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Impacts of use of conventional tillage tools on cultivated soil in Southern Alibori in Benin

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Abstract

The objective of the study was to assess the impact of motorized ploughing tools on the physicochemical and biological properties of the soils in southern Alibori in Benin. The ploughing tools tested were the disc plough for ploughing at 10 cm (CD10) and 20 cm deep (CD20), the moldboard plough at 10 cm (CS10) and 20 cm deep (CS20), the rotavator (Ro) and daba (Ho). A Random Complete Blocks Design constituted of six tools and three replications implemented on Bensékou, Kokey and Banigouré sites over three campaigns. The parameters measured on the ground were water, carbon and nitrogen content, bulk density, available water content and macrofauna biomass. The results showed that the ploughing implements significantly ($p < 0.001$) reduced the water content by 3 ± 0.25%, the bulk density by 0.2 ± 0.01 g/cm^3, the carbon content by 0.6 ± 0.05%, the nitrogen content of 0.02 ± 0.001% and the macrofauna biomass of 0.8 ± 0.07 g/100 cm^2 in a 0 - 10 cm layer. In 10 - 20 cm layer, only CS20 and CD20 ameliorated available water content by 4 ± 0.26 mm and nitrogen content by 0.3 ± 0.16% and reduced macrofauna biomass by 0.7 ± 0.09 g/100 cm^2. Given the ecology of the cotton plant, the ploughing depth required for good soil preparation is 20 cm.

Keywords: Benin, depth, ploughing, soil, tools.

Impacts de l'utilisation des outils de labour conventionnel sur les sols cultivés dans le Sud-Alibori du Bénin

Résumé

L'objectif de l'étude était d'évaluer l'impact des outils de labour motorisé sur les propriétés physico-chimiques et biologiques des sols du Sud–Alibori au Bénin. Les outils de labour testés étaient la charrue à disques utilisée à 10 cm (CD10) et 20 cm de profondeur (CD20), la charrue à socs utilisée à 10 cm (CS10) et 20 cm de profondeur (CS20), le rotavator (Ro) et la daba (Ho). Un dispositif en blocs aléatoires complets constituée de six traitements avec trois réplications a été mis en place sur les sites de Bensékou, Kokey et Banigouré sur trois campagnes agricoles. Les paramètres édaphiques mesurés étaient la teneur en eau, en carbone et en azote, la densité apparente, la réserve utile et la biomasse de la macrofaune. Les résultats ont montré que les outils de labour réduisaient significativement ($p < 0,001$) la teneur en eau de 3 ± 0,25%, la densité apparente de 0,2 ± 0,01 g/cm^3, la teneur en carbone de 0,6 ± 0,05%, la teneur en azote de 0,02 ± 0,001% et la biomasse de la macrofaune de 0,8 ± 0,07 g/100 cm^2 à l'horizon 0 - 10 cm du sol. Dans les couches 10 - 20 cm du sol, seuls CS20 et CD20 ont amélioré la réserve utile de 4 ± 0,26 mm et la teneur en azote de 0,3 ± 0,16% et réduit la biomasse de la macrofaune de 0,7 ± 0,09 g/100 cm^2. Compte tenu de l'écologie du cotonnier, la profondeur de labour nécessaire à une bonne préparation du sol est de 20 cm.

Mots-clés : Bénin, profondeur, labour, sol, outils.

INTRODUCTION

Agriculture is one of the pillars of Benin's economy representing 25.6% of the country's Gross Domestic Product (GDP) in 2017 (Baye, 2018). The climate and the diversity of soil types are favourable to the diversification of agricultural production (Ministry of Agriculture, Livestock and Fisheries (MAEP Benin), 2011) and allow the development of several agricultural sectors. Among these sectors, the cotton sector was by far the best organized and in 2013 enabled a zoning plan for the Benin cotton basin into four production zones. The most important production zone in terms of sown areas is the Alibori Department with 246,088 ha against 90,750 for the Borgou zone, 105,365 ha for the Atacora - Donga zone and 81,288 ha for Centre and South Benin (INSAE Benin, 2020). These sown areas, which are increasing from year to year, are not only the consequences of an organized sector but also of the attractiveness of cotton prices (Bonou-Zin *et al*., 2018) and agricultural motorization. In fact, initiated in 2008, the use of tractors has started to revolutionize cotton production, allowing production to grow by mowing large areas in a short time.

The examination of the environment of the zones of strong cotton production in particular the department of Alibori showed a strong erosion of the grounds and the decrease of fertility of the cultivable grounds, generated by the culture of cotton and the obsolete farming practices (Batamoussi Hermann *et al*., 2015). The increase in yield from the rudimentary period to the tractor period (211,751 tons in 2008 to 714,714 tons in 2019 (INSAE Benin, 2020) undoubtedly pleased producers and decision-makers. However, productivity during this period hardly exceeds 1.124 t/ha obtained during 2017 (INSAE Benin, 2020). The use of tractors and imported ploughs on types of soil in Benin have undoubtedly worsened the ills encountered by producers in this cotton zone. Indeed, the use of motorization raises controversies around its impact on the structural state of the soil and crop yields. Tillage by motorized traction causes more degradation than in manual cultivation and fallow (Pouya *et al*., 2013). Mechanized systems create a greater disturbance of the soil structure in relation to the nature of the equipment used (Rhyan *et al*., 2008).

