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Study of Cattle Trampling and Its Effect on Soil Properties and Sorghum Productivity in Parts of Yobe State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author MU supervised the study, managed the design and wrote the protocol. Author MGN designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Author AA added academic value to the work, served as external examiner and managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study was carried out at three different locations in Yobe State (North Eastern Nigeria), to determine the effect of cattle trampling on soil properties and sorghum productivity. The study locations were Potiskum, Nangere and Fika Local Government Areas of the state. Soil depth (25-30 cm height and diameter) were collected from each location and analyzed for particle size distribution, pH, organic carbon (OC), total nitrogen (TN), available phosphorus and exchangeable cations as well as cation exchange capacity (CEC), bulk density (BD), total porosity (Pt) and saturated hydraulic conductivity (Ksat). Each sampling involved collection from cattle trampled and un-trampled areas with sorghum as the test crop. Effect of trampling on root mass, length and stover yields were also determined after sorghum cultivation in each of the location. Results indicated that there were significant effects of cattle trampling with respect to soil properties investigated. However, post planting results of the analysis revealed that trampled soils had

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significantly lower statistical values for all yield parameters of sorghum when compared with un-trampled soils in all the study locations. There is need to improve the structure of soils in all study locations through incorporation of organic matter and proper soil management for increased permeability, root penetration, aeration and water infiltration. Also, there is need for cattle routes demarcations to provide free movement of livestock across the locations without encroachment into farmlands.

Keywords: Cattle trampling; soil properties; sorghum; productivity; Yobe State and Nigeria.

1. INTRODUCTION

In agriculture, grazing system is a method of managing livestock for balanced feeding. In this method, animals are allowed to graze in the grazing land and convert grass and other forage into meat, milk, wool and other products. They take the energy stored in those plants and convert it into energy for themselves [1]. Grazing of livestock is an important aspect to feeding the human race because grazers have the ability to move energy up to a trophic level that would have been inaccessible. Similarly, soil physical and chemical properties play an important role in the establishment and growth of crop plants [2]. Soil bulk density, mechanical resistance, porosity and infiltration rate are all affected by cattle trampling. Cattle trampling can result to soil compaction, thereby rendering it more susceptible to runoff. It can also damage plants, reduce vegetation cover and infiltration rate which can lead to increased runoff. The severity of these impacts can be determined by assessing soil conditions [3]. The organic matter content of soil stabilizes soil structure and improves water infiltration rate. Intensive grazing reduces soil organic matter, which results in the compaction of the soil surface layer, causing increased surface runoff [4].

Soil compaction is the natural packing of soil particles by natural force into a denser or closer pack. The forces acting to compact soil include cattle trampling, overburden weight of material above the soil, and implement traffic from mechanized agriculture, foot traffic, and tillage pressure due to implement movement through the soil. Over the years, the cattle trampling cause pressure on the lower layer of tilled soil. There is thus a low infiltration rate on this layer of soil. That is, the porosity becomes low and bulk density increases. Other effects of compaction are reduced permeability, aeration and water infiltration, difficulty in root penetration, poor growth and yield.

Trampling also affects soil permeability. It is the ease with which air, water and roots move through the soil [5]. The number, size, and continuity of soil pores determine the permeability of the soil. Since pore space depends on texture and structure, permeability also depends on soil texture and structure [6]. Permeability of a soil is measured by measuring movement of water through the soil; this is known as hydraulic conductivity.

Cattle trampling leads to soil physical degradation which can remove soil nutrients that are found on top soil thereby affecting crop yield. Lands grazed by cattle often experienced soil surface compaction which affects crop seed germination and root development. The severity of these impacts can be determined by assessing soil properties and its implication on crop productivity. Therefore, the objective of this study was to determine the effect of cattle trampling on soil physical and chemical properties and crop growth using sorghum as the test crop across the three locations in Yobe State, North Eastern Nigeria.

