Table 2).

Table 2: Content of different soil particles (%)

Co	Land use											
	Fields				Fallow land				Floor permanently naked			
	S	Si	C	Texture	S	Si	C	Texture	S	Si	C	Texture
Hip	29,84	43,64	20,04	LS	30,93	43,39	25,53	LSA	40,3	42,69	16,37	LS
ED	13,49	56,84	29,19	LA	33,21	39,97	26,43	LSA	26,0	50,03	23,66	LS
CD	32,27	36,43	30,63	LSA	20,87	38,77	29,37	LA	33,4	44,83	21,39	LS
GF	64,47	18,17	16,97	S	57,68	21,34	20,81	S	53,8	21,14	24,70	S
B	50,85	19,60	23,06	S	51,95	18,76	18,31	S	52,3	22,98	23,86	S
Gif	36,81	26,84	35,73	SAL	45,69	26,79	27,02	SAL	50,5	24,19	25,06	SA
CB	43,62	26,24	29,88	SAL	40,55	28,48	30,31	SAL	52,1	23,76	22,94	S

Legend : Co : corridors ; Hip : Hippotrague ; ED : Eland de Derby ; CD : Cob Défassa ; GF : Galerie Forestière ; B : Buffle ; Gif : Girafe ; CB : Cob de Buffon ; S : Sand ; Si : Silt ; C : Clay.

These good properties are due to a balanced distribution of the various particles and to the suitably associated proportions of the silts and clays. [22]in their work have obtained results different from those of the present work in cultivated soils and forests whose texture is dominated by sands. The difference may be due to the methods used by the authors.

Bulk Density (Bd) and Total Porosity (TP)

Overall, land use patterns did not influence bulk density ($\chi^2 = 0.16$, ddl = 12, P = 1), whose values were not significantly different (Table 3), the total porosity being related to the bulk density also did not vary ($\chi^2 = 2.54$, ddl = 12, P = 1). But these values are higher than those of the bulk density.

In reference to the values of [23], who estimated that average values of total porosity are between 50% and 75%, it can be concluded from the values in Table3 that soils are in a poorly compact state, the circulation of the water is more or less important, the water storage capacity is low, that there are pores necessary for the circulation of the fluids and the development of the roots. These results of the bulk density are different from those of [24] in herbicide treated fields (high density) and vegetation covered soils (lower density) but similar in plowed orchards (medium density). In comparison with the work of [18] the values of total porosity are different from those of the present study in cultivated soils but similar in fallow plots.

Table 3: Average bulk density and total porosity

Cor	Land use					
	Field Soil		Fallow land		Floor permanently naked	
	Bd (g.cm-3)	TP (%)	Bd (g.cm-3)	TP (%)	Bd (g.cm-3)	TP (%)
Hip	0,92 ± 0,01	65 ± 0,21	0,88 ±0,06	67 ± 2,35	0,92 ± 0,04	65 ± 1,25
ED	0,55 ± 0,03	79 ±1,09	0,85 ±0,06	67 ± 2,12	0,92 ± 0,04	65 ± 0,25
CD	0,89 ± 0,02	67 ±0,76	0,77 ± 0,13	71 ± 4,71	0,91 ± 0,15	66 ± 1,63
GF	0,83 ± 0,06	69 ± 2,23	0,82 ± 0,02	69 ± 0,76	0,96 ± 0,29	64 ± 4,65
B	0,97 ± 0,02	63± 0,82	0,72 ± 0,06	73 ± 2,26	0,95 ± 0,04	64 ± 0,25
Gif	0,74 ±0,13	72 ± 4,82	0,91 ± 0,02	66 ± 0,70	0,99 ± 0,06	63± 1,89
CB	0,92 ± 0,06	65 ± 2,27	0,87 ± 0,02	67 ± 0,65	0,91 ± 0,04	66 ± 1,38

Légende : Cor : corridor ; Hip : Hippotrague ; ED : Eland de Derby ; CD : Cob Défassa ; GF : Galerie Forestière ; B : Buffle ; Gif : Girafe ; CB : Cob de Buffon ;Bd : bulkdensity; TP : total porosity

3.1.2. Chemical properties of soils

The chemical properties of soils (organic matter, carbon, nitrogen, total phosphorus (P_2O_5), total potassium (K_2O), pH, and electrical conductivity) varied according to land use patterns (Table 4).

