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Soil Properties under different tillage methods in the cotton-growing area of northern Benin

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ABSTRACT

Objectives: The pattern of land use inevitably has an impact on soil quality. To assess the impact of tillage methods on the physicochemical and biological properties of soils, four tillage methods were tested in the cotton-growing area of northern Benin.

Methodology and results: These were manual tillage (Lm), conventional tillage (TC), surface tillage without soil turning (TMs) and deep tillage without soil turning (TMp). A Random Complete Blocks Design constituted of the four tillage methods and three replications was implemented on Bensékou, Kokey and Banigouré sites. The experiment was repeated over three years. The linear mixed-effects model was used to compare the effect of tillage patterns on physicochemical and biological parameters in 0 - 10 cm and 10 - 20 cm soil horizons. The results showed that all tillage methods decreased the water, carbon and nitrogen content, bulk density, available water content and macrofauna biomass ($p < 0.05$) in 0 - 10 cm layer. In 10 - 20 cm horizon, only TC improved significantly the available water content and nitrogen content ($p < 0.001$).

Conclusions and applications of findings: From this study, TC beneficially impacts soil fertility better than TMp and TMs. Subject to a study on the impacts of these tillage methods on productivity of cotton plant, it is, therefore, recommended for three successive agricultural campaigns, conventional tillage in view of the good soil preparation for the cotton cultivation.

Keywords: Soil, physicochemical, biological parameters, tillage, Benin.

INTRODUCTION

In Benin, cotton is the main source of growth and the engine of economic and social development, particularly in rural areas (Gbetoenonmon & Gbeffo, 2016). Cotton exportation contributes 80 % to the official export revenues and contributes 45 % of tax revenues (Medegnonwa, 2018). Benin is also rightly ranked first among African cotton-producing countries (Allochémé, 2018) with a national production of around 600,000 tons in 2017 - 2018, i.e. an impressive growth of 222 % in volume compared with the 2015 - 2016 campaign (Tonato, 2018). The major cotton producing areas are the cotton zone of North - Benin and the south of Alibori with about 50 % of production, Borgou (19 %) and Atakora

(18 %) in 2018 - 2019 (Gnimavo, 2018). In terms of perception, the cotton sector in the cotton zone of North - Benin (South - Alibori) occupies a prominent place among producers (Ton & Wankpo, 2004). Indeed, although not edible, this culture occupies large areas, which increase from year to year. Since 2015, mainly family-type farms have been able to sow large areas thanks to the advent of motorized soil preparation tools (MAEP Benin, 2011). Labour-related difficulties are swept away with the tractor, with the essential benefits of improving the timing of operations, the sowing of large areas and reducing the hardness of operations (Ahmed & Ariyo, 2015). Thus, several motorized conventional ploughing equipment are made available to producers for soil preparation, the primary agricultural activity. Unfortunately, this led to a clear depletion of soil resources and extensive soil erosion (Amonmide *et al.,* 2019) due to the felling of wooded ecosystems and the absence of fallows. In addition, the exclusive application of synthetic fertilizers does not promote an adequate level of organic matter in the soils, thus weakening the structure of the soils, and reducing the retention of rainwater ((Allagbe *et al.*, 2014). In short, the expansion of cotton cultivation in the cotton zone of North - Benin comes at the expense of the environment, the natural capital on which all agricultural producers depend for their employment and survival. This translates into cotton productivity of 1.13 t / ha in 2017 - 2018 (Tonato, 2018) twice that of the yield in peasant areas (2.25 t / ha (Hougni *et al.*, 2016). There are several reasons for the low yields, including the excessive use of cultivated areas. Others are linked to the use of machines and to the "conventional" soil preparation methods still used in field crops, which reduce the nutrient content in the peripheral layers of the soil (Abdellaoui *et al.,* 2011; Małecka *et al.,* 2012). By nature, soil preparation tends to improve certain physical properties of the soil, which provide favourable conditions for plant growth, especially in circumstances where the soil has areas of high strength and compaction (Menon *et al.,* 2012). In addition to reducing soil nutrients, this method of soil preparation is also considered expensive in terms of labour and fuel consumption. The adoption of "no soil turning" methods is, therefore, advocated by agricultural researchers to respond to environmental concerns and the costs involved. They require fewer instrument passages at the soil preparation stage and allow the residue from the previous harvest left on the soil surface to be increased to more than 30 % to protect the soil and prevent water loss (Dayou *et al.,* 2017; Morris *et al.,* 2010). However, the switch from conventional methods to soil conservation methods favours the proliferation of weeds and crop pests (Dayou *et al.,* 2017) requiring phytosanitary products which acidifies the soil making it unsuitable for crop development. The present work was undertaken to evaluate under the conditions of the cotton growing of northern Benin, the effect of different modes of soil preparation on the physicochemical and biological properties of soils. This is part of the popularization of soil conservation methods in agricultural development poles in Benin.

