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CHARACTERIZATION OF SOIL EROSION UNDER DIFFERENT AGRICULTURAL LAND USE TYPES IN A SEMI-ARID REGION

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Abstract
This paper presents soil erosion responses to four different land use types in Maiduguri and environs. Representative of four soils from Dalori, Chad-basin, Jimtilo, and Domboa-road areas of Maiduguri were selected for the study. The four land uses studied were cultivations of orchard, cereal, and leguminous crops alongside bare soil which served as a control. They are representatives of land use practices found throughout Maiduguri and its surrounds. The samples were subjected to rainfall from stationary rainfall simulator. Results showed runoff volumes, soil loss and soil erodibility varied with land use types and locations. Runoff volumes, soil loss and soil erodibility were all higher in cereal crop-cultivated lands, and least in leguminous-crop cultivated lands. Parallel to that, runoff, soil loss and soil erodibility were highest from soils taken from Dalori area, and they were least from soils collected from Chad basin area. Leguminous cropped areas were found to be more effective in binding soil particles than tree crops. Cereal crops demonstrated poor soil binding effectiveness. The study shows that land use changes influenced the soil erosion risk and called for adoption of appropriate soil conservation techniques to preserve the soil quality, improve crop production and sustain environmental health.

Keywords: Land use types, soil erosion, Maiduguri and environs, Semi-arid region

1. Introduction
Land is commonly and increasingly utilized for agricultural purposes in a great variety of ways, and thus, is subjected to varying types and degrees of transformations within certain duration (Lal, 1997). Shift in land use and management could lead to the degradation of scores of hectares of landscapes with relevant consequences for local populations, landscape functionality and the maintenance of ecosystem services (Lal, 2010).

Soil erosion in agricultural lands has generally been acknowledged as a solemn form of land degradation arising from agricultural land uses, among other reasons. Erosion and runoff are not the primary causes of land degradation, but are foreseeable ecological consequences of improper land use and management. Many researchers such as Senjobi and Ogunkunle (2011), Statuto *et al.* (2014), and Statuto *et al.* (2016) among others have justified a strong linear relationship between land use types and soil erosion. Millions of hectares of land in both developed and developing countries were threatened by soil erosion, especially when even marginally productive lands have to be cultivated due to population pressure (Liu *et al.*, 2010). Agricultural land use type was reported as one of the dominant land degrading factors through processes, such as erosion, oxidation, mineralization, and leaching, among others (Kiflu and Beyene, 2013). Many watersheds that were converted agricultural and other related purposes became prone to soil erosion, nutrient depletion and other environmental damages (Liu *et al.* 2010). Lal (2010) stressed that land use changes, including deforestation, over grazing, and improper cultivation of agricultural lands lead to accelerated soil erosion and associated soil nutrient deterioration.

Obviously, land use can influence the soil chemical and physical properties due to the variant anthropogenic activities, such as tillage, livestock trampling, and all sequences of crop production, among others. Some researchers have showed the linkage between agricultural land uses, soil properties, and soil erosion (Lal, 2010; Senjobi and Ogunkunle, 2011). In Nigeria, the studies of Junge *et al*. (2008), Senjobi and Ogunkunle (2011), and Vigiaka *et al*. (2011) have worked out the effects of land uses and their management on soil properties relating various forms of agricultural land uses and soil erosion and other land degradations. In the non-cultivated land, the type of vegetative cover is a factor influencing the soil organic carbon content (Liu *et al*., 2010). The types of vegetation, therefore, could have overriding effect the soil's resilience to changes. This is due to the behavior of the soils under different rooting characteristics of the various crops (Liu *et al*., 2010). Apparently improved land use practices using soil conservation practices could limit soil erosion, environmental, and agronomic challenges to a tolerable plane. Evidently, the success of any soil management in maintaining the soil's quality and sustainable productivity is a function explicit understanding of how the soil reacts to different land uses. An inspection of the local land uses and their consequences on the soil is thus imperative to gain understanding of the profound changes connected with the land uses and social, economic and environmental problems. In Maiduguri and its environs, maize, millet, sorghum, cowpea, groundnut, sesame, and orchard are the major crops grown that constitute the major agricultural land use types. However, the need to recognize the position of the soil in crop production and maintenance of environmental quality at all levels cannot be overemphasized especially that there is a spacio-temporal noticeable evidences of land degradations with socio-economic impacts at varying degrees of severity in all parts of Nigeria (Senjobi and Ogunkunle (2011). Junge *et al*. (2008) further emphasized the need to retard the accelerating trend of soil degradation that has already become one of the most critical environmental problems in Nigeria, with soil erosion as one the major soil degrading agents. Vigiaka *et al*. (2011) had suggested means of managing landuse to control soil erosion problems in some parts of Kwara State of Nigeria. While Oruk *et al*. (2012) dissected the influence of soil textural properties and land use cover type on soil erosion characteristic of Ultisols in Betem, Cross River Sate, Nigeria. Information to support planning of any agricultural land use with regards to soil quality in this area is, however, deficient. This study was therefore initiated to look into the influence of different agricultural land use types on soil erosion characteristics in Maiduguri and its environs.

