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Effects of urban land use pattern on physicochemical parameters, carbon stock and heavy metal contents of soils in Lagos, Nigeria

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ABSTRACT

It is becoming increasingly difficult to find available land in cities due to growing competition among industrial and residential use. Most often farmers use previously abandoned land to grow their crops. Unfortunately, the pollution status of these areas is often unknown, posing a potential risk to crops being grown. This study examined the impact of land use patterns on physicochemical parameters and heavy metal concentrations of soils collected from reclaimed arable land, greenhouse field and forest dry land. The samples were analyzed for physiochemical parameters and heavy metal residues using Atomic Absorption Spectrophotometer. Data were analyzed using simple descriptive statistics, Analysis of Variance and Pearson correlation coefficients. Soil physiochemical parameters and heavy metal concentrations in the soil from the different land use types differed significantly. The range of values of heavy metals in soil showed Fe = 24.71±0.20 – 94.50±10.25 mg/kg, Pb = 0.12±0.07–2.47±0.45 mg/kg, Cd=0.05±0.03–3.11±0.03 mg/kg and Mn=0.50±0.18 – 13.80±1.38 mg/kg. The accumulation of heavy metals in greenhouse fields can lead to bioaccumulation in crops, which can have serious health consequences for those who consume them. To ensure the safety of our food supply, it is best to avoid excessive use of chemical fertilizers in growing crops.

Keywords: Heavy metals, Land use, Soil composition, Chemical fertilizers, Food safety

Introduction

Rapid urbanization and excessive use of pesticides, herbicides and chemical fertilizer in cities like Lagos Nigeria are raising serious concerns as it increases the accumulation of heavy metals in urban soils. It is important to protect land as a scarce resource in most cities. Urban planning plays a central role in making optimal use of available land and ensuring sustainable cities for everyone to live. However, in many cities, urban planning and related policies are weakly designed or poorly implemented, contributing to the challenges of rapid population and economic growth (Ramaiah & Avtar, 2019). In this context, urban agricultural activities are often ignored and when they are recognized they are not well integrated into planning processes and policies. For example, there is growing competition among industrial, energy, domestic and agricultural use of land and water, which is exacerbated by water scarcity in some countries.

Water scarcity often leads to restriction of agricultural water use in favour of urban industrial, energy and domestic uses, negatively affecting food production (Odhiambo, 2016). Farmers sometimes turn to using wastewater for irrigation coupled with the application of chemical fertilizer in growing food crops, which can lead to contaminating vegetables and fruits on the farms. (Raja *et al.*, 2015). The resultant effect is poor environmental and human health.

The sources of heavy metals in the environment include pesticides, fertilizer, fuel, wastewater, sewage, vehicular exhaust, industrial effluents, and agricultural waste (He e*t al.*, 2016). The use of spray paint, chemical fertilizer, and burning of tires are also sources of heavy metals in urban gardens (Gjorgieva-Ackova, 2018; Bett *et al.*, 2019; Gabrielyan *et al.*, 2018; Musa, *et al.*, 2018). Therefore, it is crucial to examine the effects of land use patterns on physicochemical parameters and potentially toxic metals of soil in Lagos to mitigate these environmental and human health issues.

Literature Review

Environmental health refers to the ability of the environment to withstand stresses and maintain its assets both now and in the future (DFID, 2000). Hallett et al. (2016) in their study on urban agriculture pointed out two issues that needed serious attention about urban farming and the environment. The two issues are: the urban environment may be unsuitable for growing of food crops and the local environment being polluted because of urban farming activities. The first issue is primarily based on soil and water contamination from previous, adjacent, and current land uses. Soil, water, and air pollution can affect crop production, farmers' safety, and consumers' safety. Contaminants like heavy metals and pesticides that are commonly found in urban garden soils can be traced to vehicular exhaust and adjacent land uses. Other sources of contamination include stormwater runoff, improperly treated wastewater, and soil amendments (Carvalho, 2017).