MATERIAL AND METHODS

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.

Experimental design and equipment: A Random Complete Blocks Design constituted of the four tillage methods and three replications are considered for the experiment. The tillage methods were conventional tillage (TC), deep tillage without soil turning (TMp), surface tillage without soil turning (TMs) and manual tillage (Lm). Each block measured 20 m by 5 m and was subdivided into four 5 m wide square plots. Manual tillage was realized with the *daba*. Conventional tillage consisted of ploughing at 20 cm deep with the disc plough. The deep tillage without soil turning was carried out using a cultivator between 7 and 18 cm deep. The surface tillage without soil turning was carried out with a Canadian at 10 cm deep. The power tools were coupled to a 52 HP tractor.

Sampling and data collection*:* During the months of June 2019, 2020 and 2021, soil samples were taken according to the method of Mathieu & 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 Lab of the Faculty of Agronomic Sciences in Abomey-Calavi municipality 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 macrofaunae.

Statistical analyses: To compare the effect of tillage methods on soil quality parameters (bulk density, moisture, carbon and nitrogen content, available water content, macrofauna biomass) and for each soil layer (0 - 10 cm and 10 - 20 cm), the linear mixed-effects model was used. The "tillage method" was the fixed factor, the "site" and "campaign" was the random factors and the “block” was nested in the factor “site”. R 3.6.3 (R Core Team, 2019) was used for the statistical analyses.

RESULTS

Soil physical properties

Soil bulk density: The model performed on bulk density data revealed a significant effect of all tillage on soil density ($p < 0.001$) in the 0 - 10 cm layer (Table 1). Minimal tillage reduced soil compaction by 0.1 ± 0.01 g / cm^3. Manual tillage and conventional tillage had a diminutive effect of - 0.18 ± 0.01 g / cm^3 and - 0.19 ± 0.01 g / cm^3 respectively. In 10 - 20 cm horizons, only TC had a significant impact on the bulk density of the soil ($p < 0.001$) with a reducing power of - 0.22 ± 0.01 g / cm^3 (Table 1). In this layer, the culture year and site had a significant impact on the variations of conventional tillage on soil density.

Soil water content : The linear mixed-effects model carried out on the humidity data and summarized in Table 2 indicated a significant decrease in tillage methods on this soil parameter in 0 - 10 cm horizon ($p < 0.05$). While the initial soil moisture was reduced by 3.11 ± 0.25 % by TC, it was reduced by 1.31 ± 0.25 % and 1.33 ± 0.25 % by TMp and TMs respectively in surface layers. The culture year and the site had a significant impact on the data presented in *Table 5.2* ($p = 0.005$ and $p = 0.009$ respectively). In lower layers (10 - 20 cm), the model showed a significant impact of TC on soil moisture ($p < 0.001$). TC reduced the initial soil moisture by 1.75 ± 0.18 % across all study sites. As in 0 - 10 cm layers, the “ campaign ” and “ site ” factors had a significant impact on the moisture values in 10 - 20 cm layers ($p < 0.001$ and $p = 0.015$ respectively) (Table 2).