2. Materials and Methods

2.1 Study Area

The study was conducted using a stationary rainfall simulator located within the department of Agricultural and Environmental Resources Engineering Workshop, University of Maiduguri during the dry season of the year 2015. The simulator used for this study is in conformity with the works of Ekwue *et al*., (1991). The site falls in the northern Sahel savanna region of Nigeria (latitude 11^o 05' N, longitude 13^0 05' E on 350m above sea level). Maiduguri has mean annual rainfall and temperature of about 630mm and 32^{0}C respectively. It is the largest city in north-eastern Nigeria and is bordered by Jere, Konduga, and Mafa Local Government Areas. Rain fed cultivation of crops such as ground nut, cowpea, sorghum, millet, garden, orchards, and grazing among others, punctuated by little dry season irrigation constitute the major agricultural land uses of the area. Table 1 provides some physical and chemical characteristics of the soils in the study area (Arku *et al*., 2012)

Table 1: Some Physical and Chemical Characteristics of the Soils in the Study Area

Characteristics	Measured Values
Textural Composition	(%)
Sand	62.0
Silt	20.0
Clay	18.0
Infiltration rate (mmhr^{-1})	123
Available Moisture Capacity (%)	12.1
Bulk Density (gcm^{-3})	1.38
PH	6.4
Electrical Conductivity of saturation extract, ECe (msm^{-1})	3.8

2.2 Soil Sample Collection

About 30kg each of soil samples were collected using an auger at four selected areas, namely Chad-Basin (CB), Jimtilo (J), Damboa-Road (DR) and Dalori estate (DL) areas in four (4) different land use sites, namely Orchard-, cereal-, and legumes-cultivated lands, and on bare (non cultivated) lands. The samples were transported in a polyethene container (to preserve the naturality of the samples) to laboratory and to the experimental site near a stationary rainfall simulator.

2.3 Experimentation

About 5kg each of soil samples was placed in an erosion pan (90cm long, 40 cm wide and 15 deep) and then positioned under the simulator. Rain was simulated on the soil, runoff was collected and allowed to settle over a period 24 hours. The residues there from were filtered and oven-dried at 105^{o}C to arrive at sediment concentration. The soil losses from each pan were obtained as the ratio of sediment concentration to the cross sectional area of the pans. The soil erodibility factor (K) was calculated from equation (1) (Vanelslande *et al*., 1984).

$$K = \frac{A}{R \times LS} \qquad (1)$$

Where: A = observed soil loss in t ha^{-1}; R = rainfall erosivity index; and LS = topographic factor. Wischmeier and Smith (1978) and Vanelslande *et al*. (1984) presented the details of the application of Eqn. 1

3. Results and Discussion

Table 2 contained some soil erosion characteristics under different agricultural land uses. The results show that run off volume (ROV), soil loss, and erodibility values were higher on bare soils that all other land uses irrespective of the slopes. But all the values were higher under 3 % that under 2 % slopes. For instance, fewer than 2% slope, ROV was 33%, 22.8% and 18% higher from the bare soil compared to those obtained from orchard, legume and cereal cultivated lands respectively. Similar result was observed in the cases of the soil loss and erodibility values. This affirms the records of (Senjobi and Ogunkunle, 2011)) that soil loss can vary considerably different land use systems, and that soil bare soils are more vulnerable to soil erosion. The result of the multiple linear stepwise regression analysis conducted by Senjobi and Ogunkunle (2011) also showed that factors contributing to different forms of degradation differ from one land use type to another. Further look at Table 2 also shows that land used for orchard are more susceptible to erosion. This is attributed to deep rooting characteristics of trees that mostly leave the soil surface more or less bare. This points that soil the binding effects of the tree roots are only effective beneath the soil surface. Wijitkosum (2012) indicated plant roots may form a dense network in topsoil that physically binds soil particles, and that the soil-root matrix has more resilience than the soil or roots separately. In addition, plant root systems also influence the properties controlling soil erodibility, e.g. soil aggregate stability, infiltration capacity, soil bulk density, soil texture, organic content and chemical composition continued Wijitkosum (2012).

