OSUN GEOGRAPHICAL REVIEW

Journal of the Department of Geography,
Osun State University, State of Osun, Nigeria

Volume 2, 2019

ISSN: 2695 - 1959

Published by the
Department of Geography, Osun State University,
State of Osun, Nigeria

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OSUN GEOGRAPHICAL REVIEW
Published by the Department of Geography, Osun State University, State of Osun, Nigeria
ISSN: 2695 - 1959 Volume 2, 2019; 1 – 8

ASSESSMENT OF CHANGES IN SOIL PROPERTIES UNDER DIFFERENT LANDUSES IN PART OF BIU PLATEAU, BORNO, NIGERIA

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Abstract

There is a growing concern on the diminishing quality of soil resources occasioned by changes in land use which has resulted in loss of vegetation cover, changes in fertility status of soil, disturbance of soil structure, soil erosion and reduction in productive potential of the soils. This study assesses changes in selected soil physicochemical parameters under different land uses. Soil samples were drawn from four land use categories viz, cultivated land, scrubland, forested land and bare surface across five settlements in the study area. For each land use category at the study sites, surface soil samples were augered at 0-15 cm depth. A total of 20 composite samples were collected from 80 plots within the four land use categories in the study settlements and from which one kilogram (1kg) each was taken to the laboratory for analysis. The results showed that soil organic matter and soil texture were significantly affected by land use change ($P < 0.05$) and soil organic matter declined following deforestation and continuous cultivation with a mean of 2.03 g/kg^{-1} recorded for forest land and 1.41 g/kg^{-1} for cultivated land while scrubland and bare surface recorded 1.34 g/kg^{-1} and 1.25 g/kg^{-1} respectively. The soil texture was generally sandy clay. In contrast, pH, soil moisture content, cation exchange capacity, bulk density and porosity were not significantly ($P > 0.05$) different, although comparisons between cultivated land, forest land, scrubland and bare surface revealed some degree of difference for the physicochemical parameters. Soil pH is slightly acidic (6.68-6.33), relatively high bulk density (1.49 g/cm^3-1.44 g/cm^3), and medium to low mean porosity values (42-44%). The mean moisture content is highest in cultivated land (23.76%) and lowest in bare surface (15.38%). CEC values for cultivated and bare surface are low (10.47cmol/kg^{-1}) and (8.79 cmol/kg^{-1}) respectively. Findings from this study showed that the soils are acidic with generally low organic matter content and low porosity with high bulk density over cultivated, scrubland, and forest land use respectively. Recommendations made based on the findings include integrated use of inorganic and organic fertilizers and application of liming and soil conservation practice amongst others.

Keywords: Land use, Soil properties, Soil quality, Soil fertility, Soil management

Introduction

Soil properties are influenced by vegetation characteristics under which the soils are located (Senjobi and Ogunkunle, 2011). Soil management approaches involving biomass burning, soil tillage, mulching and application of fertilizer among other cropping systems play vital role in the degree of changes in soil properties. The conversion of natural vegetation to farmland and grazing reserves triggers the processes of soil degradation which hampers soil quality (Materechera and Mkhabela, 2001; Jaiyeoba, 2003; Yang et al., 2004; Liu et al., 2010; Kilic *et al.,* 2012). Frequent cropping has been observed to cause decline in soil fertility by reducing organic and inorganic colloidal materials and reduction in soil microbial activities (Celik, 2005). Landuse/ landcover change (LULC) is used to explain the modification of earth's terrestrial surface. Though man has been modifying the land through agricultural practice to produce food and other livelihood support activities, the current rates, extents and intensities of landuse/ landcover changes is far greater than ever in history, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales (Erle, 2007).