The food system is also responsible for environmental degradation, climate change and depletion of freshwater resources (Springmann *et al.*, 2018). The same effect was observed by Notarnicola et al. (2017) that the environmental impacts of food consumption, as well as its distribution on climate change, account for about 30% and more than 50% of eutrophication. Many farmers especially those in urban centres are using larger quantities of fertilizers and fungicides than recommended due to poor soil quality and high demand for food (Tull, 2018; Ninkov et al., 2018). This is leading to the depletion of non-renewable resources and negative effects on soil health (Ninkov *et al.*, 2018; Tull, 2018). It's important to address these concerns in urban environmental management.

Plants absorb and accumulate a lot of heavy metals during growth. Naturally, heavy metals occur at very low concentrations in soils. However, they become soil pollutants because of their toxicity and widespread in urban garden soil. They are mostly non-biodegradable, for this reason, they extremely persist in the soil and accumulate to toxic levels (Gabrielyan *et al.*, 2018; Ahmed, 2018). They can bioaccumulate in the bodies of man and animals because they are mostly non-degradable and affect the environment for a long time (Ahmed 2018).

Heavy metals, including Fe, Cu, Pb, Ni, Cd, Zn, Hg and Cr, are regarded as soil pollutants because of their toxicity and widespread in urban garden soil (Gjorgieva-Ackova, 2018). They can bio-accumulate in the bodies of humans and animals and cause serious health issues especially when they are present at levels higher than body requirements. There have been cases of various heart, kidney and liver diseases that have been connected to heavy metals contamination in consumed vegetables in Nigeria and other countries of the world (Gjorgieva- Ackova, 2018).

Data and methods

The study was conducted in Lagos, with five study locations selected as shown in Table 1 below.

An initial survey was carried out in the five sites to establish sampling points. Five representative sampling points were chosen in each selected site using the free survey approach (observation points that are representative of the site were chosen by the surveyors based on personal judgment and experience). In each sample plot, three replicate samples were collected, making a total of 45 samples.

Table 1: Study Locations.

Farm	Location	Prevailing Land Use and Management Practices
1	Greenhouse field I	Covered greenhouse field in cultivation of vegetable located in Lakowe, Lagos. Restricted garden for cultivation of vegetables. Pesticides and chemical fertilizer were used.
2	Greenhouse field II	Covered greenhouse field in cultivation of vegetable located in Epe, Lagos. Restricted garden for cultivation of vegetables. Pesticides and chemical fertilizer were used. Urban forest for conservation of animals and trees.
3	Forest Dry Land	Urban Forest and Animal Sanctuary in Eti-Osa, Lagos
4	Reclaimed Organic Arable Land	Reclaimed arable land located in Lagos State University (LASU School of Agric farm) in Epe for cultivation of vegetables
5	Reclaimed Conventional Arable Land	Reclaimed arable land adjacent to the urban forest and animal sanctuary in Ibeju-Lekki, Lagos for cultivation of vegetables, cassava and maize

The samples were air-dried for 72 hours and then packed in drug dispenser envelopes, which were labelled on the white side accordingly. The samples were crushed and sieved using a 2 mm sieve for the heavy metals. Particles greater than 2 mm were discarded. Each sample (0.25 g) was then placed into a 50 ml flask and 10 ml concentrated HNO3 was added. The mixtures were left in a fume cupboard to cold digest overnight. The following morning the mixture was heated for about half an hour in a microwave. The mixture was then allowed to cool at room temperature for some minutes after which 10 ml of double distilled H_2O was added filtered via 0.45μm cellulose. The concentrations of the heavy metals- Lead, Zinc, Copper, Iron, Cadmium and Manganese-in each sample were then determined using atomic absorption spectrophotometer following American Public Health Association procedures and standards.

Organic carbon contents, particle size distribution, total nitrogen, soil pH, Na, K, Ca, and Mg in the soil were also determined.

