sciendo DOI: 10.2478/ats-2023-0003 AGRICULTURA TROPICA ET SUBTROPICA, 56 OV, 19–32, 2023

Original Research Article

Comparative assessment of soil degradation potentials of commodity crops grown in Nigeria

Akeem Olawale **Olaniyi**, Wahab Ayatande **Abioye**

Department of Environmental Management, Faculty of Environmental Sciences, Kaduna State University, Kafanchan Campus, Kaduna State, Nigeria

Correspondence to:
A. O. Olaniyi, Department of Environmental Management, Faculty of Environmental Sciences, Kaduna State University, Kafanchan Campus, Kaduna State, Nigeria.
E-mail: akeem.olaniyi@kasu.edu.ng, phone: +2349030659494

Abstract

Comparative assessment of land degradation potential of commodity crops grown in Jaba Local Government Areas of Kaduna State, Nigeria was investigated to provide evidence for crop-specific land management practices in the area. Soil samples collected from plots of four (maize, ginger, mango, and oil palm) main crops grown within three (Ungwan Rana; Kurmin Kwara, and Kyari) communities were analysed for relevant physico-chemical variables using standard laboratory procedures. The preliminary results of laboratory analyses showed that soils, where annual crops were grown had a higher content of sand particles, higher bulk density, $pH_{(water)}$, mineralization (lower carbon content), and gravimetric water content when compared to soils where permanent crops were found growing. Soils, where tree crops were growing, had a higher silt, clay, and organic matter content. Results from the erodibility factor (k) estimation indicated that ginger production in Kurmin Kwara had the greatest impact of all three sites and crops investigated with an annual soil loss of 12 kg/ha/annum. Mango production in Ugwan Rana resulted in the least impact with an estimated loss of 9 kg/ha/annum of soil to erosion. Evidence of two-way analysis of variance of land degradation (erodibility) data at a 95% confidence level in SPSS version 21 indicated that the impacts resulting from the cultivation of different crops in various communities are not significantly different from one another. Therefore, soil conservation measures such as mulching, composting, land fallowing, and cover cropping would be helpful in eliminating the emerging land degradation owing to the cultivation of commodity crops in the study area.

Keywords: crop-specific; land management; practices; erodibility factor (k); land degradation; physico-chemical parameters; soil; conservation measures

INTRODUCTION

Land based agriculture is the source of about 90 percent of human calories and protein (FAOSTAT, 2021). It also provides food, fibre, and job opportunities (UNCCD, 2017) to about one-fourth of the global population (Searchinger et al., 2019; Abraham and Pingali, 2020). Unfortunately, these agricultural activities cause farmland degradation in form of soil erosion, aridity, soil salinization, and loss of soil carbon (Abdullah and Nakagoshi, 2006; Wu, 2013; FAO and ITPS, 2015; Abebaw, 2019; Khoroshev, 2020; UNEP, 2021), depletion of soil organic matter, surface sealing, compaction, salinity, acidity, metal and/or organic toxicity (Prăvălie et al., 2021) with consequent loss of biodiversity (Dainese et al., 2019) subsequently resulting in loss of agricultural yield, malnutrition and hunger

(UNEP, 2021), and eventually jeopardizing the ability of nations to meet their Sustainable Development Goals (SDGs) targets (Kaiser, 2004; Meijer et al., 2018; Nhemachena et al., 2018).

Soil is an essential resource for agricultural productivity (Keesstra et al., 2016; Borrelli et al., 2017; Robinson et al., 2017). Increasing population, urbanisation, agricultural intensification, and commercialization amongst several other human anthropogenic activities cause higher runoff against infiltration thereby causing soil erosion ((Wu and Xie, 2011 ; Ding et al., 2015; Niu et al., 2015 ; Liu, 2016). The trend over time immemorial has indicated the conversion of the natural landscape to agricultural lands (Marchant, 2018; Mucova et al., 2018; Gabiri et al., 2019) owing to the growing population, economy, and globalization (Kleemann et al., 2017; Marchant, 2018).

Soil erosion has been projected to affect about 80 percent of the global arable land (FAO and ITPS, 2015; Searchinger et al., 2019; Abraham and Pingali, 2020). Soil erosion due to cropland expansion has been estimated to cause about the one-fifth loss of global farmlands (Prăvălie et al., 2021) a loss of about 12 million hectares of croplands; a 12% reduction in the global food supply, a 30% increase in global food prices by the year 2040 (Noel et al., 2015; Kopittke et al., 2019), loss in agricultural revenue to the tune of EUR 1.25 billion in the European Union (Panagos et al., 2018), the decline in soil fertility and increase in the cost of production due to greater need for extra fertiliser on cropland (Jang et al., 2020) and degradation of about 823,700 ha of forestland (Olayide, 2021), loss of about 75 billion tonnes of arable land globally (Global Soil Partnership, GSP, 2017) with an estimated financial implication of US$400 billion annually (Borrelli et al., 2017).

Several studies attributed accelerated erosion of soil to deforestation (Oldeman, 1994; FAO, 2011), overgrazing (Pimentel and Burgess, 2013) and unsuitable agricultural practices (Montgomery, 2007; Nearing, 2013; Walling, 2013), agricultural expansion, infrastructural development and wood extraction in land degradation (Geist and Lambin, 2001; Geist and Lambin, 2002; Millennium Ecosystem Assessment, 2005; Obersteiner et al., 2009; Kissinger et al., 2012; Rohrmann et al., 2013; Zhao et al., 2014; LDNTSP, 2018).

Soil erosion involves loosening, transportation, and deposition of soil materials causing the loss of top-nutrient-rich soil; plant nutrient deprivation (on-site), and deposition of soil particles off-site (Shi et al., 2012) where it could result in flooding, river pollution, siltation, and eutrophication of water bodies (Boardman and Poesen, 2006; Montgomery et al., 2014; Al-Wadaey and Ziadat, 2014; Ding et al., 2015; Guo et al., 2015). Moreover, sediments transported to a new location may contain nutrient and/or heavy metal contaminants which would lead to siltation of the reservoirs, eutrophication, and pollution of delicate ecosystems (Bing et al., 2013). Also, soil erosion has the capacity to exacerbate climatic change through enhanced mineralization and sediment burial (Lal, 2004; Oost et al., 2007).

Soil erodibility factor (k) which is the amount of soil detached and transported over a specific time period can be estimated with the use of the Universal Soil Loss Equation (USLE) (Ostovari et al., 2019). Udosen (2013) asserted that soil erodibility is a function of vegetation cover, depth of litter cover, root content, slope inclination, soil porosity, silt/clay ratio, soil texture, and organic matter content (Imani et al., 2014; Okorafor et al., 2017). Okorafor et al. (2017) found that soils with large amounts of silt-sized particles are mostly susceptible to erosion compared to soils with clay or sand-sized particles because silt particles have a lower amount of organic matter. Conversely, soil with high organic matter content is protected from the direct impact of rain drops and soaks up rain water that would have been runoff (Shahrivar and Christopher, 2012).

Wischmeier et al. (1971) developed an analytical method for estimating soil erodibility based on the soil texture, structure and percentage of organic matter present in the soil. The Revised Universal Soil Loss Equation (RUSLE) model as described by Wischmeier et al. (1971) and used by several authors (Rosewell, 1993; Flanagan and Nearing, 1995; Hassan and Agha, 2012; Songu et al., 2020) in similar studies is:

$$K = 27.66 * m^{1.14} * 10^{-8} * (12 - a) + 0.0043 (b - 2) + 0.0033(c - 3) \quad \text{eqn 1}$$

where:
K = soil erodibility factor (t/ha/h; ha/MJ/mm)
m = [silt (%) + very fine sand (%)) (100 – clay (%)] [the product of the percent of silt and sand present in the sample]
a = organic matter (%)
b = Soil structure code (1) very granular; (2) fine granular; (3) medium or coarse granular and (4) blocky, platy or massive (Hassan and Agha, 2012).
c = Profile permeability code: (1) rapid; (2) moderate to rapid; (3) moderate; (4) moderate to slow (5) slow and (6) very slow.