Faced with the lack of knowledge of the adaptability of the motorized tools used in Benin depending on the pedoclimatic conditions of the production areas, the choice of suitable equipment becomes complex for producers and decision-makers. To overcome this knowledge gap, this study aims to describe in the short term the impact of the use of various motorized tools on the physicochemical and biological parameters of the soil in the Alibori cotton zone.

STUDY AREA

The study was carried out in the three main cotton-producing municipalities of Alibori Department, namely Banikoara, Kandi and Gogounou. The choice of these municipalities was based on the areas sown for cotton cultivation during the 2017 - 2018 campaign i.e. 109,411 ha for Banikoara, 55,744 ha for Kandi and 35,255 ha for Gogounou (INSAE Benin, 2020). In these three communes, Kokey (Banikoara), Bensékou (Kandi) and Banigouré (Gogounou) were selected as the experimental environment (Figure 1).

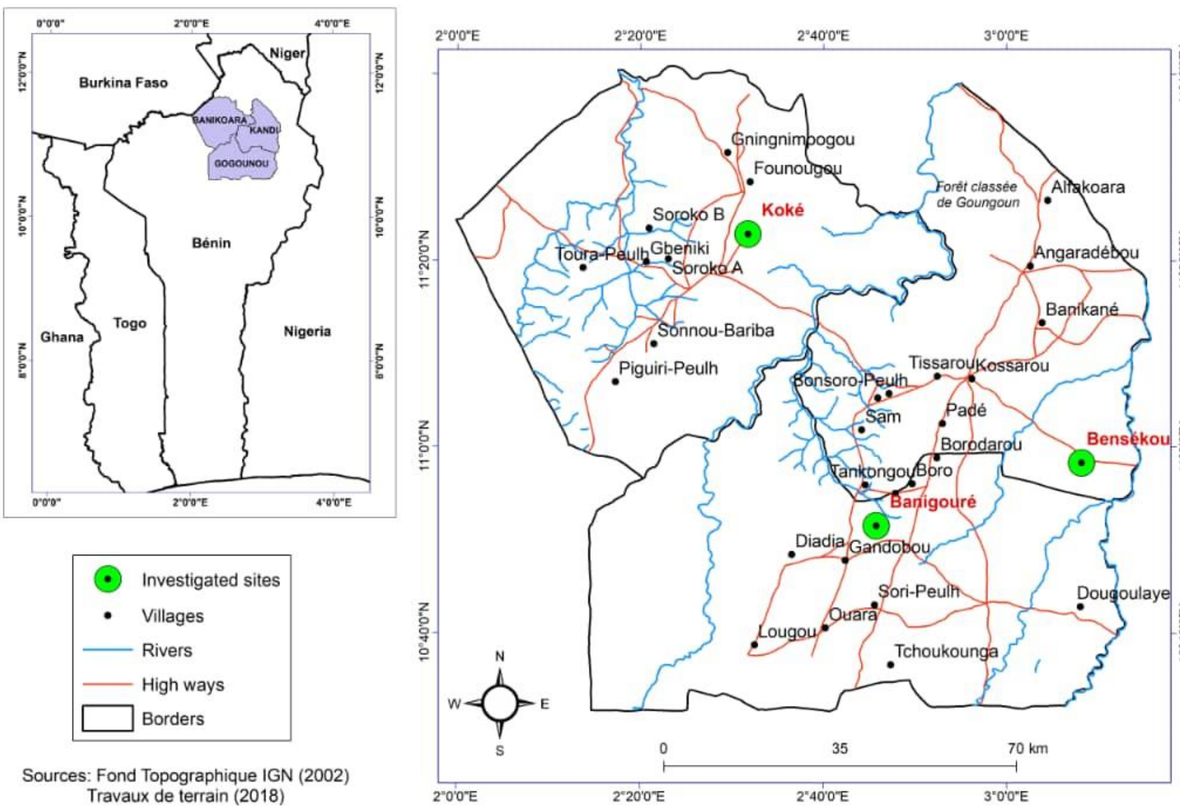

Figure 1. The location of the experimental sites

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MATERIALS AND METHODS

Equipment and experimental design

Motorized agricultural operations consisted of soil preparation operations mainly focused on ploughing. It was carried out with different ploughing tools according to the experimental device. For motorized ploughing, a 52 HP tractor was used. The various support tools used were: 3- disc plough 1.2 m wide; 3- moldboard plough 1.2 m wide; rotavator with a ploughing width of 1.3 m and daba for manual ploughing. To achieve the objective, a Random Complete Blocks Design with six treatments and three replications was implemented at the three experimental sites. These treatments included the disc plough used at 10 cm deep (CD10) and 20 cm deep (CD20), the moldboard plough at 10 cm deep (CS10) and 20 cm deep (CS20), the rotavator (Ro) and the daba (Ho). The blocks measured 30 m by 5 m, each divided into six square plots of 5 m per side.