To determine the pH of the soil samples, a glass electrode pH meter was used. The Walkley-Black Method was used to determine the percentage of organic C in the soil samples. The percentage of organic carbon was calculated on an air-dry basis using the formula below:

$$\text{\% organic C in soil (air-dry basis)} = \frac{(\text{me K2Cr2O2-meFeSO4}) * 0.003*100*(f)}{\text{g of air-dry soil}}$$

Where f (correction factor) was taken to be 1.33.
me = Normality of solution * ml of solution used.

The organic matter in the soil samples was determined by using the % Organic C x 1.729 method, while the N content was determined via the Macro-Kjeldahl Method. To do this, 10g of each soil sample (air-dried and ground to pass a 0.5 mm sieve) was weighed and transferred to a 500 ml Macro-Kjeldahl flask. 20 ml of distilled water was added and swirled for a few minutes before standing for 30 minutes. A tablet of mercury catalyst and 10g of K_2SO_4 was added, followed by 30 ml of conc. H_2SO_4 via an automatic pipette. The flasks were cautiously heated at low heat on the digestion stand, increasing the heat until the digest was cleared. The mixture was boiled, and the heating was regulated during boiling to allow H_2SO_4 to condense. The digests were then transferred into another set of clean Macro-Kjeldahl flasks, while the sand particles were retained in the original digestion flask. The sand residue was washed with 50 ml of distilled water four times, and the aliquot was transferred into the same flask. From here, 50 ml of H_3BO_3 indicator solution was added into a 500 ml Erlenmeyer flask, which was placed under the condenser of the distillation apparatus. The end of the condenser was approximately 4 cm above the surface of the H_3BO_3 solution. The distillation then commenced, with the condenser kept cool to minimize frothing and prevent sunk-back. The NH_4-N in the distillate was determined by titrating with 0.01N standard HCl using a 25-ml burette graduated at 0.1 ml intervals. The colour change at the end point is from green to pink. The %N content in each sample was then calculated.

Data were analyzed using simple descriptive statistics, ANOVA, and Pearson correlation coefficients (r) of heavy metals concentration and soil physicochemical parameters were done.

Results

The Soil Physiochemical Parameters: The pH values of the soil were slightly acidic, ranging between 6.50 to 6.70 for all samples. The study locations had a range of values for soil electrical conductivity (EC) between 160 – 290μs/cm, with the highest EC found in Greenhouse Field I (290.000±6.000 μs/cm) (Figure 1). Available nitrogen ranged from 0.23 to 0.9 % in the study locations. The Total Organic Carbon (TOC) in the farm soils investigated ranged from 0.58 % - 20.5% and the amount of organic matter (OM) also ranged from 1.0 % to 35.45%. The highest Total Nitrogen (TN), Total Organic Carbon and Organic Matter were recorded in Forest dryland (0.9±0.15), (20.5 ±0.08) and (35.45 ±0.39) respectively (Figure 1).

Available CEC-Na, K, Ca, and Mg (Meq100g) in the soil of the study site were presented in Figure 2, with Na being highest at Forest Dryland, with 0.32 Meq100g, available K being highest at Greenhouse Field II and Forest dry land (0.24 Meq100g), Ca being highest at Forest dry land (1.02 Meq/100g) while Mg was highest at Greenhouse Field II (0.98 Meq100g) (Figure 2).

Heavy Metal Concentration in the Soil of the Five Study Locations: Levels of concentrations of Cd, Cu, Fe, Mn, Pb and Zn in the soil from the study sites from the five locations are given in Table 2. The range of values of the mean concentrations of the heavy metals as presented in Table 2 such that Cd = 0.05 – 3.11 mg/kg, Cu = 0.38 – 35.71 mg/kg, Fe = 24.71 – 99.36 mg/kg, Mn = 0.50 – 14.61 mg/kg, Pb = 0. 12 – 2.45 mg/kg and Zn = 9.22 – 136.96 mg/kg. The highest concentration of Cd (3.11 mg/kg) was recorded at Greenhouse Field I whereas the lowest concentration of Cd was found in Forest Dry land (0.10 mg/kg).