Several articles have been published on the impacts of soil erosion on crop production in Africa (Taddese, 2018; Kyawt et al., 2015; Gnacadja and Wiese, 2016; UNEP, 2014). Studies of Obalum et al.

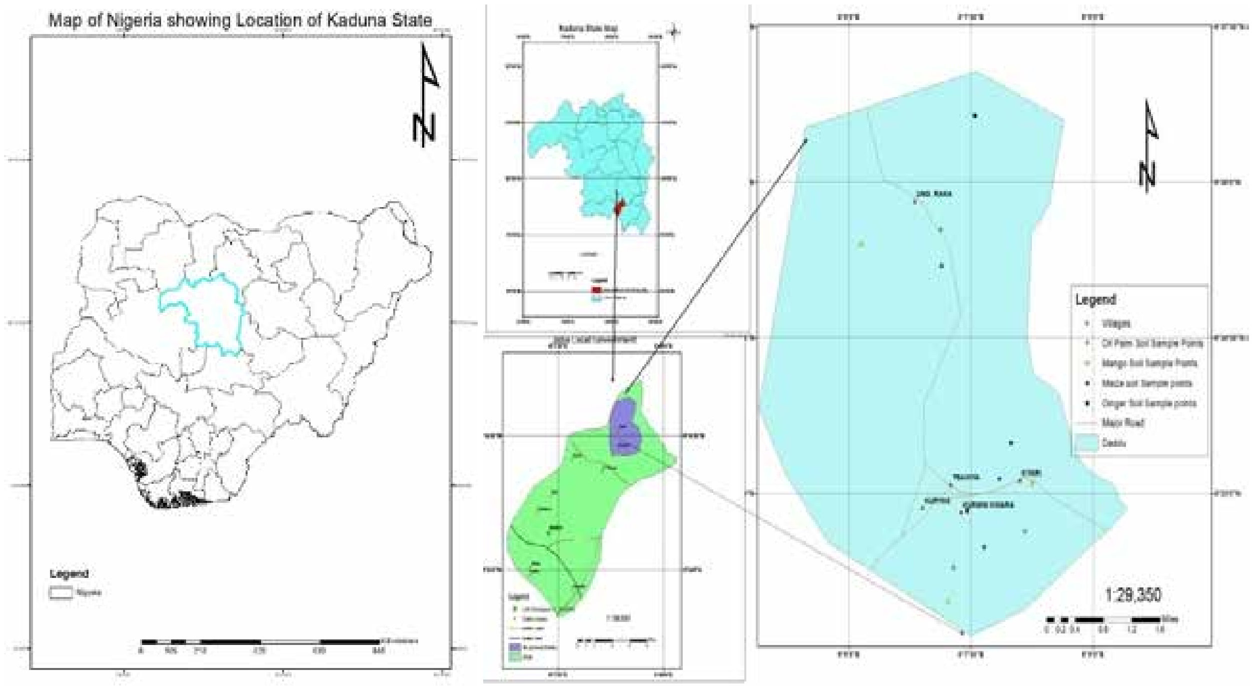

Figure 1. Map of study area; Source: Olaniyi and Gadah (2021), with permissioin of Dutse Journal of Pure and Applied Sciences (2023)

(2012); ELD Initiative and UNEP (2015) identified soil pH, organic matter content, total N, available P and cation exchange capacity as significant soil's physico-chemical properties being impacted by soil erosion. Also Sonneveld and Keyer (2003), and Tsegaye (2019) showed that the socio-economic impacts of soil erosion in Nigeria and Ethiopia could be as much as USD 1.5 and USD 1.0 billion/annually, respectively.

Given the above evidences, promotion of sustainable land use becomes important because land degradation due to soil erosion currently undermines global food security and subsequently results in impoverishment of about 3.2 billion people globally (IPBES, 2018). Previous studies of impact of soil erosion on land degradation only considered the physico-chemical and socio-economic impacts of soil erosion on land without examining the contribution of individual crops grown on land to the soil erosion and or land degradation. Identification of the respective contributions of individual crops to soil erosion owing to specific land preparation requirements of crops is very important for the design of crop-based location-specific soil erosion mitigation plans. Therefore, this study was conducted to assess the contribution of commodity crops grown in the study area (Daddu) to land degradation (soil erosion) with the aim of ascertaining whether there is a significant difference in the land degradation potential of the commodity crops grown in the study area or not.

MATERIALS AND METHODS

Study area

The study area (Dadu) is located between latitude 9°18′50″N to 9°36′46″N and longitude 8°50′0″E to 9°10′12″E, is one of the constituting districts in Jaba Local Government Area of Kaduna State (Olaniyi and Gadah, 2021).

The soil is predominantly sandy loam, red-brown to red-yellow (Olaniyi and Gadah, 2021). The soil is well drained with shallow topsoil capable of supporting cereals, yam, root and tuber, pulses and vegetables (Aregheore, 2009; Olaniyi and Gadah, 2021). Dadu is characterised by distinct wet and dry seasons with rainfall occurring between May to October and dry season starting from November to April of the subsequent year (Abaje et al., 2015). The average annual rainfall in Dadu ranges from 1000 m to 1500 m and temperature between 27 °C and 30 °C (Danladi et al., 2017), and mean relative humidity around 63% (Abaje et al., 2015). Majority of the residents in the study area are mostly farmers although some of them also engage in off-farm activities such as fishing, hunting, weaving and trading to ensure greater income security (Danladi et al., 2017).

Sample collection

Twenty-four (24) soil samples from plots under different land uses were collected using soil auger at a square quadrat of 20 m by 20 m at the depths of 0 – 30 cm for both annual (ginger and maize) and permanent (oil palm and mango) crops, respectively, from the three (Ungwan Rana; Kurmin Kwara and Kyari) communities. Samples were collected with the use of the following materials and tools: one "Inch" cylindrical metallic pipe marked at 30 cm as a soil auger, a steel hammer, a clean plastic bucket, hand trowel, permanent markers, sample bags, printed barcodes, and a handheld GPS. Crop residue was removed from the soil surface and soil probes were driven vertically into the desired depth (30 cm) with the use of a steel hammer. Upon reaching the desired depth, the probe was removed and the soil core was transferred into a bucket and thereafter into the well-labelled sample bags before being taken to the laboratory for analysis. Physico-chemical variables determined for each sample included Bulk Density, Soil Porosity, Gravimetric Moisture Content, pH [H_2O], pH [$CaCl_2$], Organic Matter, Organic Carbon, Nitrogen (%), Phosphorus (mg/kg), Potassium (meq), Cation Exchangeable Capacity (CEC), Clay (%), Silt (%) and Sand (%), and soil erodibility. Soil erodibility was derived for the soils using the data obtained from the laboratory analyses. The results obtained from the laboratory analysis of the soil samples collected were compared using simple descriptive (tables and charts) and inferential statistics (Two-way Analysis of Variance).