Sampling and data collection

During the months of June 2019, 2020 and 2021, soil samples were taken, according to the method of Mathieu and Peiltain (2003), before and after soil preparation on each elementary plot. Pits 30 cm deep were dug on each elementary plot to identify the depths of the samples (0 - 10 cm and 10 - 20 cm). The samples were taken using the standard density cylinder with a density of 100 cm^3 capacity. Composite soil samples were taken and then brought to the Soil Science Laboratory of the Faculty of Agronomic Sciences of the University of Abomey - Calavi (FSA / UAC) for analyses. These analyses focused on the nitrogen, carbon and water content, the bulk density, the available water content and the weight per unit area of the macrofauna.

Statistical analyzes

To compare the effect of ploughing tools on the physicochemical (bulk density, humidity, carbon and nitrogen content, available water content) and biological (weight of macroorganisms) properties for each soil layer (0 - 10 cm and 10 - 20 cm), the linear mixed-effects model was used. The "ploughing tools" factor was the fixed factor, the "site" and "campaign" were the random factors and the "block" nested in factor “site”. R 3.6.3 (R Core Team, 2019) was used for statistical analyzes.

RESULTS

Soil physical properties

Water content

The results of linear mixed-effect models applied to the moisture content data were summarized in Table 1. The latter showed a significant impact of all ploughing tools on the water content compared with the initial state in the 0 - 10 cm soil layer ($p < 0.001$). The impact of ploughing consisted of a reduction in water content of this layer of more than 3 ± 0.25% for all the equipment (Table 1). However, these variations were significantly dependent on site and year of culture ($p < 0.05$).

Table 1. Effects of ploughing tools on water content

Soil horizons	Source of variation	Coefficient (SE)	t value	Probability
0 - 10 cm	Intercept	12.11 (0.96)	12.66	0.001*
	CD10	-3.24 (0.25)	-12.89	< 0.001*
	CD20	-3.11 (0.25)	-12.41	< 0.001*
	CS10	-3.21 (0.25)	-12.79	< 0.001*
	CS20	-3.03 (0.25)	-12.06	< 0.001*
	Ho	-3.16 (0.25)	-12.60	< 0.001*
	Ro	-3.01 (0.25)	-12.00	< 0.001*
	Variance due to site *(Probability)*	2.234 *(0.007)* *		
	Variance due to block (site) *(Probability)*	0.003 *(0.896)*		
	Variance due to campaign *(Probability)*	0.412 *(< 0.001)* *		
	Variance to residual	1,701		
10 – 20 cm	Intercept	10.65 (0.66)	16.19	< 0.001*
	CD10	-0.18 (0.17)	-1.05	0.294

Soil horizons	Source of variation	Coefficient (SE)	t value	Probability
	CD20	-2.50 (0.17)	-14.45	< 0.001*
	CS10	-0.29 (0.17)	-1.70	0.09
	CS20	-2.60 (0.17)	-15.05	< 0.001*
	Ho	-0.23 (0.17)	-1.31	0.192
	Ro	-0.35 (0.17)	-2.01	0.044*
	Variance due to the site *(Probability)*	0.325 *(0.021)* *		
	Variance due to block (site) *(Probability)*	0.00 *(1)*		
	Variance due to campaign *(Probability)*	0.930 *(< 0.001)* *		
	Variance to residual	0.807		

Block (site): "block" nested in factor "site"; *: significance at the 5% level

Bulk density

The model applied to the bulk density data, presented in Table 2, indicated in 0 - 10 cm layer, a significant ($p < 0.001$) influence of all tillage implements on the bulk density. Compared with the initial conditions, while CD10 decreased bulk density by 0.20 ± 0.01 g/cm^3, CD20 and CS20 influenced - 0.19 ± 0.01 g/cm^3. Hu in E0 decreased by 0.18 ± 0.01 g/cm^3, 0.21 ± 0.01 g/cm^3 and 0.22 ± 0.01 g/cm^3 respectively in plots ploughed with Ho, CS20 and Ro. These variations were significantly dependent on site ($p < 0.001$) and year of culture ($p = 0.009$). In 10 - 20 cm layer, only CD20 and CS20 had a significant ($p < 0.001$) impact on bulk density with a decrease of 0.22 ± 0.01 g/cm^3 from bulk density obtained in E0.