2. MATERIALS AND METHODS

The study was carried out during 2018 cropping season at three different locations in Yobe State Northeastern Nigeria, to determine the effect of cattle trampling on soil properties and sorghum productivity. The study locations were Potiskum, Nangere and Fika Local Government Areas of the state. Soil depth (25-30 cm height and diameter) were collected from each location and analyzed differently for particle size distribution, pH, organic carbon (OC), total nitrogen (TN), available phosphorus and exchangeable cations as well as cation exchange capacity (CEC), bulk density (BD), total porosity (Pt) and saturated hydraulic conductivity (Ksat). Each sampling involved collection from cattle trampled and un-trampled areas with sorghum as the test crop.

2.1 Experimental Treatments and Design

The Potiskum location falls between latitude 11° 42' N to 11° 43' N and longitude 11° 04' E to 11°

06' E. The Nangere location falls between latitude 11° 50' N to 11° 51' N and longitude 11° 04' E to 11° 11' E while Fika location falls between latitude 11° 00' N to 11° 17' N and longitude 11° 18' E to 11° 29' E [7].

The experimental treatments consisted of 2 (cattle trampled and un-trampled soils) by 3 (Potiskum, Nangere and Fika locations) factorials laid out in a Randomized Complete Block Design (RCBD) and replicated three times.

2.2 Soil Data Collection and Analysis

Soil samples collected from each of the location at the beginning and at the end of crop growing season according to the treatments (trampled and un-trampled soils) were analyzed using standard analytical procedures. The pH was determined in water (1:1) [8]. The particle size distribution was determined by the hydrometer method [9]. The chromic acid titration method was used to determine the O.C. and O.M [8]. Total N in the soil was determined by the regular Macro-kjeldahl method [8]. The amount of cations held at exchangeable site by a unit mass of soil was determined using NH_4OAC (at pH-7.0) displacement method. The exchangeable K, Ca, Mg and Na were determined using the EDTA titration method while the available P was determined by Bray-1 method. Flame photometer was used to determine K and Na whereas AAS was used to determine Mg and Ca.

The soil physical properties investigated included bulk density (BD), total porosity (Pt) and saturated hydraulic conductivity (Ksat). Bulk density (g cm^{-3}) was determined by oven drying the soil (in soil core) to a constant weight and divided this by the total volume of the soil in the cylindrical soil core. Total porosity (%) was estimated from bulk density and particle density values. Saturated hydraulic conductivity (cm hr^{-1}) was determined using constant head method.

2.3 Crop Data Collection and Analysis

Medium-maturing sorghum variety was used as the test crop (SAMSORG 48-Kaura Bornu). Plant height was measured at 8 and 12 weeks after planting (WAP). Root mass was also taken at 8 and 12 WAP while root length and Stover yield were taken at 12 WAP. Data collected for the growth and yield parameters of sorghum were subjected to the Analysis of Variance (ANOVA) after which significant means were separated using Least Significant Difference (LSD) at $P<0.05$.

3. RESULTS AND DISCUSSION

The results of the effect of cattle trampling and locations on soil physical and chemical properties are presented on Table 1. There were no significant effects of trampling on the soil chemical properties at the beginning of the study. Soil chemical properties were statistically similar across the locations.

However, significant effects of Potiskum, Nangere and Fika locations were shown with respect to all soil chemical properties investigated. Similarly, textural classes were significantly affected by the trampling and locations. The result is in line with other authors [10] who reported on the significant effect of cattle trampling and locations on soil physical and chemical properties of Yewa north area of Ogun state, Nigeria.

Cattle trampled soil had lower sand and significantly higher clay content across the locations when compared with un-trampled soil. This according to [3] and [10] could be attributed to gradual disintegration of the coarse particles of the soil into finer particles by the cattle hooves. According to [2], animal grazing or trampling leads to soil erosion which also results to soil particle size redistribution. The result may also be attributed to the fact that Fika location is highly susceptible to soil erosion when compared with the remaining two locations. The moderately high organic matter content across the locations may be due to cattle dung deposition [11] and [10]. Organic matter content of the soil was maintained through incorporation of crop residues that was predominant on the un-trampled soil areas [12].