Table 1. Sampling locations

Ungwan Rana			
Crops	**Latitude**	**Longitude**	**Height**
Mango	9°35′21.07″N	8°6′09.68″E	746.20 m
Oil palm	9°35′36.10″N	8°07′08.66″E	759.56 m
Ginger	9°36′28.73″N	8°7′33.33″E	759.50 m
Maize	9°35′33.78″N	8°07′08.94″E	758.34 m
Kurmin Kwara			
Crops	**Latitude**	**Longitude**	**Height**
Mango	9°32′47.95″N	8°07′34.60″E	759.87 m
Oil palm	9°32′10.48″N	8°7′12.87″E	752.50 m
Ginger	9°32′35.01″N	8°7′19.67″E	755.29 m
Maize	9°32′47.78″N	8°07′26.72″E	762 m
Kyari			
Crops	**Latitude**	**Long.**	**Height**
Mango	9°33′4.41″N	8°08′15.27″E	752 m
Oil palm	9°33′01.15″N	8°08′15.59″E	758.95 m
Ginger	9°33′0.99″N	8°08′7.01″E	758.65 m
Maize	9°33′10.41″N	8°08′9.17″E	764.44 m

Source: Olaniyi and Gadah (2021), with permissioin of Dutse Journal of Pure and Applied Sciences (2023)

Laboratory analysis

Samples for laboratory analysis were collected in well labeled polythene bags and were transported to the Institute for Agricultural Research (IAR) Ahmadu Bello University Zaria (ABU, Nigeria) for the determination of the soil physico-chemical characteristics. The particle size distribution was determined by Bouycouos hydrometeric method using sodium hexa metaphosphate as a dispersant (Gee and Or, 2002) before the textural classes were determined with USDA textural triangle.

$$C = R - RL + (0.36T) \quad \text{eqn 2}$$

where: C = corrected hydrometer reading (g/l), R = hydrometer reading (g/l)
RL = Blank reading (g/l)
T = temperature of the suspension (°C)

$$\% \text{ Clay} = x \quad \text{eqn 3}$$

$$\% \text{ Silt} = - \%\text{Clay} \quad \text{eqn 4}$$

$$\% \text{ Sand} = 100 - (\%\text{Clay} + \% \text{ Silt}) \quad \text{eqn 5}$$

Bulk density was determined by the methodology described by Grossman and Reinsch (2002).

$$BD\left(g/cm^3\right) = \frac{wt\ of\ oven\ dry\ soil\ (g)}{Volume} \quad \text{eqn 6}$$

RESULTS AND DISCUSSION

Soil characteristics under different cropping systems

Tables 2–5 show the summary of the results of the laboratory analyses conducted on the soil samples for three communities (Kyari, Ugwan Rana, and Kurmin Kwara) on four (Ginger, Maize, Mango, and Oil Palm) crops.

Physical properties under different cropping systems in different communities

Soil texture

Results from the soil textural classes determination indicated that the average sand particles were 75% and 78% under annual crops (ginger and maize) and 69% and 71% under tree crops (oil palm and mango), respectively, but percentages of silt were 19% and 14% under annual crops and 21 % and 19% under tree crops, and the percentages of clay were 6% and 8% under annual crops and 10% under tree crops (Tables 2–5). The soil in the study area can be suitably classified as sandy loam. These particle size distributions and classifications

Table 2. Physico-chemical indicators of soil under ginger cropping systems at the three communities

Ginger	Kyari	Ungwan Rana	Kurmin Kwara
Depth (cm)	0–30	0 – 30	0–30
Bulk Density (gcm^{-3})	1.43	1.38	1.22
Soil Porosity (%)	30.47	17.20	12.90
Organic Matter(%)	1.13	1.23	1.70
Organic Carbon (%)	0.66	0.72	0.99
USDA Soil Texture	Sandy loam	Sandy loam	Sandy loam
Textural Class	2	2	2
Permeability Class	2	2	2
Clay (%)	6	9	6
Silt (%)	19	17.5	13
Sand (%)	75	73.5	81

Table 3. Physico-chemical indicators of soil under maize cropping systems at the three communities

Maize	Kyari	Ungwan Rana	Kurmin Kwara
Depth (cm)	0–30	0–30	0–30
Bulk Density(gcm^{-3})	1.54	1.53	1.28
Soil Porosity (%)	17.91	12.66	18.53
Organic Matter (%)	2.44	1.74	1.97
Organic Carbon (%)	1.41	1.01	1.15
USDA Soil Texture	Sandy loam	Sandy loam	Sandy loam
Textural Class	2	2	2
Permeability Class	2	2	2
Clay (%)	8	7	8
Silt (%)	14	17.5	16
Sand (%)	78	75.5	76

Table 4. Physico-chemical indicators of soil under oil palm cropping systems at the three communities

Oil palm	Kyari	Ungwan Rana	Kurmin Kwara
Depth (cm)	0–30	0–30	0–30
Bulk Density(gcm^{-3})	1.19	1.47	1.13
Soil Porosity (%)	17.93	13.08	9.6
Organic Matter (%)	1.54	2.4	2.48
Organic Carbon (%)	0.89	1.39	1.44
USDA Soil Texture	Sandy loam	Loamy sand	Loamy sand
Textural Class	2	1	1
Permeability Class	2	1	1
Clay (%)	10	6	4
Silt (%)	21	13	14
Sand (%)	69	81	82

Table 5. Physico-chemical indicators of soil under mango cropping systems at the three communities

Mango	Kyari	Ungwan Rana	Kurmin Kwara
Depth (cm)	0–30	0–30	0–30
Bulk Density(gcm^{-3})	1.04	1.07	1.14
Soil Porosity (%)	28.28	6.96	10.7
Organic Matter (%)	1.93	1.6	2.64
Organic Carbon (%)	1.12	0.93	1.53
USDA Soil Texture	Sandy loam	Loam	Loamy sand
Textural Class	2	2	1
Permeability Class	2	3	2
Clay (%)	10	6	4
Silt (%)	19	15	10
Sand (%)	71	79	86

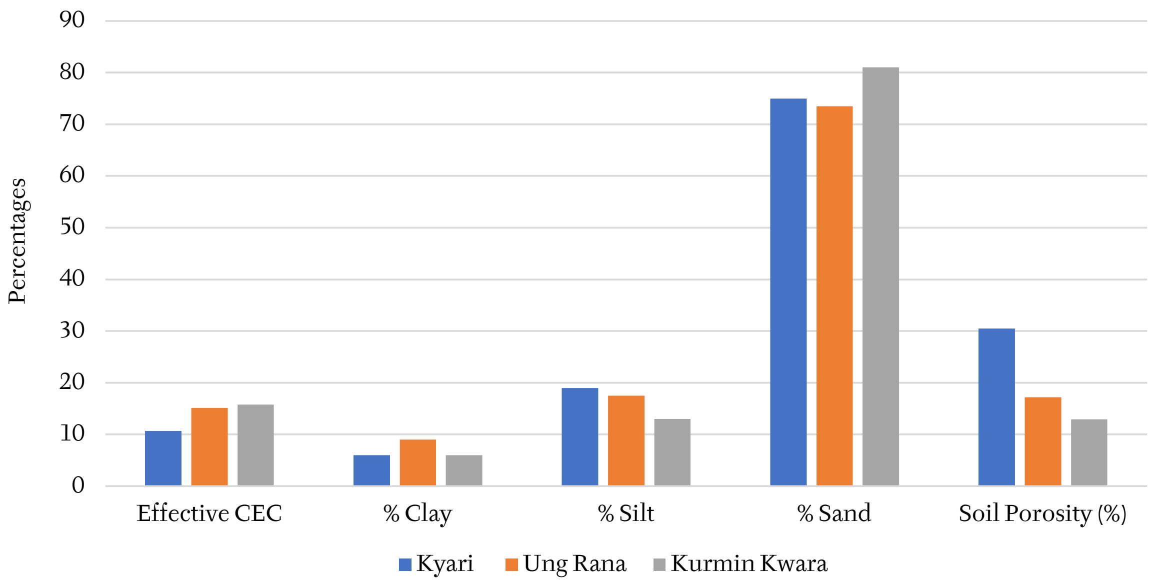

Figure 2. Physico-chemical properties of soil under ginger production at the three communities at 0–30 cm

were equally obtained by Anamayi et al. (2018) in a similar study.