Table 2. Effects of ploughing tools on bulk density

Soil horizons	Source of variation	Coefficient (SE)	t value	Probability
0 - 10 cm	Intercept	1.47 (0.02)	61.08	0.001 *
	CD10	-0.20 (0.01)	-15.79	< 0.001 *
	CD20	-0.19 (0.01)	-15.52	< 0.001 *
	CS10	-0.19 (0.01)	-15.45	< 0.001 *
	CS20	-0.21 (0.01)	-16.69	< 0.001 *
	Ho	-0.18 (0.01)	-14.25	< 0.001 *
	Ro	-0.22 (0.01)	-17.74	< 0.001 *
	Variance due to the site *(Probability)*	0.001 *(< 0.001)* *		
	Variance due to block (site) *(Probability)*	0.00 *(0.99)*		
	Variance due to campaign *(Probability)*	0.00 *(< 0.009)* *		
	Variance to residual	0.0042		
10 – 20 cm	Intercept	1.56 (0.03)	56.66	0.010 *
	CD10	-0.03 (0.01)	-2.03	0.043 *
	CD20	-0.23 (0.01)	-17.81	< 0.001 *
	CS10	-0.03 (0.01)	-2.23	0.027 *
	CS20	-0.22 (0.01)	-17.50	< 0.001 *
	Ho	-0.01 (0.01)	-1.06	0.290
	Ro	-0.02 (0.01)	-1.29	0.196
	Variance due to the site *(Probability)*	0.001 *(0.003)* *		
	Variance due to block (site) *(Probability)*	0.00 *(0.190)*		
	Variance due to campaign *(Probability)*	0.00 *(< 0.001)* *		
	Variance to residual	0.005		

Block (site): "block" nested in factor "site"; *: significance at the 5% level

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Available water content (Ru)

In Table 3 were summarized the results of linear mixed-effect models on available water content data. The model showed a significant ($p < 0.05$) effect of the tools used at 20 cm deep on Ru in the 0 - 10 cm layer. The significant effect was a reduction of Ru from the initial state of 6.35 ± 0.78 mm for CD20 and 6.16 ± 0.82 mm for CS20. Likewise, in the 10 - 20 cm layer, only the latter had a significant impact on the soil available water content in E0 ($p < 0.001$). The impact consisted of this layer at an increase of 4.07 ± 0.27 mm for CD20 and 3.99 ± 0.27 mm for CS20. For the two soil layers, the “campaign” factor significantly influenced the variations of this parameter ($p < 0.001$).

Table 3. Effects of ploughing tools on available water content

Soil horizons	Source of variation	Coefficient (SE)	t value	Probability
0 - 10 cm	Intercept	13.45 (0.63)	21.50	0.001 *
	CD10	-6.35 (2.11)	-3.02	0.131
	CD20	-6.35 (0.78)	-8.19	0.003 *
	CS10	-5.75 (2.48)	-2.33	0.172
	CS20	-6.16 (0.82)	-7.46	0.005 *
	Ho	-5.75 (2.25)	-2.56	0.146
	Ro	-6.14 (2.09)	-2.93	0.123
	Variance due to the site *(Probability)*	0.808 *(0.45)*		
	Variance due to block (site) *(Probability)*	0.04 *(0.006)* *		
	Variance due to campaign *(Probability)*	0.30 *(< 0.001)* *		
	Variance to residual	1.07		
10 - 20 cm	Intercept	8.40 (0.71)	11.90	< 0.001 *
	CD10	-0.01 (0.26)	-0.03	0.978
	CD20	4.14 (0.26)	15.94	< 0.001 *
	CS10	-0.01 (0.26)	0.05	0.957
	CS20	4.03 (0.26)	15.49	< 0.001 *
	Ho	0.14 (0.26)	0.55	0.586
	Ro	-0.03 (0.26)	-0.11	0.913
	Variance due to the site *(Probability)*	0.62 *(0.004)* *		
	Variance due to block (site) *(Probability)*	0.046 *(0.164)*		
	Variance due to campaign *(Probability)*	0.759 *(< 0.001)* *		
	Variance to residual	1.825		

Block (site): “block” nested in factor “site”; *: significance at the 5% level

Soil chemical properties

Soil carbon content

The linear model, carried out on carbon content data and summarized in Table 4, indicated a significant impact of all tillage implements on these grades in the 0 - 10 cm layer ($p < 0.001$). While Ho influenced the carbon concentration of the initial conditions of - 0.55 ± 0.05%, CD10, CD20 and CS20 had respective influences of - 0.63 ± 0.05%, - 0.68 ± 0.05% and 0.69 ± 0.05%. Ro and CS10, for their part, reduced the carbon content from the initial state by 0.64 ± 0.05% in all the experimental sites. In lower layers (10 - 20 cm), the impacts of tillage tools were not significant ($p > 0.05$) on the carbon content on all the sites and on all the agricultural campaigns.

Table 4. Effects of ploughing tools on carbon content

Soil horizons	Source of variation	Coefficient (SE)	t value	Probability
0 - 10 cm	Intercept	1.55 (0.10)	16.33	0.009 *
	CD10	-0.63 (0.05)	-13.65	< 0.001 *
	CD20	-0.68 (0.05)	-14.91	< 0.001 *

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Soil horizons	Source of variation	Coefficient (SE)	t value	Probability
	CS10	-0.64 (0.05)	-14.06	< 0.001 *
	CS20	-0.69 (0.05)	-15.14	< 0.001 *
	Ho	-0.55 (0.05)	-12.21	< 0.001 *
	Ro	-0.64 (0.05)	-13.93	< 0.001 *
	Variance due to the site *(Probability)*	0.00 *(1)*		
	Variance due to block (site) *(Probability)*	0.32 *(< 0.001)* *		
	Variance due to campaign *(Probability)*	0.217 *(< 0.001)* *		
	Variance to residual	0.768		
10 – 20 cm	Intercept	0.79 (0.20)	4.06	0.016 *
	CD10	-0.04 (0.05)	-0.77	0.487
	CD20	0.03 (0.32)	0.08	0.945
	CS10	-0.04 (0.04)	-1.11	0.287
	CS20	0.02 (0.31)	0.06	0.956
	Ho	-0.05 (0.06)	-0.84	0.463
	Ro	-0.03 (0.04)	-0.64	0.544
	Variance due to site *(Probability)*	0.72 *(1)*		
	Variance due to block (site) *(Probability)*	0.007 *(0.052)* *		
	Variance due to campaign *(Probability)*	0.797 *(< 0.001)* *		
	Variance to residual	0.545		