Table 1: Effects of tillage modes on bulk density

Soils horizons	Source of variation	Coef (SE)	t value	Prob.
0 – 10 cm	Intercept	1.47 (0.03)	75.82	0.009*
	Lm	-0.18 (0.01)	-17.00	<0.001*
	TC	-0.19 (0.01)	-18.52	<0.001*
	TMp	-0.10 (0.01)	-9.98	<0.001*
	TMs	-0.10 (0.01)	-9.76	<0.001*
	Variance due to site *(Prob)*	0.17 *(<0.001)**		
	Variance due to block (site) *(Prob)*	0.00 *(0.99)*		
	Variance due to campaign *(Prob)*	0.019 *(0.491)*		
	Variance of residual	0.148		
10 – 20 cm	Intercept	1.55 (0.03)	51.32	0.02 *
	Lm	-0.01 (0.01)	-0.75	0.451
	TC	-0.22 (0.01)	-17.54	<0.001*
	TMp	-0.06 (0.01)	-4.55	0.021*
	TMs	-0.01 (0.01)	-0.62	0.536
	Variance due to site *(Prob)*	0.002 *(0.005)**		
	Variance due to block (site) *(Prob)*	0.00 *(0.128)*		
	Variance due to campaign *(Prob)*	0.00 *(<0.001)**		
	Variance of residual	0.004		

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

Table 2: Effects of tillage modes on water content

Soils horizons	Source of variation	Coef (SE)	t value	Prob.
	Intercept	12.1 (0.88)	13.81	0.003*
	Lm	-3.16 (0.25)	-12.45	<0.001*
	TC	-3.11 (0.25)	-12.25	<0.001*
	TMp	-1.31 (0.25)	-5.17	0.004*
0 – 10 cm	TMs	-1.33 (0.25)	-5.23	0.003*
	Variance due to site *(Prob)*	2.096 *(0.009)**		
	Variance due to block (site) *(Prob)*	0.00 *(1)*		
	Variance due to campaign *(Prob)*	0.115 *(0.005)**		
	Variance of residual	1.744		
10 – 20 cm	Intercept	10.4 (0.69)	14.91	<0.001*
	Lm	-0.05 (0.18)	-0.28	0.782
	TC	-1.75 (0.18)	-9.70	<0.001*
	TMp	-0.20 (0.18)	-1.10	0.274
	TMs	-0.10 (0.18)	-0.54	<0.591
	Variance due to site *(Prob)*	3.388 *(0.015)**		
	Variance due to block (site) *(Prob)*	0.00 *(1)*		
	Variance due to campaign *(Prob)*	1.829 *(<0.001)**		
	Variance of residual	3,223		

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

Soil available water content (Ru): The influence of tillage methods on Ru, reported in table 3, was significant with TC in 0 - 10 cm ($p = 0.002$) and 10 - 20 cm ($p < 0.001$). In 0 - 10 cm layers, TC decreased the available water content in E0 by 6.35 ± 0.76 mm while in 10 - 20 cm, TC increased Ru by 4.59 ± 0.23 mm. In each soil layer, the effects of "site" and "year" factors were preponderant in the variations induced on the available water content by TC ($p < 0.05$).

Table 3: Effects of tillage modes on available water content

Soils horizons	Source of variation	Coef (SE)	t value	Prob.
0 – 10 cm	Intercept	13.4 (0.59)	22.20	<0.001*
	Lm	-5.75 (2.01)	-2.85	0.085
	TC	-6.35 (0.76)	-8.35	0.002*
	TMp	-1.82 (1.48)	-1.23	0.339
	TMs	-1.51 (0.99)	-1.52	0.227
	Variance due to site *(Prob)*	0.702 *(0.015)**		
	Variance due to block (site) *(Prob)*	0.049 *(0.011)**		
	Variance due to campaign *(Prob)*	0.256 *(<0.001)**		
	Variance of residual	1,241		
10 – 20 cm	Intercept	8.03 (0.80)	10.02	0.002*
	Lm	0.14 (0.23)	0.60	0.549
	TC	4.59 (0.23)	19.72	<0.001*
	TMp	0.19 (0.23)	0.83	0.409
	TMs	0.30 (0.23)	1.29	0.200
	Variance due to site *(Prob)*	0.289 *(0.01)**		
	Variance due to block (site) *(Prob)*	0.014 *(0.651)*		
	Variance due to campaign *(Prob)*	1.551 *(<0.001)**		
	Variance of residual	1,465		

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

Soil chemical properties: The comparative study of the impact of tillage methods revealed a significant impact of all the tillage methods studied on carbon content on all sites and during the three crops years of cultivation in 0 - 10 cm horizon ($p < 0.05$) (Table 4). The carbon content in E0 was reduced by 0.68 ± 0.06 % in TC, 0.18 ± 0.06 % in TMp and 0.13 ± 0.06 % in TMs. In 10 - 20 cm layers, the impact of tillage methods was not significant on the carbon content ($p > 0.05$) (Table 4) in all the sites and during the three agricultural campaigns.