At the community level, the results of the textural class determination indicated that the percentage of clay was highest in Ugwan Rana; on the other hand, the percentages of sand and silt were highest in Kurmin Kwara and Kyari, respectively (Figure 3). In Ugwan Rana, where clay particles were relatively high in number, infiltration may be limited due to low permeability of the clay particles. Therefore, a relatively higher percentage of clay particles in Kyari and Ugwan Rana communities suggests limited infiltration due to the low permeability of the clay and consequently higher runoff (Dutal and Reis, 2020; Olorunfemi et al., 2018; Houston et al., 2013).

At the crop level, the effects of ginger cultivation on soil textural classes in the three communities investigated are presented in Figure 2. The figure shows that the percentages of particles were highest in Kurmin Kwara whereas the percentage of silt was highest in Kyari. At the same time, Ugwan Rana had the highest content of clay particles.
The effects of maize cultivation on soil textural classes in the three communities investigated are presented in Table 3 and Figure 3. The figure shows that the percentage of silt was highest in Ugwan Rana during this time, the percent of sand was highest in Kyari and the percent of soil porosity was highest in Kurmin Kwara.

The summary of the textural class analysis of the soil samples collected for the three communities (Kyari,

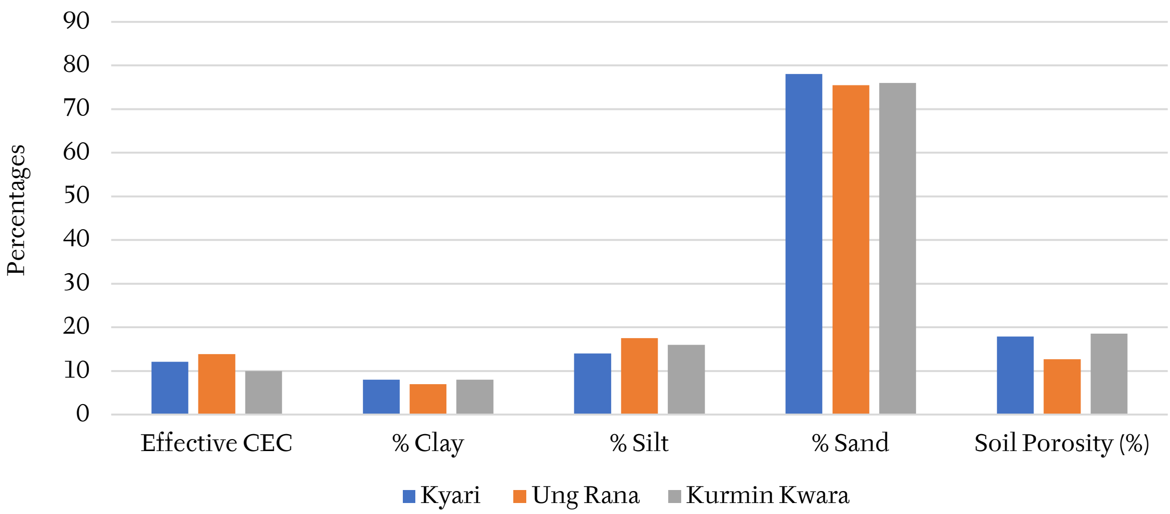

Figure 3. Physico-chemical properties of soil under maize cropping systems at the three communities at 0 –30 cm

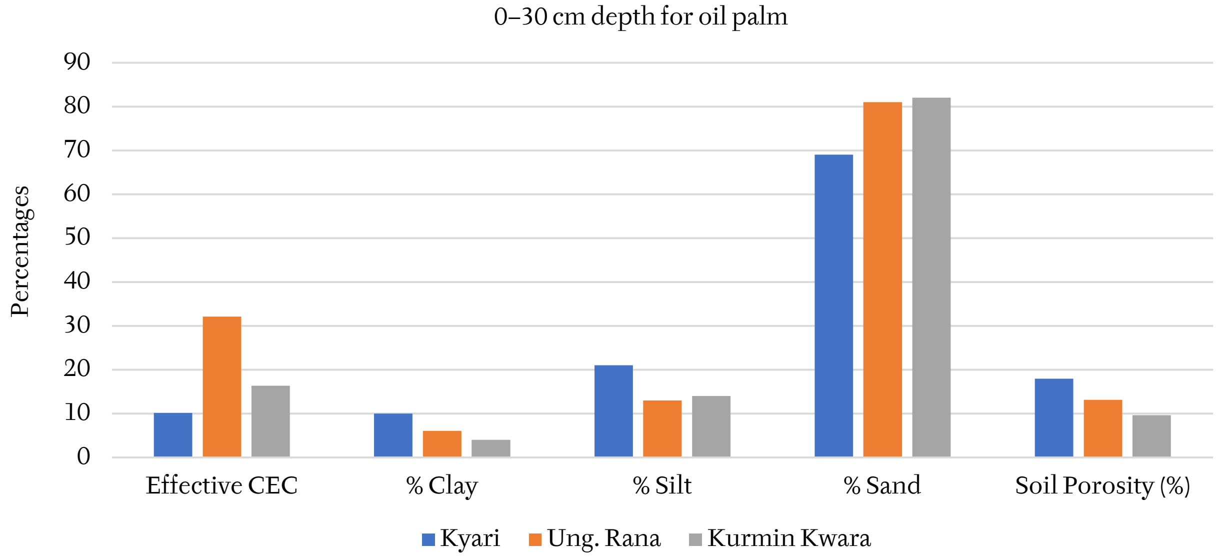

Figure 4. Physico-chemical properties of oil palm production at the three communities at 0 – 30 cm

Ugwan Rana, and Kurmin Kwara) on oil palm farmland showed that the percentage of clay and silt is highest in Kyari whereas the percentage of sand is highest in Kurmin Kwara (Figure 4).

The soil textural class distribution in the three communities investigated under mango cultivation is shown in Figure 5. The result of the textural class distribution showed that the percentage of sand was highest in Kurmin Kwara whereas those of clay and silt were highest in Kyari.

Bulk density: Generally, soils under annual crops had higher (1.54 gcm^{-3} – 1.22 gcm^{-3}) bulk densities compared to soils under permanent (1.47 gcm^{-3} – 1.04 gcm^{-3}) crop cultivation. Specifically, the bulk density of the soil was highest (1.54 gcm^{-3}) under maize production in Kyari and lowest under mango production in the same community (Kyari). The bulk density has implications on the erodibility of the soils because soils with high bulk density would be resistant to the impact of a raindrop (Houston et al. 2013) and there is a direct relationship between particle size and bulk density and an indirect relationship between clay and silt particles and bulk density.

Total porosity (TP): Soil porosity ranged between 30.47% and 12.66% under annual crops, and between 28.28% and 6.96% under tree crops indicating a comparatively higher soil porosity under annual crop production. Relatively higher contents of sand and clay particles in the soil under annual crop production could be responsible for higher porosity in the soil.