Block (site): “block” nested in factor “site”; *: significance at the 5% level

Soil nitrogen content

The impact of all ploughing tools was significant ($p < 0.05$) on the nitrogen content in the surface layers of the soil (table 5). Ploughing implements reduced the nitrogen content of the initial soil state by 0.02 ± 0.003%. This decrease varied greatly from site to site in 0 - 10 cm horizon. In 10 - 20 cm layers, the model revealed a significant impact of the disc and moldboard ploughing at 20 cm depth ($p < 0.001$). The “site” and “campaign” factors also had a significant ($p < 0.05$) impact on the variations in this parameter, induced by power tools.

Table 5. Effects of ploughing tools on nitrogen content

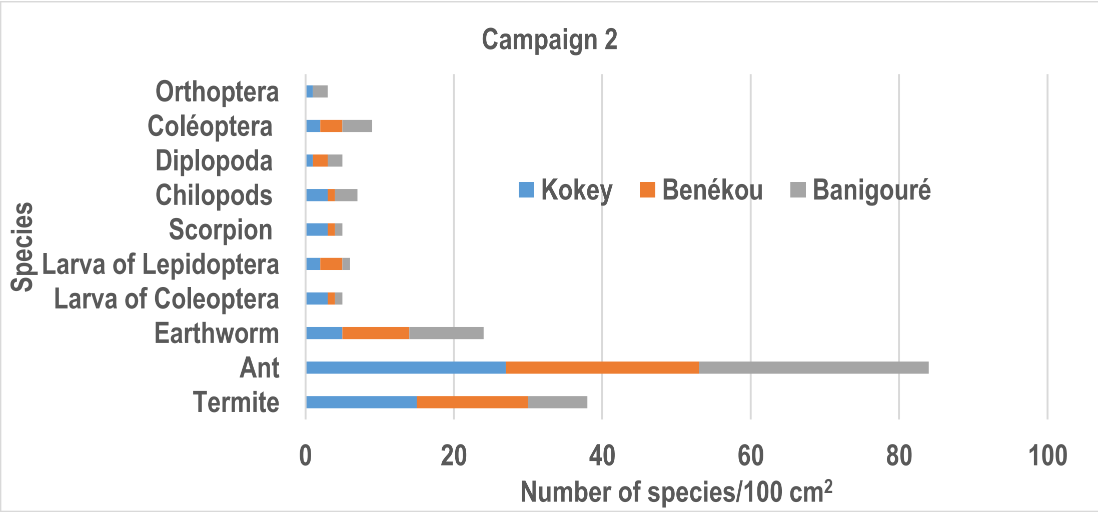
Soil horizons	Source of variation	Coefficient (SE)	t value	Probability
0 - 10 cm	Intercept	0.07 (0.004)	17.04	0.009 *
	CD10	-0.02 (0.00)	-5.98	< 0.001 *
	CD20	-0.02 (0.00)	-7.12	< 0.001 *
	CS10	-0.02 (0.00)	-6.99	< 0.001 *
	CS20	-0.02 (0.00)	-5.53	0.002 *
	Ho	-0.02 (0.00)	-6.55	< 0.001 *
	Ro	-0.02 (0.00)	-6.56	< 0.001 *
	Variance due to the site *(Probability)*	0.0189 *(0.004)* *		
	Variance due to block (site) *(Probability)*	0.00 *(0.999)*		
	Variance due to campaign *(Probability)*	0.0015 *(0.085)*		
	Variance to residual	0.05		
10 – 20 cm	Intercept	0.58 (0.28)	7.63	< 0.001 *
	CD10	0.16 (0.16)	0.28	0.778
	CD20	0.30 (0.16)	7.11	< 0.001 *
	CS10	-0.34 (0.16)	-2.17	0.030 *
	CS20	0.26 (0.16)	6.12	< 0.001 *

Soil horizons	Source of variation	Coefficient (SE)	t value	Probability
	Ho	-0.06 (0.16)	-0.41	0.684
	Ro	-0.38 (0.16)	-2.43	0.016 *
	Variance due to the site *(Probability)*	0.031 *(0.018)* *		
	Variance due to block (site) *(Probability)*	0.016 *(0.165)*		
	Variance due to campaign *(Probability)*	0.022 *(0.007)* *		
	Variance to residual	0.048		

Block (site): "block" nested in factor "site"; *: significance at the 5% level

Soil biological properties

In the study area, several groups of macroorganisms were identified according to soil layers. On both campaigns, in 0 - 10 cm layers, there were large groups of Ants, Termites and Earthworms. Scorpions, Diplopods, Coleoptera and their larvae, Lepidoptera larvae and Orthoptera were present in small numbers. Chilopodes were only distinguished during C2 in 0 - 10 cm layers. Spiders and beetles larva were counted during campaign 3 (Figure 2). Likewise, following the agricultural campaigns in 10 - 20 cm layers, the strongly represented groups were Termites, Ants and Earthworms. Scorpions were notified in C3 only (Figure 3).