The effect of slope has a direct proportionality with soil loss and all other erosion characteristics. This is illustrated by the R^2 value of 0.989 relating soil loss and slope of 2%. The results have the same trend with 3% slope. This upholds the findings of Brath *et al*. (2002)

Table 2: Comparison of soil erosion characteristics under different Agricultural land uses

	Runoff Volumes (cm^3)		Soil loss (tha^{-1})		Measured K-values	
Slope (%)	2	3	2	3	2	3
Land uses						
Bare soil	2140.38	2036.5	0.23148	0.2177	0.42808	0.3905
Orchard-cultivated	1430.25	1738.7	0.164675	0.28645	0.27255	0.3161
Legume-Cultivated	1651.75	1421.45	0.19645	0.333625	0.3211	0.367925
Cereal-Cultivated	1738.95	1794.7	0.2155	0.350925	0.356725	0.387125

Table 3 shows the interactive effects of locations and land use on soil erosion characteristics under different agricultural land uses and two different slopes. The Table shows that larger runoff volume was generated from soils taken form Damboa-road (DR) irrespective of land use type. This was closely followed by soil samples from Chad basin area. Soil loss was however, greater in from Jimtilo soils. Generally, soil losses were highest in cereal-cultivated lands irrespective of the site. This means that cereal crops had exhibited poor soil binding efficiencies, resulting into loose and erosion-prone soil particles. It is also apparent from Table 3 that soil losses were minimal in orchard cultivated lands, followed by lands upon which leguminous crops were grown. The mean values of soil loss were highest in cereal-cultivated lands.

Table 3: Combined effects of location and land use on soil erosion characteristics under different Agricultural land uses

	Runoff volumes cm^3		Soil loss (th^{-1})		Measured k values		Cumulative k values	
Slope (%)	2	3	2	3	2	3	2	3
Location/Land uses								
J Br	473.59	481.3	64.35	52	0.1065	0.096	0.2808	0.3486
DL Br	500.5	430.2	59.67	63.2	0.0988	0.0998	0.2564	0.3746
DR Br	602.29	562	74.36	51.3	0.1231	0.095	0.3289	0.3548
CB Br	564	563	33.1	51.2	0.0997	0.0997	0.3666	0.3715
Mean	***535.1***	***509.1***	***57.87***	***54.43***	***0.107***	***0.098***	***0.308***	***0.362***
Jo	293	343.3	39.7	64.3	0.0657	0.0709	0.0657	0.0709
DLo	293.3	363.3	34.5	75.6	0.0571	0.0834	0.0571	0.0834
DR o	353.3	499	43.6	69.5	0.0722	0.0767	0.0722	0.0767
CB o	439	460	45.7	71.2	0.0756	0.0786	0.0756	0.0786
Mean	***344.7***	***416.4***	***40.88***	***70.15***	***0.068***	***0.077***	***0.068***	***0.077***
J L	355	418.3	41.3	79.5	0.0684	0.0877	0.1341	0.1586
DL L	303.3	320.5	38.7	83.2	0.0641	0.0918	0.1212	0.1752
DR L	393.1	337	52	81.6	0.0861	0.09	0.1583	0.1667
CB L	454	396	58.2	86.2	0.093	0.095	0.1686	0.1736
Mean	***401.4***	***368***	***47.55***	***82.63***	***0.078***	***0.091***	***0.146***	***0.169***
Jcr	364.3	323.3	49.5	85.2	0.0819	0.094	0.216	0.2526
DL cr	385	385	45.9	90.3	0.076	0.0996	0.1972	0.2748
DR cr	463.3	521	57.2	84.4	0.0947	0.0931	0.253	0.2598
CB cr	470	465.1	59.4	89	0.0983	0.0982	0.2669	0.2718

Mean	***420.7***	***423.6***	***53***	***87.23***	***0.088***	***0.096***	***0.233***	***0.265***

Key: JO=Jimtilo Orchard, JL=Jimtilo Legume, JCr = Jimtilo Cereal, J Br = Jimtilo Bare soil, DLO=Dalori Orchard, DLL=Dalori Legume, DL Br = Dalori bare soil, DCr =Dalori Cereals, DRO=Damboa Road Orchard, DR Br = Damboa road bare soil, CBL=Chad Basin Legume, CB Cr = Chad Basin Cereals, CB Br = Chad basin bare soil.

4. Conclusions

Soil erosion has continued to be one of the foremost challenges for sustainable crop production in the north eastern sub-region of Nigeria, particularly in Maiduguri and its environs. Variations in unsustainable agricultural practices, high population pressure, climate change, topographical features and various agricultural land uses are the core facilitators for severe erosion. Characterizing the variability of soil erosion in relation to land use becomes imperative. It was understood in this study that more runoff occurs in orchard-cultivated lands, but with little soil loss. Correspondingly, lands used for growing cereal crops produced highest soil losses. It points that some appropriate soil conservation measures need to be adopted to retard soil erosion in cereal- and orchard-cultivated lands respectively. The highest K-values were from Dalori estate soils that were subjected to cereals crop cultivation and the lowest K-values were from Jimtilo soils upon which tree crops were grown. Generally, a practical approach of soil management technique that would encourage continuous substantial vegetal cover on the soil to improve on the soil structures toward depressing soil erodibility and mitigating the effects of soil erosion is needed in Maiduguri and its environs. Additional study to investigate the long term, rather that short term effects of all factors contributing to soil erosion in order to draw a reliable conclusion on the real behavior of the soil under varied conditions is hereby recommended.

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