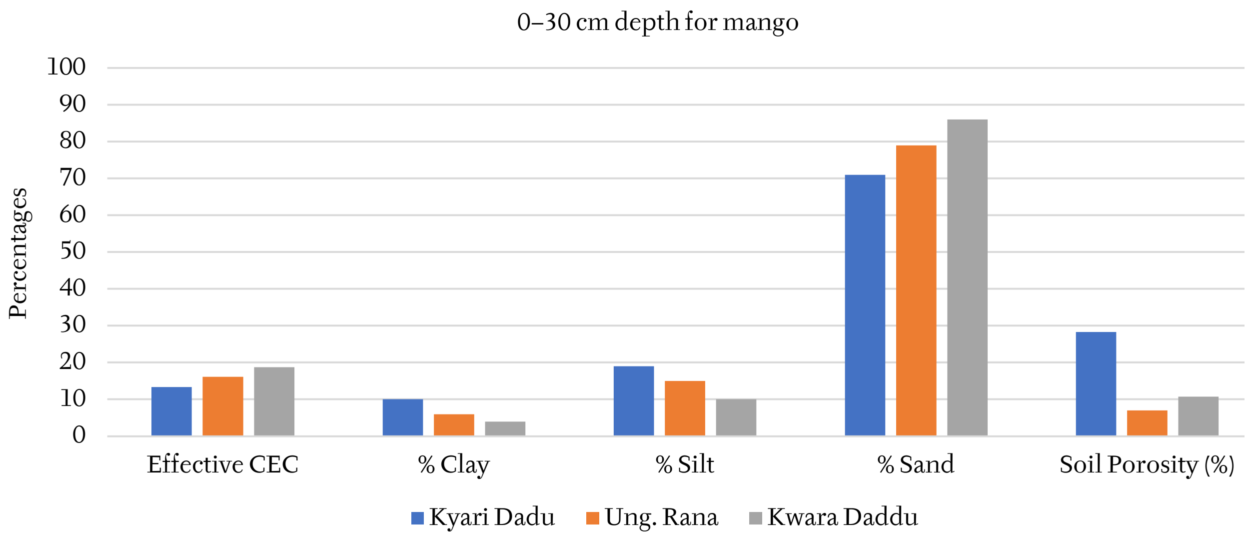

Figure 5. Physico-chemical properties of mango production at the three communities at 0–30 cm

Table 6. Erodibility factor of soil under different agricultural land use

Cultivated crops	Kyari	Ugwan Rana	Kurmin Kwara
Ginger	0.01197	0.01161	0.01004
Maize	0.00910	0.01013	0.00934
Oil palm	0.01045	0.00959	0.01004
Mango	0.01004	0.00934	0.01028

Specifically, the soil under ginger production has the highest porosity (30.47%), particularly in Kyari and the lowest (6.96%) was recorded in Ugwan Rana under mango cultivation.

Organic matter: The organic matter depositions were between 2.44% and 1.13% under annual crops, and between 2.64% and 1.54% under tree crops. At the same time, the organic carbon under annual crops was 1.41% to 0.66% and 1.53% to 0.89% under annual and tree crops, respectively. This result shows that there is a higher organic matter accumulation and lower organic matter mineralization in the soil where tree crops were found growing and *vice versa* in the soil where annual crops were grown. Since the organic matter (humus) is very important for helping to bind soil particles together to resist the tractive force of runoff and build the soil's resistance against the shearing effect of surface wash.

The results for erodibility factor (k) are explained here from two perspectives: from the crop and community perspectives. From the crop perspectives, the result of erodibility factor (k) indicated that ginger cultivation in Kyari produced the comparatively greatest soil loss; with moderate soil loss in Ugwan Rana and the lowest soil loss being recorded in Kurmin Kwara, respectively. Also, maize cultivation produced the greatest soil loss in Ugwan Rana, moderate soil loss in Kurmin Kwara, and the lowest soil loss in Kyari. Oil

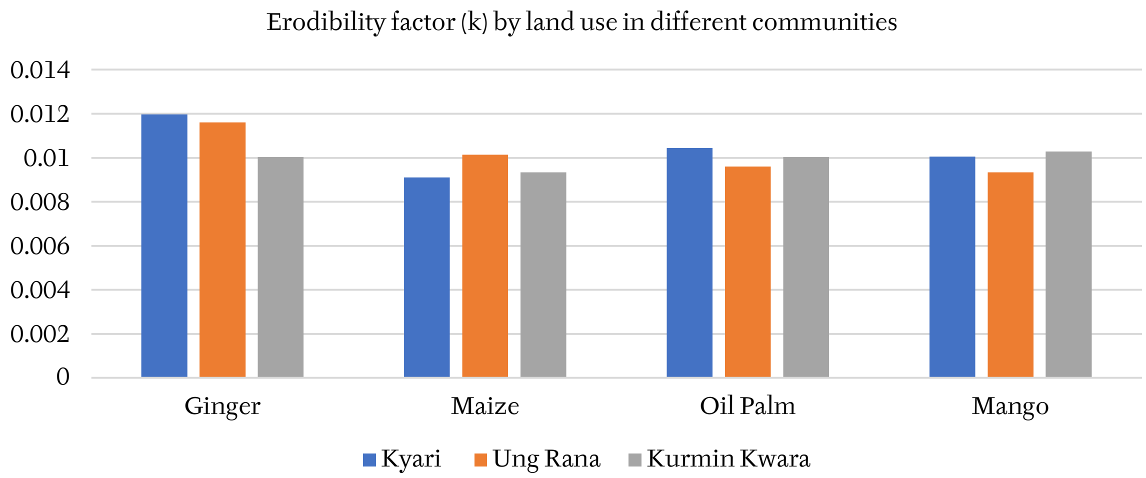

Figure 6. Description of erodibility by agricultural land uses in different communities

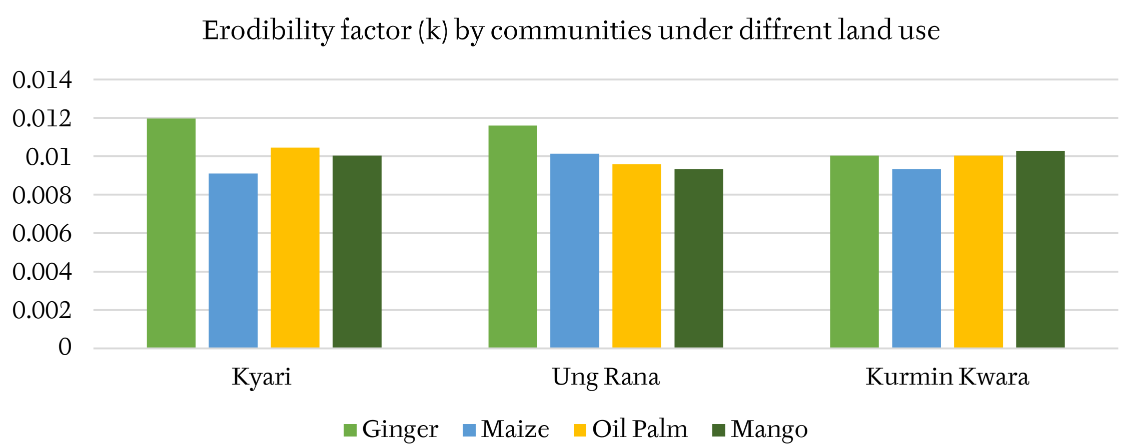

Figure 7. Erodibility of agricultural lands in different communities

Table 7. Threshold (USLE – K) range classes of soil

Class	Description	Range
1	Very slightly erodible	0.00–0.05
2	Slightly erodible	0.05–0.10
3	Moderately erodible	0.10–0.20
4	Highly erodible	0.20–0.40
5	Very highly erodible	0.40–0.60

Source (Wischmeier and Smith, 1978)

Table 8. Test of significant difference in erodibility amongst different communities and crops

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8.069E-006[a]	10	8.069E-007	3.294	.406
Intercept	.001	1	.001	4679.086	.009
Communities	3.891E-007	2	1.946E-007	.794	.622
Crops	7.637E-006	8	9.546E-007	3.896	.374
Communities * Crops	.000	0	.	.	.
Error	2.450E-007	1	2.450E-007		
Total	.001	12			
Corrected Total	8.314E-006	11			

Dependent Variable: Erodibility
a. R Squared = .971 (Adjusted R Squared = .676)

palm cultivation resulted in comparatively greatest soil loss in Kyari; moderate soil loss in Kurmin Kwara and the lowest soil loss in Ugwan Rana; and finally, mango cultivation resulted in the greatest soil loss in Kurmin Kwara with comparatively moderate impact in Kyari and the least impact in Ugwan Rana (Figure 6).

However, at the community level, the result of the erodibility estimates in Kyari showed that ginger followed by oil palm, mango, and finally maize are the sources of soil loss in that order. On the other hand, for Ungwan Rana, ginger, followed by maize, oil palm, and mango in that sequence are contributors to soil loss. In the Kurmin Kwara community, mango, ginger, oil palm, and maize are the sources of soil loss (Figure 7).