The highest value of Cu (35.71 mg/kg) was recorded at Forest Dryland. However, the lowest Cu was noticed in Greenhouse Field II (0.38 mg/kg). Greenhouse Field II had the highest value for Fe (99.36 mg/kg) whereas Forest dry land contained the lowest concentration of Fe (24.71 mg/kg). The highest concentrations of Mn (14.61 mg/kg) and Pb (2.45 mg/kg) and Zn (136.96 mg/kg) were noticed in Greenhouse Field II whereas the lowest concentrations of Mn (0.50 mg/kg) and Pb (0.12 mg/kg) were recorded at Forest Dry Land while lowest concentration of Zn (9.22 mg/kg) were recorded at Forest dry land and Reclaimed Conventional Arable Land respectively. All the heavy metals except for Cd at Greenhouse Field I and Greenhouse Field II evaluated and determined in this study were all below the WHO/FAO permissible limit (Table 2).

Correlation Coefficient (r) of Heavy Metals and Physico-chemical Parameters in the soil: Table 3 displays the correlation coefficient (r) values for the soil heavy metals and physico-chemical parameters in the study locations. The pH had a positive correlation ($p<0.05$) with Fe (r = 0.373), Pb (r = 0.384), Zn (r = 0.457) and Mn (r = 0.442) and at ($p<0.01$) with Cu (r = 0.545). EC has a positive correlation ($p<0.01$) with Fe (r = 0.727), Zn (r = 0.651) and Cu (r = 0.580). TN has a negative correlation ($p<0.05$) with Cu (r = 0.368) and Mn (r = 0.409). TOC has a positive correlation ($p <0.05$) with Zn (r = 0.411). OM has a positive correlation ($p <0.05$) with Zn (r = 0.366). Na has a negative correlation ($p <0.05$) with Fe (r = 0.440), Pb (r = 0.377), Cd (r = 0.377) and at ($p<0.01$) with Zn (r = 0.493), Cu (r = 0.696) and Mn (r = 0.606). Ca has a negative correlation ($p <0.01$) with Cu (r = 0.613), Mn (r = 0.623) and at ($p< 0.05$) with Cd (r = 0.451).

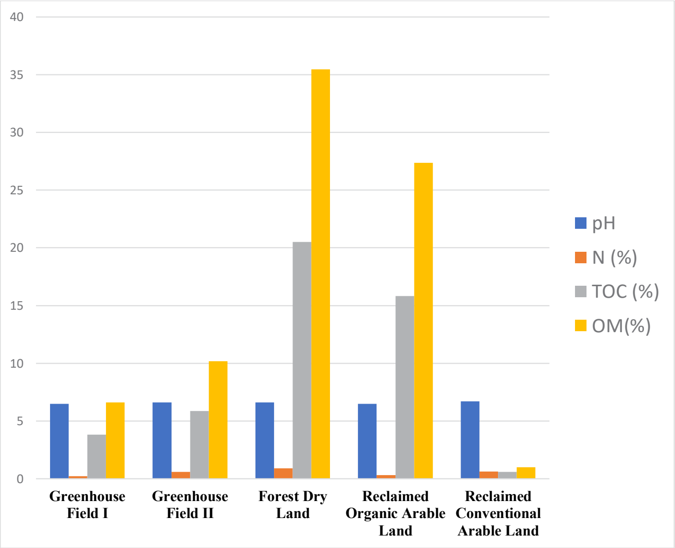

Figure 2: Soil pH, electrical conductivity, total organic carbon and organic matter of the soil from the study locations (N= available nitrogen, TOC = Total organic carbon, OM = Organic matter).