Table 4: Effects of tillage modes on chemical properties

Parameters	**Soil horizons**	**0 - 10 cm**			**10 - 20 cm**		
	Source of variation	**Coef (SE)**	**t value**	**Prob.**	**Coef (SE)**	**t value**	**Prob.**
Carbon content	Intercept	1.55 (0.09)	16.40	0.004*	0.78 (0.20)	3.936	0.016*
	Lm	-0.56 (0.06)	-10.03	<0.001*	-0.01 (0.04)	-0.409	0.692
	TC	-0.68 (0.06)	-12.25	<0.001*	0.06 (0.29)	0.204	0.851
	TMp	-0.18 (0.06)	-3.27	0.001*	-0.03 (0.06)	-0.558	0.613
	TMs	-0.13 (0.06)	-2.42	0.016*	-0.06 (0.06)	-1.077	0.392
	Variance due to site *(Prob)*	0.00 *(0.99)*			0.835 *(1)*		
	Variance due to block (site) *(Prob)*	0.027 *(<0.001)**			0.327 *(0.129)*		
	Variance due to campaign *(Prob)*	0.013 *(0.01)**			0.674 *(<0.001)**		
	Variance of residual	0.082			0.512		
Nitrogen content	Intercept	0.07 (0.01)	9.639	0.001*	0.04 (0.01)	6.639	0.006*
	Lm	-0.02 (0.00)	-7.327	<0.001*	0.00 (0.00)	1,251	0.212
	TC	-0.02 (0.00)	-7.967	<0.001*	0.02 (0.00)	7.069	<0.001*
	TMp	-0.01 (0.00)	-3.178	0.002*	-0.00 (0.00)	-0.664	0.507
	TMs	-0.01 (0.00)	-2.397	0.017*	0.01 (0.00)	-0.817	0.07
	Variance due to site *(Prob)*	0.024 *(0.023)**			0.065 *(<0.001)**		
	Variance due to block (site) *(Prob)*	0.009 *(0.453)*			0.009 *(1)*		
	Variance due to campaign *(Prob)*	0.019 (< *0.001)**			0.01 *(0.011)**		
	Variance of residual	0.04			0.048		

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

Soil biological parameters: The studies of Figure 1 revealed in the surface layer: i-) in campaign C3, there were more living organisms than in C2 and ii-) the biomass of macroinvertebrates was higher in E0 than in ploughed plots.