The average USLE-K values obtained in this study were 11.21 kg/ha/yr; 9.52 kg/ha/yr; 10.02 kg/ha/yr and 9.89 kg/ha/yr for ginger, maize, oil palm, and mango farmlands, respectively, which when compared with the threshold (k) values (Table 7) gave indications that erosion potential sowing to the cultivation of commodity crops in the study area ranged between slight erosion in maize and mango to moderate erosion in ginger and oil palm crops. So also at the community level, soils in Kurmin Kwara are slightly erodible whereas soils in Kyari and Ugwan Rana are moderately erodible (Table 7). The comparatively lower organic matter content and permeability in Kyari and Ugwan Rana soils could be the reason for their higher erodibility values. Generally, soil tillage practices lead to a disturbance in soil macro aggregates, expose the soil organic carbon to microbial decomposition at a higher rate, damage the distribution of pore sizes decreasing macro-porosity by soil compaction (Allen 1985; Celik, 2005) and thus leading to rapid decomposition of soil organic matter and therefore causing higher erodibility (Jeloudar et al., 2018; Ebabu et al., 2019). Therefore, erodibility increases due to lower infiltration. Removal of crop residue would lead to a lower soil organic matter during agricultural productivity (Jeloudar et al., 2018) thus increasing the potential for soil erosion. Lower erodibility in the Krumin Kwara can be attributed to the higher soil organic matter (SOM) content. The outcome of this study gave a clear indication of the need for sustainable soil management and the adoption of good agricultural practices in the study area.

The results of soil erodibility (k-value) for the sites (Kyari) under ginger cultivation were found to be 1.2×10^{-2} kg/ha/annum. This estimated range of potential erodibility has been generally categorized as being low (Okoroafor et al., 2017). This low erodibility (k) value in study areas can be attributed to the presence of moderate components of clay and organic matter in the soil in Kyari which enhances soil cohesiveness, infiltration, and greater resistance to runoff (detachment and transportation) of soil sediments (Okorafor et al., 2017).

A test of significant differences in the erodibility amongst the communities (Kyari, Ugwan Rana, and Kurmin Kwara) and different crops (ginger, maize, oil palm, and mango) is presented in Table 8. From the table, it is evident that there is no statistically significant difference in the mean erodibility values amongst different communities ($p = 0.662$), and under different crops ($p = 0.374$).

CONCLUSION AND RECOMMENDATION

The knowledge of soil fertility status under different commodity crop production is of paramount importance in understanding the influence of the (commodity) crop production on land degradation. To this end, relevant physico-chemical properties for deriving erodibility factor (k) of soil under different land uses were assessed to provide the basis for crop-specific land management practices. The results obtained from this study showed that land degradation in the study area owing to the cultivation of commodity crops ranged between slightly erodible (9.34 kg/ha/yr) to moderately erodible (11.97 kg/ha/yr) and the values were not statistically significantly different amongst one another. Slightly erodible – k values were obtained on soil with good texture and structure (moderate clay particles, good litter content), and moderately erodible values were obtained on soil with lower clay, litter, and organic matter content but with higher sand particles. This study contributed to our understanding of the impacts of commodity crop production on landscape structure, patterns, processes, and functions, with implications for combatting poverty, hunger, climate change, and biodiversity loss. Therefore, the adoption of sustainable land management practices such as cover cropping, mulching, organic manuring, land fallowing, conservation agriculture, agroforestry, zero tillage, and shifts towards less land-degrading crops is important for achieving sustainable production of commodity crops in the study areas in particular and Nigeria in general.

ACKNOWLEDGEMENT

The authors hereby appreciate the contributions made by the anonymous reviewers in improving this manuscript.

CONFLICT OF INTEREST

The authors declared no conflicts of interest with respect to the research, authorship, and publication of this article.

ETHICAL COMPLIANCE

The authors have followed ethical standards in conducting the research and preparing the manuscript.

REFERENCES

Abaje I. B., Sawa B. A., Iguisi E. O., Ibrahim A. A. (2015): Assessment of Rural Communities' Adaptive Capacity to Climate Change in Kaduna State, Nigeria. Journal of Environment and Earth Science 520: 14–23.

Abdullah S. A., Nakagoshi N. (2006): Changes in landscape spatial pattern in the highly developing state of Selangor Peninsula Malaysia. Landscape and Urban Planning 77: 263–275.

Abebaw W. A. (2019): Review on Impacts of Land Degradation on Agricultural Production in Ethiopia. Journal of Resources Development and Management 27: 21–29.

Abraham M., Pingali P. (2020): Transforming smallholder agriculture to achieve the SDGs. In: The Role of Smallholder Farms in Food and Nutrition Security. Gomez y Paloma, S., Riesgo L. and Louhichi K. (Eds). Springer, pp. 173–209.

Allen J. (1985): Soil response to forest clearing in the United States and in the tropics: geological and biological factors. Biotropica 11: 15–27.

Al-Wadaey A., Ziadat F. (2014): A participatory GIS approach to identify critical land degradation areas and prioritize soil conservation for mountainous olive groves – case study. Journal of Mountain Science 11: 782–791.

Anamayi S. E., Anamayi R. M.(2018): Resource use efficiency in ginger production in Jaba Local Government Areas of Kaduna State, Nigeria. Journal of Humanities and Social Science 23: 14–21.

Aregheore M. E. (2009): Country Pasture/Forage Resource Profile Nigeria. Retrieved from https://www.scribd.com/document/346440160/FAO-Profile-Nigeria.

Boardman J., Poesen J. (2006): Soil Erosion in Europe. (1st ed.) Wiley, New York.

Bing H., Wu Y., Liu E., Yang X. (2013): Assessment of heavy metal enrichment and its human impact in lacustrine sediments from four lakes in the mid-low reaches of the Yangtze River, China. Journal of Environmental Sciences 25: 1300–1309.

Borrelli P., Robinson D. A., Fleischer L. R., Lugato E., Ballabio C., Alewell C., Meusburger K., Modugno S., Schütt B., Ferro V., Bagarello V., Van Oost K., Montanarella L., Panagos P. (2017): An assessment of the global impact of 21st century land use change on soil erosion. Nature Communications 8:1.

Celik I. (2005): Land-use effects on organic matter and physical properties of soil in a southern Mediterranean highland of Turkey. Soil and Tillage Research 83: 270–277.

Dainese M., Martin E. A., Aizen M. A., Albrecht M., Bartomeus I., Bommarco R. et al. (2019): A global synthesis reveals biodiversity-mediated benefits for crop production. Science Advances 5:10.

Danladi E., Akinola, M. O., Banta A. L., Makarau S. B., Hussain A. (2017): Socio-economic assessment of Ginger production in Jaba Local Government of Kaduna State, Nigeria. Asian Journal of Agricultural Extension, Economics and Sociology. 15: 1–11.

Ding L., Chen, K. L., Cheng S. G., Wang X. (2015): Water ecological carrying capacity of urban lakes in the context of rapid urbanization: a case study of East Lake in Wuhan. Physics and Chemistry of the Earth, Parts A/B/C, 89–90: 104–113.

Dutal H., Reis M. (2020): Determining the effects of land use on soil erodibility in the Mediterranean highland regions of Turkey: a case study of the Korsulu stream watershed. Environmental Monitoring and Assessment 192: 192.

Ebabu K., Tsunekawa A., Haregeweyn N., Adgo E., Meshesha D. T., Aklog D., Masunaga T., Tsubo M., Sultan D., Fenta A., Yibeltal M. (2019): Effects of land use and sustainable land management practices on runoff and soil loss in the Upper Blue Nile basin Ethiopia. Science of Total Environment 648: 1462–1475.