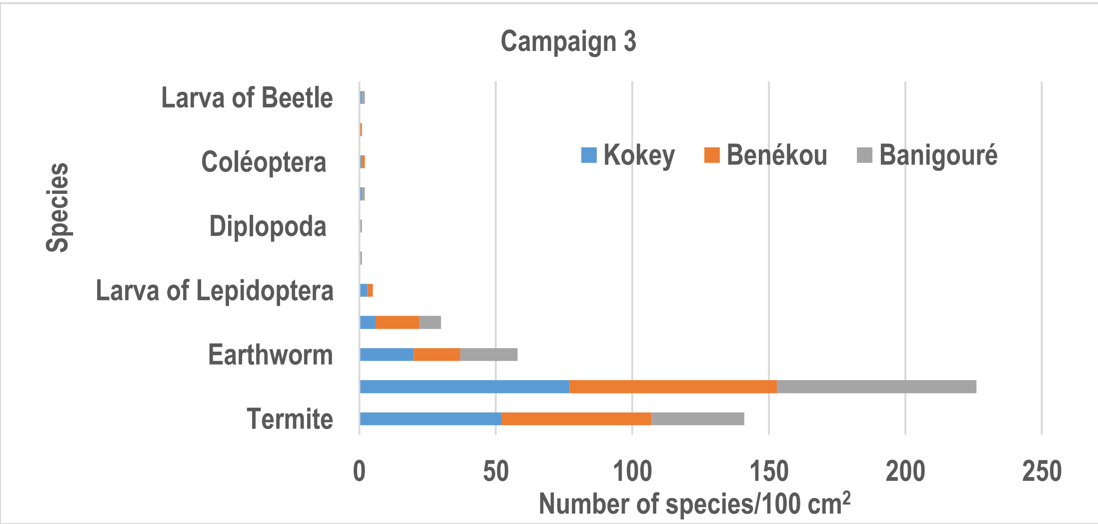


Figure 2. **Macrofauna groups present in 0 - 10 cm layers**

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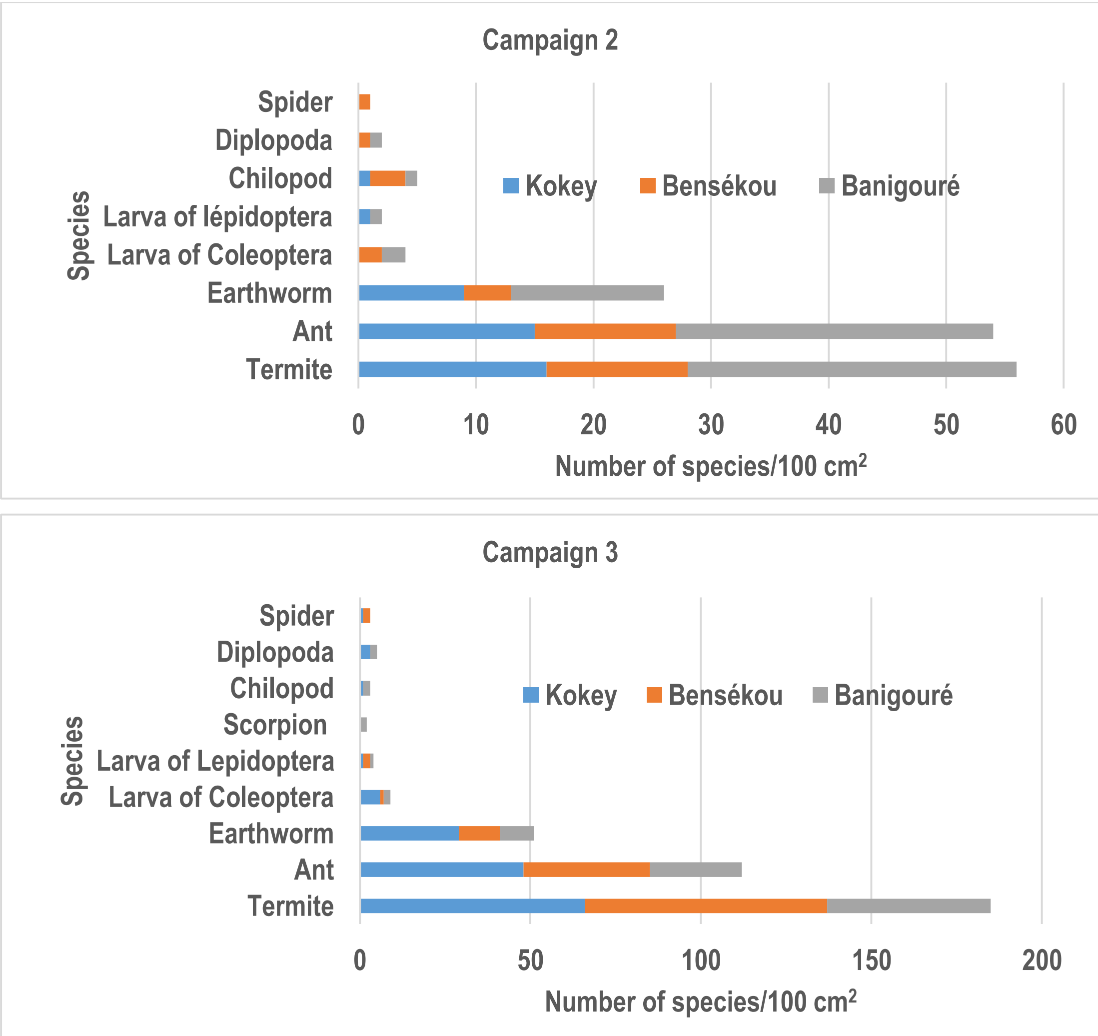