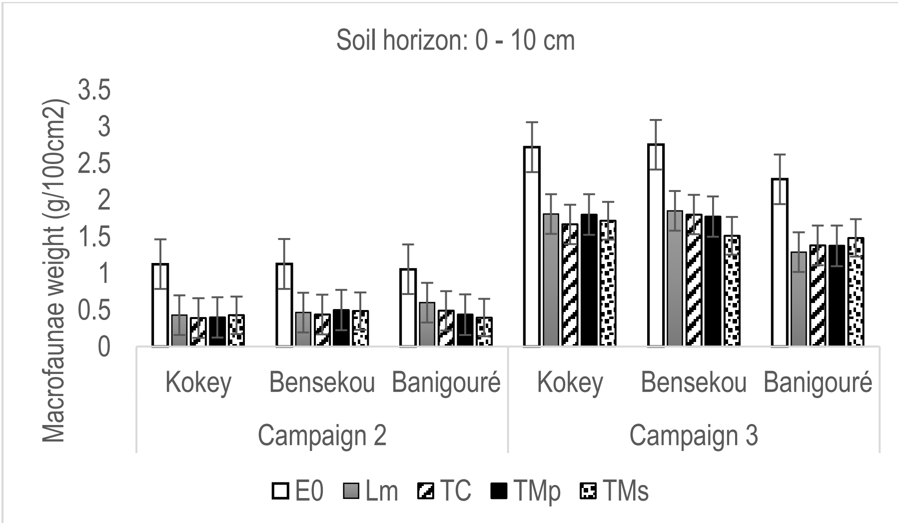

Figure 1: Weight of macroinvertebrates in different sites in 0 - 10 cm

This reduction in biomass induced by tillage methods was significant on all sites and agricultural campaigns ($p < 0.001$) (Table 5) in 0 - 10 cm layers. Indeed, the biomass of E0 was reduced by 0.82 ± 0.08 g / 100 cm^2 in the conventional tillage plots. On the TMp and TMs plots, the reduction was respectively 0.80 ± 0.08 g / 100 cm^2 and 0.78 ± 0.08 g / 100 cm^2. The "campaign" factor also significantly influenced these variations ($p < 0.001$). In 10 - 20 cm horizon, only TC significantly influenced macrofauna biomass ($p < 0.001$). Said biomass was reduced by 0.51 ± 0.13 g / 100 cm^2. These variations were a function of the site ($p = 0.012$) and the agricultural season ($p < 0.001$) (Table 5; Figure 2).

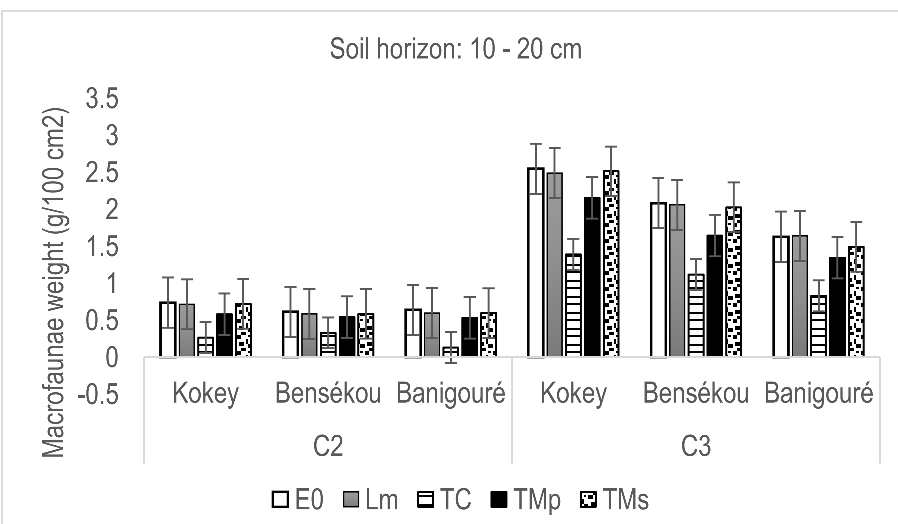

Figure 2: Weight of macroorganisms in different sites in 10 - 20 cm

Table 5: Effects of tillage methods on the weight of macrofauna

Soils horizons	Source of variation	Coef (SE)	t value	Prob.
0 – 10 cm	Intercept	1.84 (0.63)	2.92	0.204
	Lm	-0.77 (0.08)	-10.11	<0.001*
	TC	-0.82 (0.08)	-10.72	<0.001*
	TMp	-0.80 (0.08)	-10.45	<0.001*
	TMs	-0.78 (0.08)	-10.27	<0.001*
	Variance due to site *(Prob)*	0.008 *(0.474)*		
	Variance due to block (site) *(Prob)*	0.014 *(0.006)**		
	Variance due to campaign *(Prob)*	0.784 *(<0.001)**		
	Variance of residual	0.104		
10 – 20 cm	Intercept	1.38 (0.68)	2.01	0.272
	Lm	-0.02 (0.13)	-0.19	0.850
	TC	-0.51 (0.13)	-3.89	<0.001*
	TMp	-0.24 (0.13)	-1.85	0.066
	TMs	-0.05 (0.13)	-0.41	0.680
	Variance due to site *(Prob)*	0.793 *(0.012)**		
	Variance due to block (site) *(Prob)*	0.000 *(0.997)*		
	Variance due to campaign *(Prob)*	3.22 *(<0.001)**		
	Variance of residual	1,149		

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

Summary of impacts of tillage methods on soil fertility: Table 6 summarizes the impacts of tillage methods on soil fertility in the cotton area in northern Benin. In this synthesis, the impacts of tillage methods on soil fertility are considered binary. Indeed, beneficial impacts in terms of soil fertility are taken as "1" while negative or neutral impacts on soil fertility are taken as "0". In the case of neutrality and negativity between impacts on the same soil parameter, neutrality takes "1" and negativity takes "0". The sum of the benefits of the types of tillage on fertility is counted. The tillage method with the greatest amount has a better impact on the fertility of the soil for a cotton crop. The impact of minimum tillage on soil fertility in 0 - 10 cm layers (Si = 3) is better than that of conventional tillage (Si = 2). However, in 10 - 20 cm layers, the impact on this fertility of conventional tillage (Si = 5) is better than deep minimum tillage (Si = 3) and superficial minimum tillage (Si = 2). In 0 - 20 cm horizon, conventional tillage has a better impact on soil fertility (Si = 7) than deep minimum tillage (Si = 6) and surface minimum tillage (Si = 5).