Lowest values of N and P were recorded for trampled soils. This may be as a result of continuous cultivation of crops in these areas [13]. Similarly, exchangeable bases, base saturation and CEC reduced in un-trampled soils but remarkably increased in trampled soils due to incorporation of organic matter and deposition of animal dung which may have increased nutrients (N, P, Mg, K, Ca, CEC and base saturation) in the soil [14].

The effects of cattle trampling and location on soil physical and chemical properties after sorghum cultivation are shown on Table 2. Total porosity (Pt), saturated hydraulic conductivity (Ksat) and bulk density (BD) were significantly ($P<0.05$) affected by cattle trampling and locations. The results were statistically similar across the locations. Pt was higher in Fika followed by Nangere and Potiskum (Fig. 1). Similar trend was observed for Ksat but the effects of BD were slightly different across the locations.

Fig. 2 presents the effect of trampling and locations on root mass, length and Stover yield across the locations. Results indicated that there were significant effects of trampling and locations with respect to all parameters studied. However, un-trampled soils produced statistically larger root mass, longer root length and larger Stover yield when compared with trampled soils. This is because sorghum crops grown on trampled soil conditions may have experienced soil compaction which may have impeded root growth and consequently uptake of both water and nutrients. Un-trampled soil may have increased porosity and root penetrability thus allowing roots to have better access to water and nutrients [15].

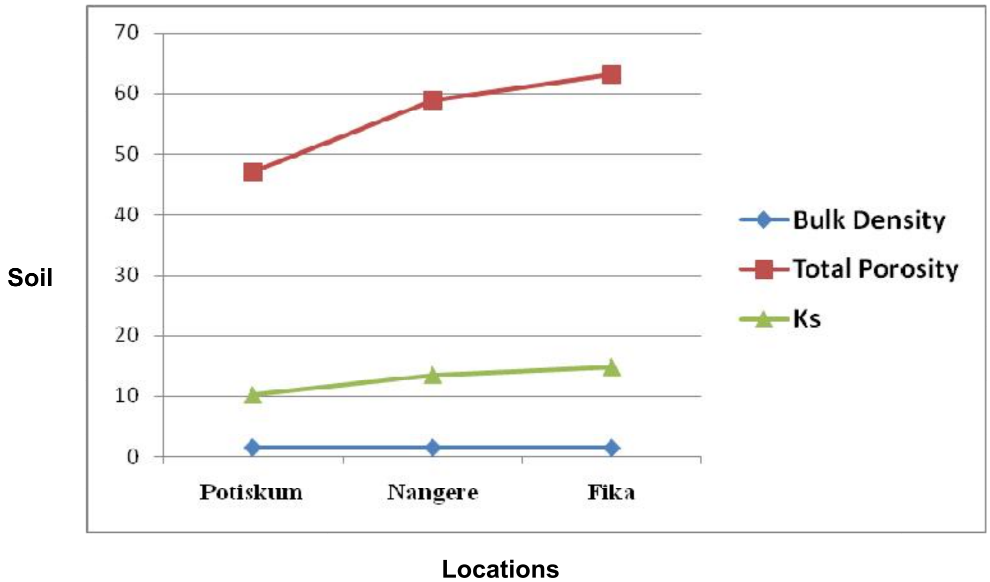


Fig. 1 Effect of cattle trampling and locations on soil properties after sorghum cultivation