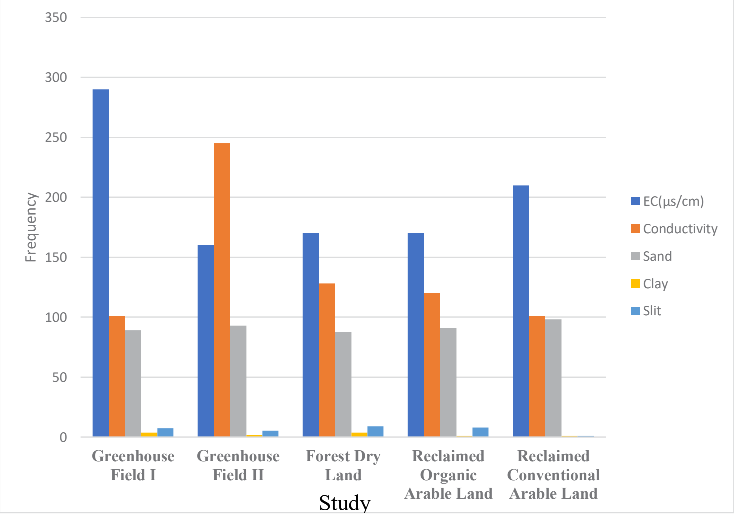

Figure 3 Showing soil properties (EC, Conductivity and Soil particles)

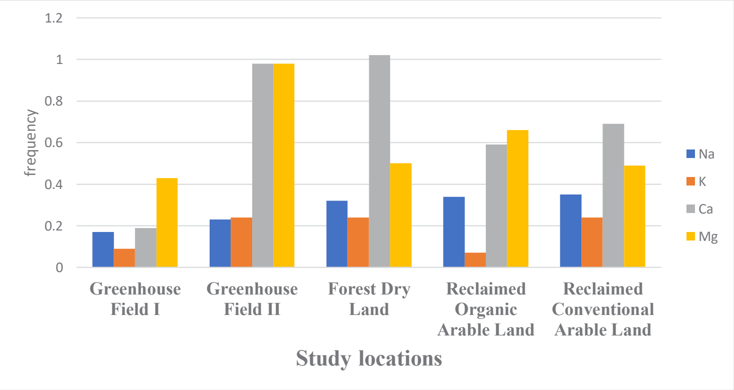

Figure 4 showing the mean concentrations of elements (mg/kg) in the soil from the study locations

Table 2: Mean concentrations of heavy metals (mg/kg) in the soil from the study locations

Sample Location	Cd±SD (mg/kg)	Cu ±SD (mg/kg)	Fe ±SD (mg/kg)	Mn±SD (mg/kg)	Pb±SD (mg/kg)	Zn±SD (mg/kg)
WHO/FAO Permissible Level	3.00	100.00	50000.00	2000.00	100.00	300.00
Greenhouse Field I	3.11±0.03c	0.40±0.08b	94.50±10.25c	13.80±1.38c	1.43±0.45c	120.3±0.05b
Greenhouse Field II	3.06±0.02b	0.38±0.07a	99.36±17.20c	14.61±0.02c	2.45±0.08d	136.96±0.02
Forest Dry Land	0.05±0.03a	35.71±0.06e	24.71±0.20a	0.50±0.18a	0.12±0.06a	14.8±0.05
Reclaimed Organic Arable Land	0.10±0.02b	26.23±0.04d	28.71±5.19b	5.05±0.15b	0.23±0.01b	65.08±0.07
Reclaimed Conventional Arable Land	0.18±0.02b	19.72±0.09c	32.59±8.19b	0.52±0.20a	0.36±0.03b	9.22±0.06

**Fe= Iron, Pb= Lead, Cd= Cadmium, Zn= Zinc, Cu= Copper, Mn= Manganese. Means having the same letter(s) in the same column are not significantly ($P < 0.05$) different.*

Table 3. Pearson correlation coefficients (r) of potential toxic metals concentration and physico-chemical parameters of the soil in the study locations