Tableau 6: Summary of impacts of tillage methods on soil fertility

		TC				**TMp**				**Lm**				**TMs**		
		Disc plow ploughing at 20 cm depth				**Minimum tillage with a cultivator (between 7 and 18 cm deep)**				**Daba ploughing**				**Minimum tillage with a Canadian (< 10 cm deep)**		
		0 – 10 cm	10 – 20 cm	0 – 20 cm		0 – 10 cm	10 – 20 cm	0 – 20 cm		0 – 10 cm	10 – 20 cm	0 – 20 cm		0 – 10 cm	10 – 20 cm	0 – 20 cm
Water content		1	1	2		1	0	1		1	0	1		1	0	1
Bulk density		1	1	2		1	1	2		1	0	1		1	0	1
Available water content		0	1	1		1	0	1		1	0	1		1	0	1
Carbon content		0	1	1		0	1	1		0	1	1		0	1	1
Nitrogen content		0	1	1		0	0	1		0	0	0		0	0	0
Macrofauna density		0	0	0		0	1	0		0	1	1		0	1	1
Totals (Si)		**2**	**5**	**7**		**3**	**3**	**6**		**3**	**2**	**5**		**3**	**2**	**5**

DISCUSSION

Effects of tillage methods on the soils physical properties: Improving the physical properties of soil is one of the most desired tillage goals (Abla *et al.,* 2016). The modifications of the physical properties for good fertility are among others the reduction of the soil resistance to rooting, better porosity, infiltration and water retention capacity. In the cotton zone of northern Benin, the experiments showed a significant decrease in the bulk density of the soil in the ploughed plots in comparison to the initial states. The significant decrease in relative soil moisture in the cultivated plots compared with E0 states indicated an improvement in soil porosity. These results are similar to those of Bhattacharyya *et al.*, (2006) who indicated that minimum tillage retained more water. The more pronounced impact of conventional tillage on the reduction of soil strength and relative humidity, compared with that of minimum tillage, was due to the actions of clod breaking and layer turning. These actions specific to conventional tillage have more effectively reduced the barriers formed by crop residues and clods of soil to evaporation and the upwelling of water in depth by capillarity (Al - Ouda, 2010; Razafimbelo *et al.,* 2010; Belhadj, 2015;). The displacement of crop residues towards the deep layers, due to the turning actions of the plough, favoured an important soil available water content in 10 - 20 cm horizons. The water retention capacity in the surface layers has, therefore, been reduced in the plots in conventional tillage and not in minimum tillage. Abdellaoui *et al.,* (2011) and Garane *et al.,* (2017) who concluded that the simplified tillage allowed better water retention compared with conventional ploughing with the plough corroborate these results. The water retention capacity of soil in the initial state and that of the plots in minimum tillage were significantly similar in the cotton zone of northern Benin.

Impacts of tillage methods on the soil chemical properties:m Improving chemical properties is also one of the objectives of tillage (Abla *et al.,* 2016). Changes in chemical properties for good fertility include, among other things, the availability of nutrient reserves (carbon, nitrogen). The distribution of nutrients along the soil profile in cultivated plots is widely studied in the literature (Gál *et al.,* 2007; Tourdonnet *et al.,* 2007; D'Haene *et al.,* 2008). It has lower concentrations of organic carbon and nitrogen in the surface layers of ploughed plots than in minimum tillage plots. In the cotton zone of North - Benin, conventional tillage reduced the carbon concentrations of the surface horizons by 0.68 % compared with the reduction rate (- 0.18 % and - 0.13 % respectively) of TMp and TMs. The incorporation of crop residues by the action of the disc plough made the organic carbon concentrations homogeneous along the ploughed horizons while in the minimum tillage systems, the contents were maximum in the surface and decreased with the depth (Müller *et al.,* 2007). In this study, no significant difference was detected between the concentrations of plots ploughed in 10 - 20 cm layers and the initial state of the soil. These conclusions were supported by the studies by Balesdent *et al.,* (2000) which indicated that few differences appear in-depth between the carbon concentrations of tilled systems and those of soil conservation. On the other hand, the nitrogen contents of the lower layers of the soil were increased over the entire study area.