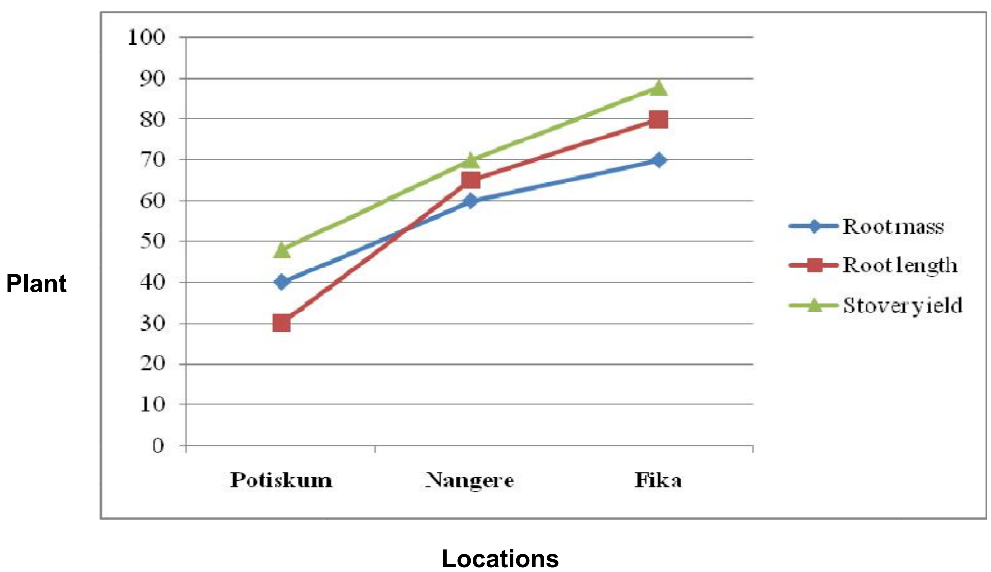


Fig. 2. Effect of cattle trampling and locations on root mass, length and stover yield

Table 1. Effect of cattle trampling and locations on physical and chemical properties of soil

Cattle trampling	Particle size distribution				pH		Org	Org		Bray-1	Exch. Cations ($CmolKg^{-1}$)					Base
	Sand	Silt	Clay	Textural	H_2O	KCl	C	M	N	P	Ca	Mg	K	Na	CEC	Saturation
	(%)	(%)	(%)	Class	1:1	1:1	(%)	(%)	(%)	(ppm)					($Cmolkg^{-1}$)	(%)
TS	45.0	15.0	40.0	SCL	6.40	5.50	0.87	1.51	0.077	3.20	3.29	1.51	0.25	0.55	6.30	86.10
UTS	42.2	17.8	40.0	SCL	6.55	5.60	0.90	1.56	0.070	3.50	3.01	1.30	0.23	0.53	6.10	86.60
LSD (0.05)	1.84	1.09	2.98		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Locations																
Potiskum	44.0	16.0	40.0	SCL	6.65	5.90	0.92	1.60	0.088	4.00	3.80	1.60	0.30	0.71	6.00	86.70
Nangere	41.0	19.0	40.0	SCL	6.40	5.60	0.80	1.38	0.097	2.90	2.84	1.28	0.24	0.55	5.40	89.40
Fika	43.8	18.0	38.2	SCL	6.70	5.95	0.87	1.51	0.091	3.30	3.57	1.37	0.26	0.58	6.22	88.50
LSD (0.05)	1.91	1.34	1.98		0.13	0.22	0.62	0.03	0.021	1.42	1.03	0.12	0.11	0.31	0.91	10.32

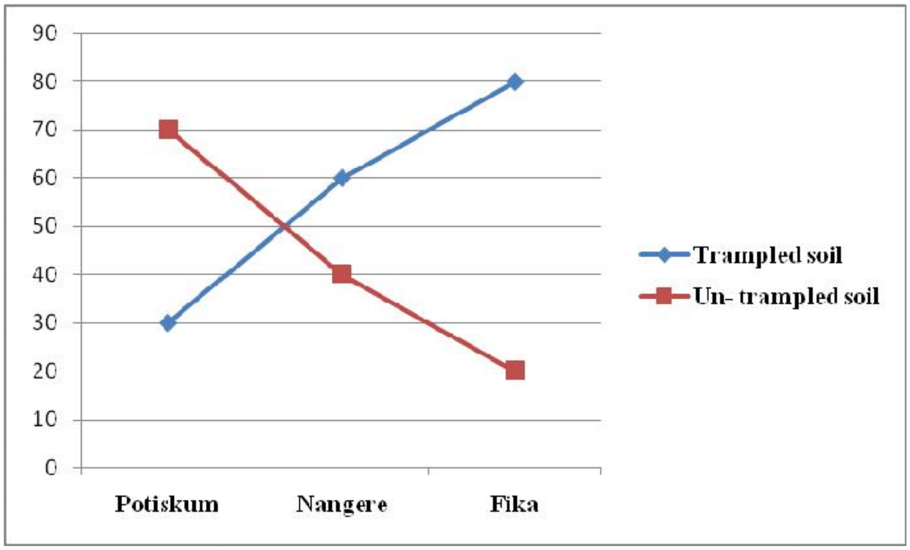
Key; TS= Trampled Soil; UTS= Un-trampled Soil; NS= Not Significant; SCL= Sandy Clay Loam

