

IMPACT OF TOPOSEQUENCE ON HEAVY METALS IN THE FLOODPLAIN SOILS OF GADABIYU, KWALI AREA COUNCIL, ABUJA, NIGERIA

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Abstract

Monitoring the effects of irrigation on soil quality is considered as central to the issue of sustainable harvest and productivity in irrigated areas. This is largely due to realization of the fact that it can have unfavorable effect on soil properties leading to loss of sustainable productivity if not frequent monitored. Consequently, many studies have been carried out in many parts of the world documenting the various ways in which irrigation alters soil conditions, more especially how irrigation water impact negatively on soil quality. However, such studies are limited in scope as most have not considered the effect of soil catena on productivity of irrigated soils. This study assessed the effect of toposequence position on heavy metals in the flood plain soils of GADA BIYU, KWALI Area Council, Abuja, FCT. Two catena (A and B) and three slope segments were identified. Soil samples were collected from each profile pit in accordance with horizons starting from lower horizons to avoid contaminating samples. Transect placement and sampling intervals along transects were determined subjectively to capture the full range of soil variability within landforms. The depth of the auger borings was 0-15 and 15- 30 cm (surface and sub-surface respectively). The soils were analyzed for lead (Pb), Nickel (Ni), Chromium (Cr) and Cobalt (Co). Descriptive statistics and a One-way Analysis of Variance were used to analyze the data. Findings revealed that values gotten for Lead(Pb) were decreasing with increase in soil depth suggesting that surface horizons of the soils had higher Pb values in the study area, generally Pb was extremely high with values that ranged from 90.75 to 3505.50 mgkg⁻¹ with a mean value of 1326.33 mgkg⁻¹ and standard deviation of 986.20 (SE±239.01). In the same vein, the values recorded for Co was rated as very high, whereas Nickel (Ni) values were rated as being moderate. Cr was higher in the surface soil horizons than on the sub-surface soils. Generally, the study showed that heavy metals in the soils vary within and between the catena and also along the slope. Based on the findings the study recommended periodic test of soil and water sources within the area based on slope positions. This will ensure sustainable soil quality and suitability control. It is important to include this aspect in all plans for irrigation and sustainable soil quality management.

Keywords: Toposequence, Catena, Irrigation, Heavy Metals.

Introduction

Heavy metals or trace metals are a large group of trace elements which are both industrially and biologically important. Heavy metal is the most widely used term for the large group of elements with an atomic density greater than 6g/cm³ (Beighton, 2013). The normal abundance of an element is commonly referred to by geochemists as background; this varies according to the geology and soil type of an area, with initial hydrological processes such as land runoff and flow, providing the initial transportation of heavy metals.

Soil pollution by heavy metals is a significant environmental problem worldwide (Alloway, 1995). In particular, heavy metal pollution of surface soils, due to intense industrialization and urbanization has become a serious concern in many developing countries (Mireles *et al.*, 2012; Wei and Yang 2010; Yaylal 2011). The accumulation of heavy metals in surface soils is affected by many environmental variables, including parent material and soil properties as well as human activities such as industrial production, traffic, farming, and irrigation among others. Large areas of land can be contaminated with heavy metals released from smelters, waste incinerators, industrial wastewater, application of sludge or municipal compost, pesticides, and fertilizers. Irrespective of their sources in the soil, accumulation of heavy metals can degrade soil quality, reduce crop yield and the quality of agricultural products, and thus negatively impact the health of human, animals, and the ecosystem (Nagajyoti *et al.*, 2010). It is important to identify the sources of heavy metals, besides quantifying their concentrations and spatial variability in the soils.

Irrigation is the artificial application of water to the land or soil. It is used to assist in the growing of agricultural crops, maintenance of landscapes, and revegetation of disturbed soils in dry areas and during periods of inadequate rainfall. Irrigation has been a central feature of agriculture for over 5000 years and was the basis of the economy and survival of numerous societies, ranging from Asia, Africa to the Americans (Jibril, *et al.*, 2008).

In Nigeria, irrigation systems have existed long before the advent of colonial period. The systems involved cultivation of seasonally inundated depressions in upland areas of the south and parts of the middle belt that received heavy rainfall, shallow swamps, and seasonally flooded riverine land. In the north, irrigation was also done along rivers, and some use was made of wells (Jamala, *et al.*, 2012). Moreover, irrigation agriculture has continued to face superfluity of problems, prominent of which is soil fertility decline. Brown, (2004) cited slope effects, weathering and human activities as principal factors of soil fertility degradation in the tropics. Hence this study analyses the impact of toposequence on heavy metal in floodplain soils of Gadabiyu area of Kwali Area council, Abuja Federal Capital Territory, Nigeria. The objective of this study is to determine the impact of toposequence on the heavy metal content of the soil, using appropriate statistical methods, and to determine soil quality variations between and within different topographic units in the soils of Gada Biyu area of Kwali area council.