The percentage of organic matter ($\chi^2 = 32.35$, ddl = 6, P> 0.01) and carbon ($\chi^2 = 11.27$, ddl = 6, P <0.05) in fields and soils permanently naked. All the same, the values of these two parameters are significant in the fields of the corridors Galerie Forestière and Cob Défassa. This high content of organic matter and carbon can be explained by the density of the vegetation and the fauna of the soil as well as by the low runoff of the rainy waters. These results are different from those obtained by [24] that showed significant variation in organic matter in herbicide treated plots, plowed plots and fallow plots.

Field soils ($\chi^2 = 22.98$, ddl = 6, P <0.01) and fallow soils are more nitrogen-rich ($\chi^2 = 14.55$, ddl = 6, P <0.01) than permanently bare floors. This result can be explained by the use of N / P / K inputs (20/10/10) in fields and by the abundance of earthworms in fallow plots. The same is true for phosphorus and potassium which have high values in fields where N / P / K inputs are used (20/10/10) than in fallow soils and permanently naked soils. These results are similar to those of [21] whose NPK content was high in the fields where these inputs were used.

With some exception, the soils are predominantly saline because the electrical conductivity values are less than 25 mS / cm. This result is different from that of [21]whose electric conductivity values are less than 4 dS / m certainly because of the types of soil studied that are not only rich in water but contain many microorganisms.

The pH is low in the soils of permanently bare plots and ranges from 5.50 ± 0.01 to 6.07 ± 0.09. Soils of this type are appropriate for plant growth as indicated by [25]. This result may explain the scarcity of vegetation on the parks that are permanently naked.