Table 2. Effect of cattle trampling and locations on physical and chemical properties of soil after sorghum production

Cattle trampling	Particle size distribution				pH		Org	Org		Bray-1	Exch. Cations ($CmolKg^{-1}$)				Pt	Ks
	Sand	Silt	Clay	BD	H_2O	KCl	C	M	N	P	Ca	Mg	K	Na		
	(%)	(%)	(%)	(gcm^{-3})	1:1	1:1	(%)	(%)	(%)	(ppm)					(%)	($cm\ hr^{-1}$)
TS	70.0	15.0	15.0	1.91	6.20	5.30	0.67	1.16	0.075	3.30	3.30	1.41	0.26	0.56	67.77	11.23
UTS	68.0	15.0	17.0	1.65	6.35	5.10	0.70	1.21	0.067	3.60	3.05	1.28	0.25	0.54	70.51	15.17
LSD (0.05)	1.44	NS	1.10	0.32	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	11.43	12.30
Locations																
Potiskum	71.8	11.2	17.0	1.50	6.55	5.80	0.90	1.56	0.088	4.00	3.80	1.60	0.30	0.71	46.99	10.21
Nangere	73.2	13.1	13.7	1.48	6.30	5.50	0.83	1.44	0.097	2.90	2.84	1.28	0.24	0.55	58.89	13.53
Fika	71.3	14.1	14.6	1.45	6.60	5.65	0.85	1.47	0.091	3.30	3.57	1.37	0.26	0.58	63.15	14.87
LSD (0.05)	1.21	1.24	1.78	0.03	NS	NS	NS	NS	0.021	1.42	1.03	0.12	0.11	0.31	13.54	11.33

Key; TS= Trampled Soil; UTS= Un-trampled Soil; NS= Not Significant; BD= Bulk Density; Pt= Total Porosity; Ks= Saturated Hydraulic Conductivity

Farmland



Locations

Fig. 3. Effect of cattle trampling and un-trampling on locations

Un-trampled soils showed significant increase in mean number of growth parameters of sorghum. The growth and yield (Figs. 1-3) parameters were significantly lower in trampled than un-trampled soils. This may be partly attributed to reduced vertical root distance in trampled soils which reduced the soil depth explored by the roots. This further indicated that certain stress prevailed in trampled soils [16] that must have led to the poor performance of sorghum, though this observation may depended on the agro-ecological zone and the rainfall pattern during crop growth. Tillage-based soil management practices usually have relatively little effects on soil water contents at planting [17].

4. CONCLUSION AND RECOMMENDATIONS

Cattle trampling results to soil compaction and the negative effect of soil compaction due to livestock trampling has been linked to poor root development. Lands grazed by cattle across the locations were exposed to surface soil compaction which affects total porosity, seed germination and establishment as well as water infiltration. Results of the study indicated that there were significant effects of cattle trampling with respect to all soil properties investigated. However, post planting results of analysis revealed that trampled soils had significantly lower statistical values for all yield parameters of sorghum. It is recommended that there is need to improve the structure of soils in all study locations through incorporation of organic matter and proper soil management for increased permeability, root penetration, aeration and water infiltration. It is also recommended that, there is need for cattle routes demarcation in order to provide free movement of livestock across the locations without encroachment into farmlands.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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