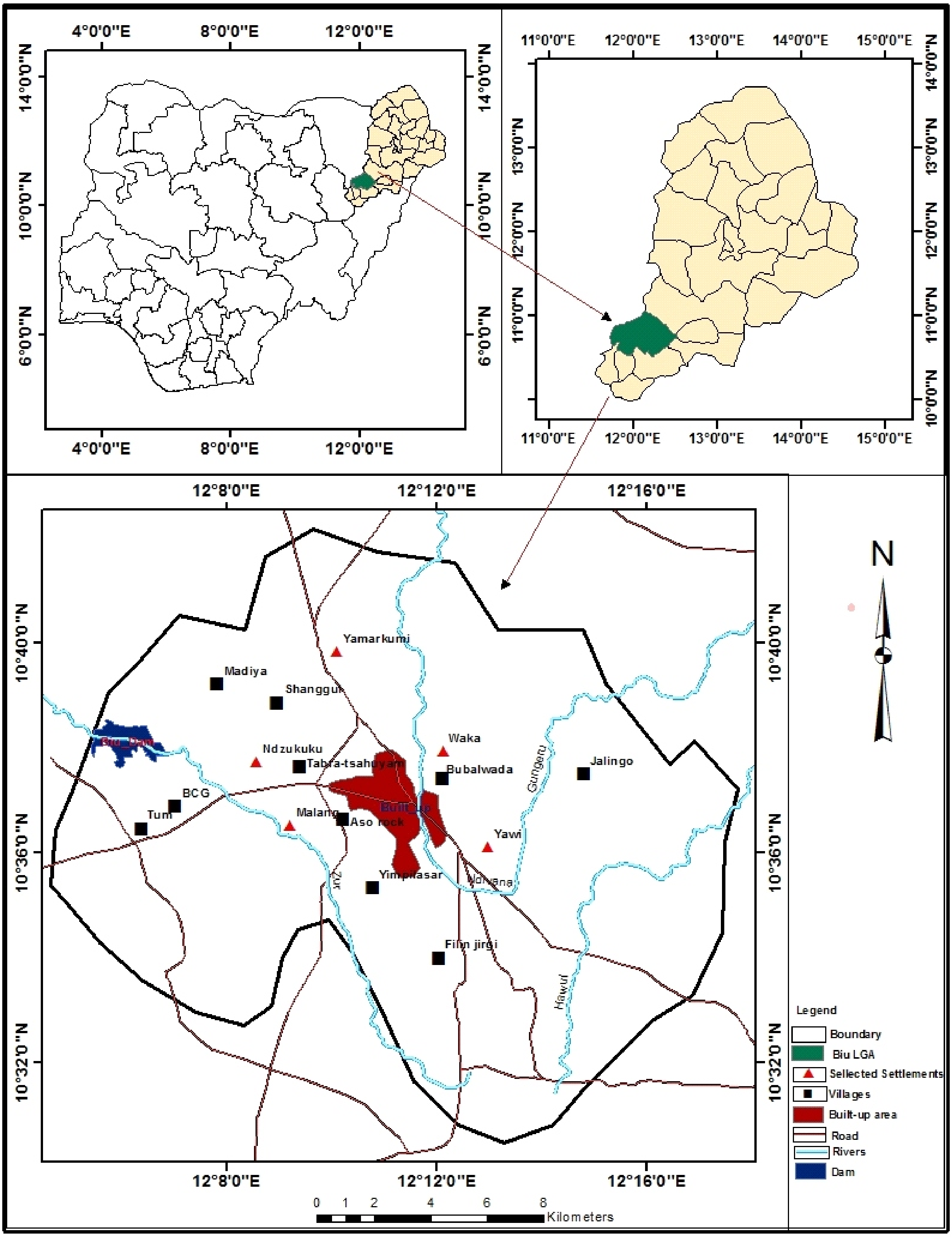

Fig. 1: Location of the Study Area

Changes in land cover due to agricultural intensification result in loss of soil productive capacity in many parts of the arid and semi-arid areas (Zewdie, 2001). Studies have shown that land use changes affect the physical and chemical properties of the soil thereby leading to soil degradation (Kilic et al, 2012; Aminu and Jaiyeoba, 2015). However, the rate and extent of changes in soil properties through human intervention is location specific given that soils of different localities that experienced similar pedogenic processes can be differentially affected depending on the intensity of landuse practices. Therefore, the objective of this study is to assess the conditions of soil physical and chemical properties under different land uses and their implications on soil fertility in the study area.

Materials and Methods

Description of the study area

Biu plateau is located in the southern part of Borno State on latitude 10°30□0□□N-10°40□11□□N and longitude 12°4□0□□E-12°20□0□□E. The entire Biu area covering the plateau has a land area of 2,492.4km^2 with an average elevation of over 626 m above sea level (Fig. 1). The climate over the plateau is described as tropical continental climate. Temperature is high all year round with a mean annual air temperature of 30^{0}c. The highest temperatures are recorded during the dry heat wave months of between March and May with maximum air temperature of above 37^{0}c. During the rainy season, the temperature drops considerably due to dense cloud cover between July and August as well as during the harmattan period of November to February. Rainfall is strongly seasonal due to the oscillation of the inter-tropical convergence zone (ITCZ) which controls the Tropical Maritime and the Tropical Continental air masses of contrasting air moisture and relative humidity over the study area. The mean annual rainfall total ranges from 835 mm to 982 mm and the geology of the Plateau is mainly fine grain basaltic materials of tertiary and quaternary age. Extension of the geology is also the weathered basement complex of granites, gneiss and lenses of schist, shale among others. The plateau is drained by River Hawul which flows southward and discharges into the Gongola River. Soils derived from weathered basement complex vary from clayey loamy soil, sandy soil to silt. The soils are reddish brown and experiences fertility decline under continuous cropping. Vegetation of the study area falls within the Sudan Savannah characterized by short grasses and scattered short deciduous trees. Commonest trees found in the area include neem, acacia, shea-butter, locust bean, tamarind, baobab, gum arabic among others. The vegetation has been altered by human activities of deforestation resulting from logging, construction, grazing, bush burning and continuous cropping (Daura, 2001).