Table 4: Soil chemical parameters in corridors according to types of land use

Corridors	Types of land use	OM (g/kg)	C (g/kg)	N (Kg/ha)	P_2O_5 (Kg/ha)	K_2O (Kg/ha)	pH	EC (mS/cm)
				Averagechemicalparametersstudied				
Hippotrague	FS	$23,17 \pm 11,94^a$	$13,47 \pm 6,94^a$	$198,15 \pm 2,70^a$	$4,2 \pm 6,26^b$	$61,47 \pm 0,43^a$	$6,31 \pm 0,01^a$	$45,43 \pm 0,50^a$
	T1	$91,07 \pm 11,42^a$	$52,95 \pm 6,40^b$	$113,5 \pm 1,80^a$	$0,7 \pm 3,74^a$	$25,9 \pm 0,67^b$	$6,98 \pm 0,01^a$	$35,13 \pm 0,67^b$
	T2	$10,33 \pm 0,88^b$	$6,01 \pm 0,51^b$	$13,9 \pm 2,71^b$	$1,5 \pm 0,01^a$	$16,33 \pm 0,14^{ba}$	$5,56 \pm 0,01^a$	$28,97 \pm 0,28^b$
Eland de Derby	FS	$18,60 \pm 12,30^a$	$10,81 \pm 7,15^a$	$117 \pm 52,49^a$	$6,6 \pm 6,60^a$	$71,27 \pm 0,74^a$	$6,68 \pm 0,01^a$	$25,40 \pm 0,53^a$
	T1	$84,20 \pm 11,28^b$	$48,95 \pm 6,42^b$	$132,5 \pm 2,25^a$	$1,6 \pm 9,90^b$	$23,70 \pm 1,50^b$	$6,89 \pm 0,01^a$	$44,20 \pm 0,51^b$
	T2	$13,07 \pm 0,12^a$	$7,60 \pm 0,07^a$	$24,0 \pm 2,88^b$	$1,9 \pm 0,00^b$	$19,23 \pm 0,55^b$	$5,75 \pm 0,01^a$	$34,67 \pm 062^b$
Cob Défassa	FS	$50,27 \pm 39,12^a$	$29,22 \pm 22,75^a$	$87,9 \pm 38,25^a$	$2,8 \pm 0,04^a$	$53,90 \pm 0,76^a$	$6,86 \pm 0,01^a$	$19,20 \pm 0,70^a$
	T1	$90,13 \pm 11,04^a$	$52,40 \pm 6,42^a$	$109,2 \pm 1,85^a$	$2,9 \pm 0,04^a$	$21,37 \pm 0,58^b$	$6,76 \pm 0,01^a$	$40,67 \pm 1,07^b$
	T2	$9,67 \pm 0,33^b$	$5,62 \pm 0,19^b$	$31,3 \pm 1,37^b$	$2,5 \pm 0,01^a$	$16,80 \pm 0,36^b$	$5,50 \pm 0,01^a$	$45,40 \pm 0,42^b$
Galerie Forestière	FS	$69,93 \pm 23,12^a$	$25,37 \pm 14,53^a$	$159,1 \pm 106,93^a$	$7,6 \pm 8,29^a$	$66,67 \pm 0,70^a$	$6,63 \pm 0,01^a$	$24 \pm 0,55^a$
	T1	$100,70 \pm 5,62^a$	$58,55 \pm 3,28^a$	$141,5 \pm 2,05^a$	$1,5 \pm 14,3b^a$	$35,33 \pm 0,71^b$	$6,91 \pm 0,01^a$	$44,35 \pm 0,61^b$
	T2	$23,03 \pm 0,15^b$	$13,39 \pm 0,08^b$	$17,4 \pm 2,25^b$	$2,7 \pm 0,08^b$	$22,17 \pm 0,34^b$	$6,03 \pm 0,09^a$	$41,67 \pm 0,37^b$
Buffle	FS	$19,63 \pm 6,04^a$	$11,41 \pm 14,53^a$	$128,5 \pm 54,39^a$	$9,8 \pm 28,30^a$	$80,83 \pm 0,39^a$	$6,90 \pm 0,06^a$	$49,73 \pm 0,26^a$
	T1	$88,03 \pm 5,27^b$	$51,18 \pm 3,06^b$	$174,9 \pm 48,69^a$	$1,2 \pm 26,11^b$	$31,60 \pm 0,46^b$	$7,18 \pm 0,04^a$	$41,71 \pm 0,54^b$
	T2	$13,23 \pm 0,18^a$	$7,69 \pm 0,10^a$	$25,6 \pm 2,40^b$	$0,8 \pm 0,02^b$	$25,80 \pm 0,25^b$	$6,07 \pm 0,09^a$	$45,23 \pm 0,38^b$
Girafe	FS	$18,43 \pm 9,68^a$	$10,72 \pm 5,63^a$	$141,2 \pm 74,45^a$	$8,7 \pm 20,60^a$	$76,20 \pm 0,38^a$	$7,71 \pm 0,01^a$	$29,27 \pm 0,33^a$
	T1	$105,93 \pm 11,27^b$	$61,59 \pm 6,55^b$	$119,5 \pm 1,20^a$	$1,9 \pm 17,29^b$	$24,83 \pm 0,47^b$	$7 \pm 0,06^a$	$45,73 \pm 0,62^b$
	T2	$11,00 \pm 0,58^a$	$6,01 \pm 0,16^a$	$30,5 \pm 6,22^b$	$0,9 \pm 0,02^b$	$31,83 \pm 0,38^b$	$5,90 \pm 0,06^a$	$39,83 \pm 0,55^b$
Cob de Buffon	FS	$25,60 \pm 13,45^a$	$14,88 \pm 7,82^a$	$135,1 \pm 14,43^a$	$5,9 \pm 9,40^a$	$135,53 \pm 0,69^a$	$6,88 \pm 0,01^a$	$23,87 \pm 12,15^a$
	T1	$86,07 \pm 8,19^b$	$50,04 \pm 4,76^b$	$124,1 \pm 0,89^a$	$1,1 \pm 5,20^b$	$27,20 \pm 0,61^b$	$6,90 \pm 0,06^a$	$34,58 \pm 0,64^b$
	T2	$11,67 \pm 0,88^a$	$7,36 \pm 0,16^a$	$21,5 \pm 5,58^b$	$0,8 \pm 0,02^b$	$21,37 \pm 0,67^b$	$5,62 \pm 0,01^a$	$42,13 \pm 0,32^b$

Legend : FS : Field Soil ; T1 :Fallow land; T2 :Permanently bare soil; The values preceded by the same alphabetical letter are not statistically different from the probability threshold dP = 0,05 ; OM :Organic Matter ; C : carbon ; N : nitrogen ; P_2O_5 : total phosphorus ; K_2O : Total potassium; EC :electrical conductivity.

Conclusion

At the end of this work focused on the assessment of the level of soil degradation in the corridors of the Benoue National Park (BNP).The influx of the population around the park and its periphery is at the origin of the crowding of the corridors and so a change of occupation of the soil. The evaluation of physical and chemical properties of the soil (tree) in function to their occupation has shown a variation of different parameters.

The properties of the soils of the fields in comparison with the fallow soils and the soils permanently naked made it possible to observe that the soils of the fields have lost some of their physical parameters; chemical and biological invading with an approachment with the properties of the soils permanently Nudes. Loss of these properties inevitably leads to loss of soil functions and consequent loss of corridor functions. However, inputs used by farmers to optimize soil fertility do not supplant the role played by soil microorganisms, in this case earthworms. It will be necessary to develop measures to limit farmers' access to the surrounding park and urgent to implement methods of erosion control, soil restoration and conservation methods. These methods must take into account the peasant techniques, their financial means and their levels of study.

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