Figure 3. Macrofauna groups present in 10 - 20 cm layers

The linear model carried out on macrofauna data (Table 6) indicated in the 0 - 10 cm horizon, a significant impact of all tillage tools on the density of macroorganisms ($p < 0.001$). In this layer, the tools reduced the density of macrofauna by 0.8 ± 0.07 g/100 cm^2 in all sites and campaigns. In the 10 - 20 cm horizon, the impacts of disc plough and moldboard plough used at 20 cm depth were therefore significant on the density of macrofauna (respectively p = 0.006 and p = 0.001) (Table 6). On all campaigns and sites, ploughing with CD20 and CS20 reduced the density of macrofauna 0.70 ± 0.09 g/100 cm^2 and 0.67 ± 0.09 g/100 cm^2 respectively.

Table 6. Effects of tillage tools on the density of macroorganisms

Soil horizons	Source of variation	Coefficient (SE)	t value	Probability
0 - 10 cm	Intercept	1,84 (0.62)	2.95	0.2000
	CD10	-0.81 (0.07)	-10.34	< 0.001 *
	CD20	-0.82 (0.07)	-10.46	< 0.001 *
	CS10	-0.83 (0.07)	-10.64	< 0.001 *
	CS20	-0.81 (0.07)	-10.31	< 0.001 *
	Ho	-0.77 (0.07)	-9.81	< 0.001 *
	Ro	-0.87 (0.07)	-11.15	< 0.001 *
	Variance due to the site *(Probability)*	0.01 *(0.282)*		
	Variance due to block (site) *(Probability)*	0.01 *(0.005)**		
	Variance due to campaign *(Probability)*	0.76 *(< 0.001)**		

Soil horizons	Source of variation	Coefficient (SE)	t value	Probability
	Variance to residual	0.11		
10 – 20 cm	Intercept	1.37 (0.65)	2.10	0.262
	CD10	0.05 (0.09)	-0.54	0.593
	CD20	-0.70 (0.09)	-7.94	< 0.001 *
	CS10	0.00 (0.09)	0.05	0.959
	CS20	-0.67 (0.09)	-7.60	< 0.001 *
	Ho	-0.03 (0.09)	-0.31	0.755
	Ro	-0.00 (0.09)	-0.05	0.964
	Variance due to the site *(Probability)*	0.054 *(0.024)**		
	Variance due to block (site) *(Probability)*	0.012 *(0.01)**		
	Variance due to campaign *(Probability)*	0.809 *(< 0.001)**		
	Variance to residual	0.139		

Block (site): "block" factor nested in factor "site" *: significance at the 5% level

DISCUSSION

Although it is part of the popularization of motorization of ploughing in Benin, this research is circumspect to the cotton zone of northern Benin. Indeed, the climatic and agricultural realities have made it possible to differentiate the different agricultural zones in Benin. Finally, it helps to understand the impact of motorized ploughing in the said area and to identify the most degrading techniques for agricultural soils.

Effect of conventional tillage on physical properties of soil

"Ploughing is an agricultural technique consisting of opening and turning the topsoil in order to sow it" (Page, 2014). The result, after ploughing, an extremely heterogeneous structure composed of an assembly of fine soil, compacted or not compacted clods, crop residues distributed along the ploughing strip, voids and cracks resulting from the action overturning, displacement and fragmentation of ploughing tools on the ploughed soil layers (Roger-Estrade *et al*., 2001). The study carried out on the soils of south Alibori showed the impact of conventional ploughing tools on the soil's physical parameters. The decrease in water content in the ploughed layers of the soil is due to the burial of crop residues which served as shading and blocking the evaporation of water as shown by Bescansa *et al*. (2006) and Bhattacharyya *et al*. (2006).