ELD Initiative & UNEP (2015): The Economics of Land Degradation in Africa: Benefits of Action Outweigh the Costs; A complementary report to the ELD Initiative. Retrieved from https://www.unep.org/resources/report/economics-land-degradation-africa-benefits-action-outweigh-costsa-complementary

FAO (2021): The State of the World's Land and Water Resources for Food and Agriculture – Systems at breaking point. Synthesis report 2021. Rome. Retrieved from https://www.fao.org/documents/card/en/c/cb7654en

Flanagan D. C., Nearing M. A. (1995): USDA-Water Erosion Prediction Project (WEPP) Hillslope Profile and Watershed Model Documentation. NSERL Report No. 10, National Soil Erosion Research Laboratory, USDA-Agricultural Research Service, West Lafayette, Indiana. Retrieved from https://www.ars.usda.gov/ARSUserFiles/50201000/WEPP/weppHistory.pdf.

Food and Agricultural Organization of the United Nations (FAO) and Intergovernmental Technical Panel on Soils [ITPS] (2015): Status of the World's Soil Resources: Main Report. Rome: FAO and ITPS: Retrieved from: https://www.pwc.com/ng/en/assets/pdf/transforming-nigeria-s-agric-value-chain.pdf

Gabiri G., Leemhuis C., Diekkrüger B., Näschen K., Steinbach S., Thonfeld F. (2019): Modelling the impact of land use management on water resources in a tropical inland valley catchment of Central Uganda, East Africa. Sci. Total Environment 653: 1052–1066.

Gee G. W., Or D. (2002): Particle size analysis. In: Dane J. H., Topp G. C. (Eds): Methods of soil analysis (part 4, physical methods). Soil Science Society of America. Book series No. 5. ASA and SSA Madison, WI, USA, pp. 255–295.

Geist H., Lambin E. (2001): What drives tropical deforestation? A meta-analysis of proximate and underlying causes of deforestation based on subnational case study evidence. Land-Use and Land-Cover Change (LUCC) Project, International Geosphere-Biosphere Programme (IGBP). LUCC Report Series 4. Retrieved from: https://agris.fao.org/agrissearch/search.do?recordID=GB2013200077.

Geist H., Lambin E. (2002): Proximate causes and underlying driving forces of tropical deforestation. BioScience 52: 143–150.

GSP Global Soil Partnership (2017): Global soil partnership endorses guidelines on sustainable soil management. Retrieved from http://www.fao.org/global-soil-partnership/resources/highlights/ detail/en/c/416516/.

Guo Q., Hao Y., Liu B. (2015): Rates of soil erosion in China: A study based on runoff plot data. Catena 124: 68–76.

Hassan K. F., Agha M. D. (2012): Effects of calcium carbonate on the erodibility of some calcareous soils by water erosion. Mesopotamia Journal of Agriculture 40: 11–19.

Houston A., Tranter G. Miller I. (2013): Bulk Density. Retrieved from htthttps://projects.sare.org/wp-content/uploads/1008833Proceedings_Lauren-Pfenning_Bulk-Density_8-4-14.pdf p://www.usyd.edu.au/agric/web04/Bulk%20density%20the%20final.htm.

Imani R., Ghasemieh H., Mirzavand M. (2014): Determining and mapping soil erodibility factor – case study: Yamchi Watershed in Northwest of Iran. Open Journal of Soil Science 4: 168–173.

Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) (2018): Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services. Scholes R., Montanarella L., Brainich A., Barger N., ten Brink B., Cantele M., Erasmus B., Fisher J., Gardner T., Holland T. G., Kohler F., Kotiaho J. S., Von Maltitz G., Nangendo G., Pandit R., Parrotta J., Potts M. D., Prince S., Sankaran M., Willemen L. (Eds) (2018): IPBES secretariat, Bonn, Germany.

Jang W. S., Neff J. C., Im Y., Doro L. Herrick J. E. (2020): The hidden costs of land degradation in US maize agriculture. Earth's Future 9: 1–19.

Jeloudar F. T., Sepanlou M. G., Emadi S. M. (2018): Impact of land use change on soil erodibility. Global Journal of Environmental Science and Management 4: 59–70.

Kaiser J. (2004): Wounding earth's fragile skin. Science 304: 1616–1618.

Keesstra S. D., Bouma J., Wallinga J., Tittonell P., Smith P., Cerdà A., Montanarella L., Quinton J. N., Pachepsky Y., van der Putten W. H., Bardgett R. D., Moolenaar S., Mol G., Jansen B., Fresco L. O. (2016): The significance of soils and soil science towards realization of the United Nations Sustainable Development Goals, SOIL 2: 111–128.

Khoroshev A. (2020): Landscape-ecological approach to spatial planning as a tool to minimize socio-ecological conflicts: case study of Agrolandscape in the Taiga Zone of Russia. Land 9: 192.

Kissinger G., Herold M., De Sy V. (2012): Drivers of deforestation and forest degradation: A synthesis report for REDD+ policymakers. Lexeme Consulting, Vancouver Canada, Retrieved from https://www.cifor.org/knowledge/publication/5167.

Kleemann J., Baysal G., Bulley H. N. N., Fürst C. (2017): Assessing driving forces of land use and land cover change by a mixed-method approach in north-eastern Ghana, West Africa. Journal of Environmental Management 196: 411–442.

Kopittke P. M., Menzies N. W., Wang P., McKenna, B. A., Lombi E. (2019): Soil and the intensification of agriculture for global food security. Environment International 132: 105078

Kyawt K. K. Tun, Shrestha R. P., Datta A. (2015): Assessment of land degradation and its impact on crop production in the Dry Zone of Myanmar, International Journal of Sustainable Development and World Ecology 22: 533–544.

Lal R. (2004): Soil carbon sequestration impacts on global climate change and food security. Science 304: 1623–1627.

Land Degradation Neutrality Target Setting Programme (LDNTSP) (2018): Nigeria: Final report of the land degradation neutrality target setting programme. 47 p. Retrieved from https://knowledge.unccd.int/sites/default/files/ldn_targets/Nigeria LDNTSP Country Report.pdf.

Liu X., Niu X., Wang B., Gao P., Liu Y. (2016): Driving forces of dynamic changes in soil erosion in the Dahei Mountain ecological restoration area of northern China based on GIS and RS. PLoS One 3: 1–15.

Marchant R., Richer S., Boles O., Capitani C., Courtney-Mustaphi C. J., Lane P., Prendergast M. E., Stump D., De Cort G., Kaplan J. O., Phelps, L. N., Wright D. (2018): Drivers and trajectories of land cover change in East Africa: Human and environmental interactions from 6000 years ago to present. Earth Science Review 178: 322–378.

Meijer J., Shames S., Scherr S. J., Giesen P. (2018): Spatial Scenario Modelling to Support Integrated Landscape Management in the Kilombero Valley Landscape in Tanzania; PBL Netherlands Environmental Assessment Agency: The Hague, The Netherlands. Retrieved from https://www.pbl.nl/sites/default/files/downloads/PBL_2018_2613_spatial-modelling-of-participatory-landscape-scenarios_UK.pdf

Millennium Ecosystem Assessment (2005): Ecosystems and human well-being: Synthesis. Island Press, Washington, DC. Retrieved from https://www.millenniumassessment.org/documents/document.356.aspx.pdf.

Montgomery D. R. (2007): Soil erosion and agricultural sustainability. Proceedings of National Academy of Science 104: 13268–13272.

Montgomery D. R., Huang M. Y. F., Huang A. Y. L. (2014): Regional soil erosion in response to land use and increased typhoon frequency and intensity, Taiwan. Quaternary Research 1: 15–20.

Mucova S. A. R., Filho W. L., Azeiteiro U. M., Pereira M. J. (2018): Assessment of land use and land cover changes from 1979 to 2017 and biodiversity and land management approach in Quirimbas National Park, Northern Mozambique, Africa. Global Ecology and Conservation 16: e00447.