Influences of tillage methods on the soil biological properties: The presence of organic matter is a guarantee of the presence of macroorganisms in the soil (Souza Andrade *et al.,* 2002). Organic matter is a source of nutrients for the macrofauna that they transform into humus and climatic conditions (temperature humidity) favour the increase of their activities in the first few centimetres of the soil. In cropping systems, tillage strongly disturbed the activity of macroorganisms in the first horizons of the soil (Carof, 2006; Johnson Maynard *et al.*, 2007; Berner *et al.*, 2013). Conventional tillage negatively affects populations of worms and termites through mechanical damage, exposure to predators or a desiccation phenomenon due to soil turning (Chan, 2001; Kladivko, 2001). The impact of tillage methods has been significant on the population of large groups of macroorganisms in the cotton zone of North - Benin. The intensity of tillage was predominant in reducing the species groups as follows in descending order: TC, TMp and TMs. Indeed, the damage caused to macroorganisms by the plough is the destruction of clods of earth and the incorporation of crop residues, the natural habitat of anecic species. In the lower layers of the soil, conventional tillage reduced the development of macroorganisms. The modifications engendered in the lower layers of the soil have disturbed the populations of macroorganisms by probably destroying their natural habitats or by the mechanical action of the plough. Specifically, minimum deep tillage and conventional tillage most affected the termite and ant groups. The minimum tillage was much less harmful than the conventional tillage because it was less intense and did not turn the ground. Nevertheless, thanks to the action of the cultivator's teeth, the minimum deep tillage has harmed termites and ants by destroying their habitats.

Implication of the study on cotton cultivation: This study was on the impact of soil preparation methods in the cotton-growing area of northern Benin with a view to their valuation. The different models applied to the physicochemical and biological data of these soils have shown that conventional tillage has favoured better soil aeration, contributing to a strong decrease in the bulk density of the soil compared to minimum tillage. However, the cotton plant requires a deeply homogeneous, loosened and permeable soil (Kabore, 2014) for a better circulation of air and water in the soil. The soils that are better loosened in conventional tillage are, therefore, better suited to growing cotton. Likewise, improving the retention capacity in the lower layers of the soil and the nitrogen rate can contribute to better root development in the cotton plant. However, the severe decrease in the carbon content and its corollaries, the loss of the macrofauna and the decrease in the water content available in the 0 - 10 cm horizons, could constitute a brake on the development of cotton in the turned plots. After three agricultural seasons, it was concluded that on the physical level, conventional tillage could contribute to a better development of cotton cultivation. It is at the chemical and biological level that minimum tillage has favoured a better structuring of the soil and incidentally a consequent development of cotton cultivation. However, in 0 - 20 cm layer, conventional tillage has impacts that are more beneficial on the cotton plant compared to minimum tillage. However, data on cotton productivity would help in deciding which tillage method(s) to use for preparing the land for cotton production.

CONCLUSION AND APPLICATION OF RESULTS

This study made it possible to understand the impact of tillage methods on the physical, chemical and biological properties of the soil in the cotton zone of northern Benin. It makes it possible to choose the appropriate tillage methods for good soil preparation in cotton-growing area of northern Benin, an area of high agricultural production in the country. In 0 - 10 cm horizons, the physicochemical and biological properties studied are greatly reduced under the action of tillage methods with a more increased incidence of conventional tillage. In the lower layers of the soil, only conventional tillage enabled soil furnishings and improved soil retention capacity. Likewise, at this timeframe, the carbon and nitrogen contents did not undergo significant variations compared with the initial conditions under minimal tillage. Taking into account the beneficial impacts of tillage methods on soil fertility, conventional tillage appears to be the best method for good soil preparation. A full study on the yield of cotton crop would confirm the choice of suitable tillage methods for maintaining fertility and optimal cotton production.

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