Furnishing the floor is one of the objectives of conventional tillage. The seeds of buried crops require less compact soil for their development. The actions of soil fragmentation operated by the ploughing tools favoured the opening of the pores in the ploughed layers. However, the increase in pores decreases the soil density which becomes less heavy (Garane *et al*., 2017). Some authors have concluded that the infiltration rate in ploughed plots compared to non-ploughed plots has increased (Ahuchaogu *et al*., 2015). The bulk density difference between ploughed soil and unworked soil is greatest after the passage of tools and decreases during the growing season (Blanco-Canqui and Lal, 2007). Regarding the soil's available water content, the study showed a decrease in the water retention capacity in the first few centimetres in the soil. A better water capacity was noticed in the initial state of the soils. This is in accordance with Abdellaoui *et al*. (2011) who concluded, "a positive parallel between the available water content and the bulk density in the superficial soil layers". Thus, the lower the bulk density, the lower the retention capacity of the soil. In the lower horizons, the retention capacity was improved by the tools for ploughing at 20 cm. This is probably due to the incorporation of crop residues initially on the soil surface in the lower layers of the soil during ploughing at 20 cm depth (Hati *et al*., 2007).

Effect of conventional tillage on chemical properties of soil

The presence of organic matter in the soil is at the origin of the appearance of physicochemical properties favouring the development of cultured and natural plants. This presence promotes the improvement of soil structure, water infiltration, increased water retention capacity and resistance to erosion (Boudiar, 2013). In the soils of northern Benin, the carbon contents recorded in the initial states were higher than in the plots turned over in the first 10 centimetres of the soil (Table 4): Gál *et al*. (2007) attested these conclusions in a comparative study on soil carbon and nitrogen accumulation in no-till and long-term mouldboard tillage. These contents decrease in no-tillage with depth because plant residues are not buried and only decompose on the surface, according to Boudiar, (2013). Ploughing, by its action, buries and distributes these crop residues over the depth of the ploughed soil and thus in conventional tillage systems, the organic C contents are homogeneous in the first 20 cm (Müller *et al*., 2007). Therefore, high concentrations of C and N in the 0 - 10 cm layer were reduced on plots tilled 20 cm deep and the layers of 10 - 20 cm are enriched in organic C and N. This was the case in this study where during the three years of cultivation, the 10 - 20 cm layers were significantly enriched in organic nitrogen. As Baker *et al.* (2007) agreed, over several years, the stock of organic matter increases in ploughed horizons and decreases in non-fragmented horizons by tools.

Effect of conventional tillage on biological properties of soil

Agricultural soils support a rich diversity of organisms, all of which participate in important processes. For example, the study by Jossi *et al.* (2011) and Berner *et al*. (2013) revealed that earthworms and insect larvae forage and turn over the surface layers of the soil in search of dead organic matter. They aerate the earth, and the pores and their galleries can absorb water like a sponge. Centipedes, beetles, termites and ants control populations of organisms that could become pests (Berner *et al.,* 2013). In the soils of the cotton-growing area of northern Benin, many macro-organisms are counted and contributed to soil fertility, ranging from ants to Orthoptera, including earthworms and centipedes. Their activities consisted of aerating the soil and breaking down the humus into nutrients for plants, in short restoring the functioning of the agricultural ecosystem (Jouquet *et al.,* 2014). According to Vian (2009), ploughing disrupts the development of macro-organisms by reducing the mulch on the soil surface and destroying their habitat. Burying plant debris, levelling the soil and correcting excess porosity caused by ploughing operations (Angonin, 2015) expose macro-organisms to predators and desiccation. This, therefore, explains their reduced number in the horizons of ploughed plots.

Implication of study for the improvement of cotton production

The ploughing techniques studied are part of good soil preparation for the cotton crop. Examination of the influence of ploughing tools on the soil showed that ploughing promoted good soil aeration, contributing to a strong decrease in the bulk density of the soil. Soils loosened in this way with tillage tools are therefore conducive to the establishment of cotton cultivation because of their ecology (Imorou, 2013). However, the reduction in the corollary carbon content with the decrease in the available water content in 0 - 10 cm horizons, constitutes a brake on the development of crops in plots ploughed at 10 cm depth. The limited abundance of macroorganisms in ploughed soils decreases the mineralizing power of the soil. Deep ploughing (20 cm deep) maintains a reducing impact on water content and bulk density in deep horizons. The bulk density is positively correlated with resistance to root penetration, ploughing at 20 cm is therefore beneficial for cotton cultivation which seeks loose and deep soils (Centre for Environmental Law and Community Rights /PADYP, 2012).

CONCLUSION

The study reports on the impact, over three agricultural campaigns, of conventional tillage tools on the physical, chemical and biological properties of the soil in the cotton-growing area of northern Benin. In 0 - 10 cm horizon, the physical, chemical and biological parameters studied are greatly reduced under the action of motorized ploughing at 10 cm depth. The use of the moldboard or disc plough at 20 cm depth decreases soil moisture and density and macrofauna populations. The macrofauna populations don’t influence significantly the carbon content but significantly improve the nitrogen concentrations in the 10 - 20 cm horizon. It also shows that the ploughing at 20 cm promotes a better water retention capacity in 10 - 20 cm layers compared with the ploughing at 10 cm. Over three agricultural years and taking into account the ecological needs of the cotton plant, ploughing at 20 cm depth is the ploughing technique appropriate for the development of cotton cultivation in the study area. Conclusions that need further investigations.

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