Landuse and landcover classification scheme

Land use/ land cover categories of built-up area, water bodies, cultivated land, bare surface, forest area and scrubland were identified and classified in the five study settlements of Malang, Ndzukuku, Waka, Yamarkumi and Yawi each located 15km from Biu central business district. From the classified landuse/landcover, only four categories appropriate for the study (cultivated land, scrubland, forest area and bare surface) were selected. The classification scheme for the landuse/ landcover category is presented in Table 1.

Table1: Land Use/Land Cover Classification Scheme Adopted for the Study

S/N	Landuse/Landcover classes	Description
1	Cultivated Land	All agricultural land uses such as farm lands under cultivation.
2	Bare surface	Degraded lands, bare land left to fallow, areas with scanty or no vegetation cover. Expose and open grounds that are neither vegetated nor built-up.
3	Forest Area	Areas of wooded savannah vegetation, reserves and plantation.
4	Scrubland	Areas covered b y grasses, herbaceous and shrubby plants of low height trees usually less than 2 metres tall used for animal grazing and livestock farming.

Source: Adapted from Anderson et al, 1976

Method of soil sample collection, preparation and analysis

Soil samples collected for this study were drawn from four land use categories from the settlements of Malang, Ndzukuku, Waka, Yamarkumi and Yawi. For each land use category at the study sites, surface soil samples were augered at 0-15 cm depth. For each land use category at the study sites, surface soil samples were augered at 0-15 cm depth. Soil sample was collected at four different plots per landuse and at 20 cm apart to form a composite sample. A total of 20 composite samples were collected from 80 plots within the four land use categories in the study settlements and from which one kilogram (1kg) each was taken to the laboratory for analysis. The collected soil samples were air dried, crushed and passed through 2 mm mesh sieve size to remove stones and other organic residues before laboratory analysis.

Analyzed soil properties include particle size distribution (texture), bulk density, porosity, moisture content, soil pH, cation exchange capacity (CEC) and soil organic matter (SOM). Soil particle size distribution (texture) was determined by the Bouyoucos hydrometer method (Bouyoucos, 1962) and sodium hexametaphosphate was used as a dispersing agent. Bulk density was determined from undisturbed soil samples using the core sampling method after drying a defined volume of soil in an oven at 105°C for 24 hours (Blake, 1965). It was calculated as the ratio of the mass of oven dried soil to the volume of the sampling core. Porosity was calculated from the values of bulk density (BD) and particle density (PD) (Brady and Weil, 2002) as:

$$\text{Total porosity (\%)} = (1 - \tfrac{BD}{PD}) X 100$$

Soil moisture content was determined using the gravimetric method. It was calculated as soil field weight minus oven dried soil weight divided by the dry soil weight. Soil pH was measured potentiometrically using a digital pH-meter in the supernatant suspension of 1:2.5 soil to water ratio (Agbenin, 1995). The soil organic carbon (OC) was measured by wet digestion method (Nelson and Sommer, 1982). Values of soil organic carbon was multiply by a factor of 1.72 to obtain soil organic matter while cation exchange capacity (CEC) was determined by using ammonium acetate saturation method (Agbenin, 1995).

Statistical analysis

Mean, standard deviation, coefficient of variation and one-way analysis of variance (ANOVA) at $p< 0.05$ significant level was used to test the interaction of land use types on changes in soil properties.

RESULTS AND DISCUSSION

The result of the variation of soil properties under different land uses is presented in Table 2. The selected soil properties show variation among the different land uses under study with the soil pH sensitive to soil management practice resulting from human activity and changes in the natural environment. The mean pH value under the different land uses is acidic. The mean pH value for cultivated land, Scrubland, forest and bare surface are 6.33, 6.53, 6.35 and 6.68 respectively. The analysis of variance shows that the changes in pH values over the different land uses are not statistically significant. The lower pH value recorded over cultivated land is attributed to changes in land use from forest to cultivated land. Studies have shown that slightly acid nature of the soil can be attributed to the leaching of some basic cations especially calcium from the surface horizons of the soils, continuous removal of basic cations by high yielding crop varieties, use of inorganic N and P fertilizers and intensive cultivation (Wakene and Heluf, 2003; Iwara et al; 2011).