Näschen K., Diekkrüger B., Evers M., Höllermann B., Steinbach S. Thonfeld F. (2019): The impact of land use/land cover change (LULCC) on water resources in a tropical catchment in Tanzania under different climate change scenarios. Sustainability 11: 7083.

Nearing M. A. (2013): Environmental Modelling: Finding Simplicity in Complexity. (2nd ed.) Wainwright, J. and Mulligan, M.) Wiley, New York.

Nhemachena C., Matchaya G., Nhemachena C., Karuaihe S., Muchara B., Nhlengethwa S. (2018): Measuring baseline agriculture-related sustainable development goals index for Southern Africa. Sustainability 10: 849.

Niu X. Y., Yan-Hua W., Hao Y., Jia-Wen Z., Jun Z., Mei-Na X., Biao X. (2015): Effect of land use on soil erosion and nutrients in Dianchi Lake Watershed, China. Pedosphere 25: 103–111.

Noel S., Mikulcak F., Etter H., Stewart N. (2015): Economics of land degradation initiative: Report for Policy and Decision Makers. Bonn: ELD Initiative and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Retrieved from https://repo.mel.cgiar.org/handle/20.500.11766/4881

Obalum S. (2012): Soil Degradation-Induced Decline in Productivity of Sub-Saharan African Soils: The Prospects of Looking Downwards the Lowlands with the Sawah Ecotechnology. Applied and Environmental Soil Science Article ID 673926 https://doi.org/10.1155/2012/673926

Obersteiner M., Huettner M. M., Kraxner F., McCallum I., Aoki K., Bottcher H., Fritz S., Gusti M., Havlik P., Kindermann G., Rametsteiner E., Reyers B. (2009): On fair, effective and efficient REDD+ mechanism design. Carbon Balance and Management 4: 11.

Okorafor O. O., Akinbile C. O., Adeyemo A. J. (2017): Determination of soils erodibility factor (K) for selected sites in Imo State, Nigeria. Resources and Environment 8: 6–13.

Olaniyi A. O., Gadah E. (2021): Assessment of fertility status of soils under different cropping patterns and implications for sustainable agricultural land management. Dutse Journal of Pure and Applied Sciences (DUJOPAS) 7: 33–44.

Olayide E. O. (2021): Nigeria – Land, climate, energy, agriculture and development. A study in the Sudano-Sahel initiative for regional development, jobs, and food security. Center for Development Research, (ZEF), Working Paper Series, ISSN 1864-6638. Retrieved from https://www.econstor.eu/bitstream/10419/246470/1/ZEF-Working-Paper-201-Nigeria.pdf

Olorunfemi I. E., Fasinmirin J. T., Akinola F. F. (2018): Soil physico-chemical properties and fertility status of long-term land use and cover changes: A case study in Forest vegetative zone of Nigeria. Eurasian Journal of Soil Science 7: 133–150.

Oldeman L. R. (1994): The global extent of soil degradation. In: Greenland D. J. and Szabolcs I. (Eds), Soil Resilience and Sustainable Landuse, CAB International, Wallingford, pp. 99–119.

Oost V. K. (2007): The impact of agricultural soil erosion on the global carbon cycle. Science 318: 626–629.

Ostovari Y., Ghorbani-Dashtaki S., Kumar L., Shabani F. (2019): Soil erodibility and its prediction in semi-arid regions. Archives of Agronomy and Soil Science 65: 1688–1703.

Panagos P., Standardi G., Borrelli P., Lugato E., Montanarella L. Bosello F. (2018): Cost of agricultural productivity loss due to soil erosion in the European Union: From direct cost evaluation approaches to the use of macroeconomic models. Land Degradation and Development 29: 471–484.

Prăvălie R., Patriche C., Borrelli P., Panagos P., Roșca B., Dumitraşcu M. (2021): Arable lands under the pressure of multiple land degradation processes. A global perspective. Environmental Research 194: 110697.

Pimentel D., Burgess M. (2013): Soil erosion threatens food production. Agriculture 3: 443–463.

Robinson D. A., Panagos P., Borrelli P., Jones A., Montanarella L., Tye A., Obst C. G. (2017): Soil natural capital in Europe; a framework for state and change assessment. Scientific Reports 7: 6706.

Rosewell C. J. (1993): Soil Loss – A Program to Assist in the Selection of the Management Practices to Reduce Erosion, Technical Handbook No. 11. (2nd ed.) Soil Conservation Service of New South Wales.

Searchinger T., White R., Hanson C., Ranganathan J. (2019): Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050. Washington, D. C.: World Resources Institute.

Shahrivar A., Christopher T. B. S. (2012): The Effects of Soil Physical Characteristics on Gully Erosion Development in Kohgiloyeh and Boyer Ahmad Province, Iran. Advances in Environmental Biology 6: 367–405.

Shi Z. H., Fang N. F., Wu F. Z., Wang L., Yue B. J. Wu G. L. (2012): Soil erosion processes and sediment sorting associated with transport mechanisms on steep slopes. Journal of Hydrology 454–455: 123–130.

Songu G. A., Abu R. D., Temwa N. M., Yiye S. T., Wahab, S., Mohammed B. G. (2021): Analysis of Soil Erodibility Factor for Hydrologic Processes in Kereke Watershed, North Central Nigeria. Journal of Applied Science and Environmental Management 25: 425–432.

Sonneveld B. G., Keyser M. A. (2003): Land under pressure: Soil conservation concerns and opportunities for Ethiopia. Land Degradation and Development 14: 5–23.

Taddese S. (2018): The Impacts of Land Degradation on Crop Productivity in Ethiopia. A Review. Journal of Environment and Earth Science 8: 102–106.

Tsegaye B. (2019): Effect of Land Use and Land Cover Changes on Soil Erosion in Ethiopia. International

Journal of Agricultural Science and Food Technology 5: 026–034.

Udosen C. E. (2013): Gully Erosion and Cities: An Unwanted Partnership. A paper presented at the Faculty of Social Sciences Seminar at CBN Hall, University of Uyo, pp. 1–15.

UNCCD (2017): Global Support Programme: Land Degradation Neutrality Target Setting Programme, Methodological note to set national voluntary Land Degradation Neutrality (LDN) targets using the UNCCD indicator framework. Retrieved from: https://knowledge.unccd.int/sites/default/files/2018-08/LDNMethodological Note_02-06-2017 ENG.pdf.

United Nations Environment Programme UNEP (2021): Ecosystem restoration for people, nature and climate. Nairobi. United Nations Environment Programme (UNEP) and UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC). Retrieved from:https://www.unep.org/resources/ecosystem-restoration-people-nature-climate.

United Nations Environment Programme (UNEP) (2014): Senegal Joins the Partnership for Action on Green, Retrieved from: http://www.unep.org/greeneconomy/, United Nations Environment Programme (UNEP), Nairobi, Kenya.

Walling D. E. (2013): The evolution of sediment source fingerprinting investigations in fluvial systems. Journal of Soil Science 13: 1658–1675.

Wischmeier W. H., Johnson C. B. V. (1971): A soil erodibility nomograph for farmland and construction sites. Journal of Soil Water Conservation 26: 189–193.

Wu J. J. L. (2013): Landscape sustainability science. Ecosystem services and human wellbeing in changing landscapes. Landscape Ecology 28: 999–1023.

Wu J., Xie, H. (2011): Research on characteristics of changes of lakes in Wuhan's main urban area. Procedia Engineering 21: 395–404.

Zhao Q., Li D., Zhuo M., Guo T., Liao Y., Xie Z. (2014): Effects of rainfall intensity and slope gradient on erosion characteristics of the red soil slope. Stochastic Environmental Research and Risk Assessment 2: 609–621.

Received: May 9, 2022
Accepted after revisions: February 12, 2023