	Fe	**Pb**	**Cd**	**Zn**	**Cu**	**Mn**
Location	0.160	-0.702**	-0.486**	-0.057	-0.198	-0.449**
Ph	0.373*	0.384*	0.260	0.457*	0.545**	0.442*
EC	0.727**	0-.113	-0.126	0.651**	0.580**	0.200
TN	-0.081	-0.316	-0.346	0.002	-0.368*	-0.409*
TOC	0.273	-0.023	-0.129	0.411*	0.097	-0.030
OM	0.229	-0.069	-0.154	0.366*	0.045	-0.072
Na	-0.440*	-0.377*	-0.377*	-0.493**	-0.696**	-0.606**
K	0.202	-0.260	-0.173	0.193	.074	-0.088
Ca	-0.241	-0.326	-0.451*	-0.309	-0.613**	-.623**
Mg	-0.081	0-.207	-0.157	-0.248	-0.251	-0.228

**Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).*

Discussion

Values of soil pH in various study locations varied, although they were generally slightly acidic. Soil pH is an important indicator of the health of the soil. It controls nutrient availability, crop productivity and microbial activities. The pH of all the studied locations was slightly acidic which can support plant growth and microbial activities (Msimbira & Smith, 2020). Nonetheless, it is important to keep a close eye on the soil's pH levels by monitoring it regularly (Bhatnagar & Chandra, 2019). The differences in pH value can be attributed to prevailing land use management practices. Organic matter (OM) is considered an important sink for a large fraction of metals of anthropogenic origin. This result agrees with the finding of Abure, (2022). OM content in soils investigated was relatively low, indicating low potential for binding heavy metals in insoluble form and bioavailability of heavy metal. The observed variations in all the soil for EC, TOC, TN and OM across the study sites were indications of the heterogeneous nature of these sites. The same result was observed by Negasa *et al.* (2017). The organic matter in the soil varied significantly, which could be an indication of different levels of potentially toxic metals present. It's important to monitor and understand these levels to ensure the safety of any plants or organisms that may be living in the soil (Sürücü *et al.*, 2018).

The levels of concentrations of Cd, Cu, Fe, Mn, Pb, and Zn in the soil from the study sites from the five locations were also evaluated and determined. All the heavy metals except for Cd at Greenhouse Field I and Greenhouse Field II evaluated and determined in this study were all below the WHO/FAO permissible limit. The heavy metals recorded in forest fields, and arable organic fields were found to be lower than those in soils of greenhouses fields. This finding agreed with the finding of Wan *et al.* (2022). The high levels of Cd found in soil samples from Greenhouse Field I and II are likely due to the excessive use of chemical fertilizers. This result agrees with the findings of Wei *et al.* (2020). It is important to address the issue of excessive use of chemical fertilizers and find sustainable alternatives to these harmful chemicals to protect our environment and our health (Fang *et al.* in 2011; Makanjuola *et al.* 2019). The impact of land usage on heavy metal concentrations in the soil is evident, with distinct differences between soil samples observed.

Limitations

The study only examined the effects of urban land use patterns on physicochemical parameters, carbon stock and heavy metal contents of soils in Ibeju- Lekki and Epe Local government areas of Lagos State in Nigeria. The study only examined the concentrations of only six heavy metals- Lead, Zinc, Copper, Iron, Cadmium and Manganese-in each sample that was taken using atomic absorption spectrophotometer. American Public Health Association procedures and standards were followed.

Conclusion

Specifically, the level of heavy metals observed in soil under this study was mostly influenced by land use patterns. Many changes occur in the soil properties due to land use and land cover change in Lagos Nigeria which may also have an impact on the vegetation and livelihood of the Lagosians. This study indicated significant variations of heavy metal fractions as affected by soils of different land uses. Higher concentrations of heavy metals were observed in greenhouse fields whereas lower concentrations were noticed in the forest land and organic arable land.

Recommendations

This study will help in providing valuable information for further studies and will be useful for environmental quality management and rehabilitation of heavy metal polluted soils in various land uses in Lagos. In addition, it is important for both Lagosians and farmers to be aware of the potential dangers of using chemical fertilizers for growing food crops. The accumulation of heavy metals in these areas can lead to bioaccumulation in the crops, which can have serious health consequences for those who consume them. To ensure the safety of our food supply, it is best to avoid excessive use of chemical fertilizers for agricultural purposes.

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