Changes in land use from forested area to cultivated field and open grazing lands usually results in reduction of both the concentration and stock of soil organic matter (SOM). Soil organic matter varied significantly under soils of different land uses ($p<0.05$). The mean soil organic matter content was highest on soils under forest land (2.03 g/kg^{-1}) and lowest (1.25 g/kg^{-1}) on bare surface with cultivated land and scrubland recording (1.41 g/kg^{-1}) and (1.34 g/kg^{-1}) respectively. The decline in soil organic matter content in the cultivated land can be attributed to deforestation and removal of crop residue after harvesting to feed livestock.

Table 2: Variation of Soil Properties Under Different Land Uses

Land uses	pH (1:2.5)	SOM (g/kg^{-1})	MC (%)	CEC (cmol/kg)	Sand (%)	Silt (%)	Clay (%)	BD (g/cm^3)	Porosity (%)
Cultivated Land									
Mean	6.33	1.41	23.76	10.47	59.80	12.60	27.60	1.49	43.00
SD	0.15	0.29	6.22	1.32	24.44	10.03	16.67	0.00	1.55
CV%	2.37	20.57	26.18	12.61	40.87	76.60	60.40	0.00	3.60
Scrubland									
Mean	6.53	1.34	18.97	10.97	62.80	16.00	21.20	1.46	44.00
SD	0.26	0.19	6.53	4.56	10.38	11.01	9.85	0.06	3.03
CV%	3.98	14.18	34.42	41.57	16.53	68.81	46.46	4.11	6.89
Forest									
Mean	6.35	2.03	22.33	10.66	65.56	13.24	21.60	1.46	42.20
SD	0.28	1.19	8.81	0.60	26.20	12.55	13.66	0.12	0.40
CV%	4.14	58.62	39.45	5.62	39.96	94.79	63.24	8.22	0.95
Bare surface									
Mean	6.68	1.25	15.38	8.79	58.56	16.60	27.00	1.44	42.40
SD	0.06	0.56	4.53	1.46	26.19	14.12	14.68	0.12	1.69
CV%	0.90	44.80	29.45	16.61	44.72	85.06	54.37	8.33	3.99
ANOVA	4.20^{ns}	5.04^{*}	1.11^{ns}	0.78^{ns}	0.16^{*}	0.38^{*}	1.81^{*}	0.31^{ns}	0.53^{ns}

** Statistically significant at $p < 0.05$; ns not significant*
Source: Laboratory analysis, 2018

The reductions on the bare surface and scrubland is a reflection of diminishing vegetal cover as a result of urbanization, extension of paved urban surfaces and the increasing rates of animal grazing. The result of this study is in agreement with the findings of Lobe et al, (2001); Jaiyeoba, (2003); Aminu and Jaiyeoba, (2015) who reported that soil organic matter content decreases in soils under continuous cultivation and pasture with the top soil containing less organic matter compare to forest land due to forest clearance and rapid oxidative decomposition resulting from high temperatures.

Soil moisture content shows slight variation in the mean values of cultivated land (23.76%) and forest land (22.33%). On the other hand scrubland and bare surface recorded a mean value of 18.97% and 15.38% respectively. The coefficient of variation for soil moisture content is high over the forest (39.45%) and lowest over the grazing land (22.98%). Result of analysis of variance shows no significant difference in soil moisture over the different land uses at 0.05 significant levels. The observed difference in the moisture content of the soil across the different land use can be partly attributed to the undulating plateau nature of basement complex that is not thoroughly weathered and fissured in parts of the study area. Other factors that contributed to differentials in the moisture content include surface compaction from logging activities and animal grazing. The higher mean values of soil moisture content over cultivated and forest land use may be attributed to the nature of the soils which is mostly clayey loam with improved water holding capacity. The result of this study is in agreement with the findings of Wakene, (2001); Ahmed, (2002); Tilahun, (2007) and Chemeda et al, (2017) who reported that soils under different land use differed in their water content both at field capacity (FC) and permanent wilting point (PWP) because they vary in sand, silt and clay contents.