Materials and Methods

Study Area

Kwali Area Council of the Federal Capital Territory was created on the 1st October 1996. It lies between $8^{\circ} 28' - 8^{\circ} 54'N$ and $6^{\circ} 50' - 7^{\circ} 13' E$. The council has a total land mass of about 1700km square. The settlement pattern is dispersed with the indigenous clustered type within Kwali, Leda, Dangara, Gada-biyu, Sheda, Kilankawa, Dabi and Pai. The main ethnic groupings include the Gbari, Ganagana, Bassa, Fulani, and others (Compendium on Implementation of the Fadama III project in Federal Capital Territory (CIFIIP), 2013).

The climate is the hot and humid tropical type. It is such that its elements have ranges that are transitional from those of the southern and northern parts of the country. The area has distinct wet (March - October) and dry (November - February) seasons with average annual rainfall of 1358.7mm and mean temperature range of between $20.70^{\circ}C - 30.80^{\circ}C$ (Balogun, 2001). Rainfall play a vital role with respect to agricultural activities within the study area and most farming activities highly depend on rainfall (Balogun, 2001).

Soil of the study area is influenced with alluvial soil of Iku plains, gleysols and fluvisols. soils are complex in their degree of taxonomic variations. Drainage conditions of the soil depend on the depth of water table. The colour of the soils is modified by mottling due to poor drainage. The area has clayish and sandy loam soil texture with occasional swampy areas used for wetland (irrigated) farming. These are the upland soils of the ferruginous red tropical type, often derived from crystalline acid or sandy rocks and contained high proportion of silt. They are most suited for cereal and tuber production (Balogun, 2001).