Changes in land use and variable surface accumulation of organic matter affect the CEC of soils. The mean value of CEC is highest over scrubland (10.97$cmol/kg^{-1}$) and lowest over the bare surface (8.79$cmol/kg^{-1}$) while the cultivated land and forest land recorded mean values of 10.47$cmol/kg^{-1}$ and 10.66$cmol/kg^{-1}$ respectively. The proportion of CEC recorded did not vary significantly under soils of different land uses ($p>0.05$). The highest CEC value recorded on scrubland is attributable to the concentration of organic matter from animal dung on the surface by grazing animals. In comparison to cultivated land, the relatively higher values of CEC recorded in forest soils is attributable to the concentration of large amount of biomass whose decay contribute humus to forest soil and therefore increase the capacity to hold cations thereby resulting greater potential fertility in the soil. Findings from the studies of Alemayehu and Sheleme, (2013); Wasihun et al, (2015) also reported high cation exchange capacity (CEC) values for soils under grassland and grazing land compared to cultivated land where crop residues are largely removed to provide folders for animals.

The soil particle size distributions were affected by the interaction of land use and reveals significant variation in soil textural classes under soils of different land uses ($p<0.05$) with higher mean value of 65.56% (sand) and 16.60% (silt) contents recorded on forest land and bare surface respectively. In like manner, the highest mean value (27.60%) clay content was recorded on cultivated land, whereas the lowest mean value (21.20%) clay content was observed on scrubland. The result of this study is also in agreement with the findings of Shiferaw (2004) who reported an increase in clay content with depth under cultivated lands due to long period of cultivation. Similarly, studies have shown that continuous cropping and intensive land use affected soil particle size distribution (Voundi and Tonye, 2002; Jaiyeoba, 2003; Agoume, 2009).

The values of bulk density show relative homogeneity amongst the land use and were not statistically significant at ($p<0.05$). However, numerically higher mean value (1.49 g/cm^3) of bulk density was recorded on farm land and the lowest mean value (1.44g/cm^3) on bare surface while scrubland and forest land use both recorded (1.46g/cm^3). It is most likely that surface compaction resulting from intensive cultivation, grazing animals, haulage vehicle used for logging of timber might have caused the relatively higher bulk density values observed in the surface soil layers of the cultivated land, scrubland and forest land respectively. The findings from the studies of Chemada *et. al.* (2017); Kerenku and Orkpe (2017) also reported higher mean values of bulk density for soils under cultivated land use. Their studies attributed lower bulk density to the high soil organic matter, porosity and less disturbance of the land under forest and higher bulk density under the cultivated areas were attributed to compaction of soil surface by intensive cropping and deforestation.

Porosity mean value ranges from 44.00% to 42.20%. The lower value of porosity over cultivated land in comparison to the higher value over scrubland is attributed to the higher bulk density recorded for cultivated land that impede infiltration minimally. However, the changes in porosity value as observed were not statistically significant at ($p<0.05$). The result of this study is in agreement with the earlier findings of Islam and Weil, (2000); Jaiyeoba, (2003); Chimdi et al, (2012); Heluf, (2013); Aminu and Jaiyeoba, (2015) who reported that conversion of natural forest ecosystem to cultivated with continuous tillage and cropping subject the soil to compaction that subsequently decreased porosity.

Generally, the drive towards food security is anchored on good soil management practice, however, changes in land use causes important changes in physical and chemical characteristics of soil. Soil fertility is declining in many parts of sub-Saharan Africa and the major constraints to crop production faced by smallholder subsistence farmers is the inadequate supply of nutrients. Farmers are entirely abandoning the traditional practice of natural fallow to restore soil fertility as a result of population pressure and increasing demand for land. The use of mineral fertilizers is declining as they are increasingly beyond the means and reach of most small scale farmers. Accelerated soil erosion and severe run-off are further depleting existing soil nutrient reserves, while levels of soil organic matter are declining as land is subjected to agricultural intensification.

Conclusion and recommendations

The findings of this study indicate changes in the soil physical properties under different land uses. The study showed that the soils are slightly acidic with generally low organic matter content and low porosity with high bulk density over cultivated, scrubland, and forest land use respectively. Deforestation, animal grazing and agricultural intensification without adequate soils management practice in the study area had a far reaching effect on soil quality leading to soil degradation and ultimately loss of land productive value. Based on the findings, the following recommendations were made:

i. Farmers should recycle crop residues after harvest in such a way that it will decompose to improve soil nutrient and soil fertility.

ii. Periodic bush fallowing should be encouraged to increase soil organic matter and stabilize soil aggregates.

iii. Towards reduction of accelerated soil erosion and soil degradation, the practice of agroforestry, conservation tillage and mulching should be encouraged to improve the soil micro-climate that is required for bacteria, fungi, micro-fauna and other soil microbes that facilitate organic matter decomposition, thereby facilitating carbon sequestration in the soil.

iv. Controlled animal grazing that reduces cattle trampling and lowers soil mean bulk density so as to increase porosity should be practiced.

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