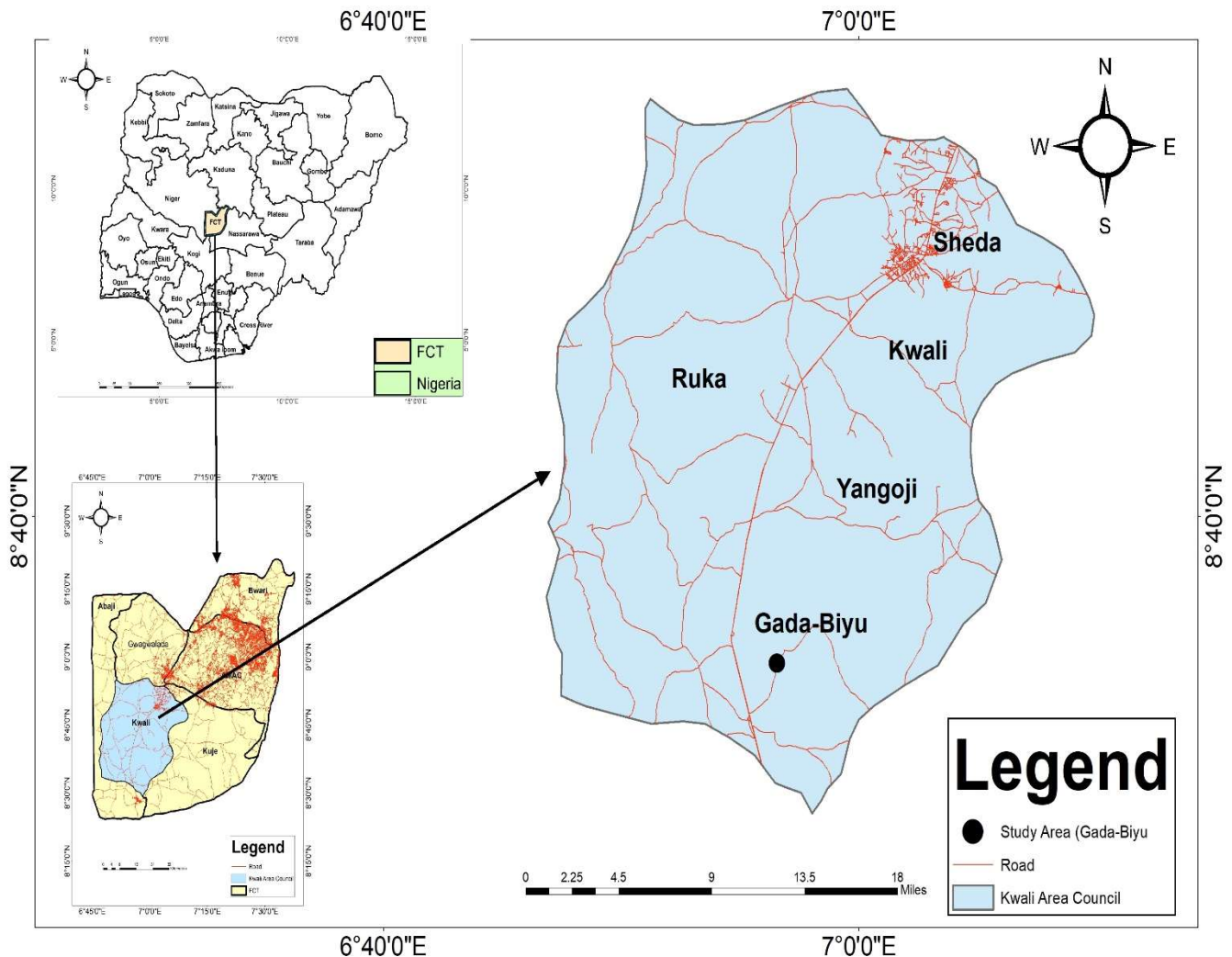


Figure 1: Kwali Area Council showing the Study Area

Source: UniAbuja Gis Lab

The study area has a vast land conducive for agricultural activities. The rich and fertile land makes it suitable for cultivation of varieties of crops with large spread of fadama land estimated to be over 40,000 hectares and suitable for rice farming (CIFIIIP, 2013).

The Climate favours the production of a wide variety of crops, which include legumes (groundnuts, soyabean, lima bean, bambara nut and pigeon pea), cereals (maize, millet, sorghum and rice),

solanaceous crops (peppers, tomato, garden eggs and ginger), tree crops (guava, cashew, mango, orange and paw-paw), and root and tuber crops (yam, sweet potatoes, cocoyam and cassava). For livestock production, the animals that are mostly kept are swine, goats, sheep and poultry. Hunting and bee-keeping are also practiced (CIFIIIP, 2013). The area is mainly occupied by small holding rain fed and irrigation farmers who grow yam, rice, melon seed, cocoyam, cassava, pepper, tomato, okra rice, onion, garden eggs, spinach, beniseed and millet among others (CIFIIIP, 2013).

2. Field Procedures

The toposequence survey was carried out using a Garmin Geographical Position system (GPS) to detect both the various segments of the geodetic elevation and coordinates of the segments (Mapping Units). Transects were taken with the use of tape. Two catenas (A and B) and three slope segments were detected and the slopes are classified as shown in Table 1:

Table 1: **Topo sequence slope segments Elevation, Interval Distance and Coordinates.**

SYMBOL OF SLOPE	SLOPE	ELEVATION/HIGHT	INTERVAL HORIZONTAL DISTANCE	COORDINATES OF SLOPE SEGMENTS		COORDINATES OF PROFILE PITS			
						CATANA A		CATANA B	
MU1	Upper slope	6m	0-200	N08°36'753"	E006°55'165'	E6.919432	N8.61257	E6.920833	N8.612515
MU2	Mid-slope	85m	200-700	N08°36'649"	E006°55'134'	E6.918897	N8.610845	E6.920262	N8.610763
MU3	Lower slope	78m	700-1000	N08°36'385"	E006°54'835'	E6.9139	N8.606472	E6.915265	N8.60633

Source Field Work (2018)

Sampling Procedure

Profile Pits Preparation and Soil sample collection

Prior to the preparation of profile pits, two parallel toposequences (50m apart) were selected and delineated into three slope positions. Three (3) slope units were realized: MU1, MU2, and MU3 (upper slope, middle slope and lower slope respectively). Two (2) profile pits (A and B) were dug in each of the soil units established along the three slope segments, maintaining the standard dimension of 2m x 1.5m x 2m (Length x width x depth respectively).

Soil samples were collected from each profile pit in accordance with horizons starting from lower horizons to avoid contaminating samples. Transect placement and sampling intervals along transects were determined subjectively to capture the full range of soil variability within landforms as described by Young, (1992). Random auger borings were made around each profile pit and bulked together to form composite samples for each soil unit studied. Surface (0-15cm) and subsurface (15- 30 cm) samples were collected using a soil auger. These layers are considered

the most productive soil layers that exert the greatest effect on crop yield and geomorphologic processes are enacted within such layers (Aweto and Enaruvbe, 2010). Deep auger borings were made in each of the profile pits beyond 200cm (Plate 1 to 2).



Plate 1: Researcher and her field assistants taking Measurements along Transects at Gada-biyu Irrigation Area.

Source: Author's fieldwork (2018)



Statistical Analysis

SPSS and Ms excel spread sheet were used to analyses data to determine the impact of topo sequence on the heavy metal content of the soil by calculating the mean, standard deviation and standard error of the mean of each sample result.

The statistical analysis considered is ANOVA was used to determine soil quality variations between and within different topographic units in the soils of Gada Biyu area of kwali area council.

Results and Discussion

Impact of Topo Sequence On the Heavy Metal Content of the Soil

The concentration of heavy metals of the soils is presented in Tables 2 and 3 for all the three soil units studied in the Gada-biyu Irrigation area and the findings are explained as follows.

LEAD

Lead (Pb) in the upper slope section of catenae as shown in Table 2 and 3 range from 3.78 to 14.95 mgkg⁻¹ with a mean value of 11.06 mgkg⁻¹ and standard deviation of 7.12 (SE±0.84). This mean is rated as low. In the middle slope section, Pb ranged from 15.43 to 23.88 mgkg⁻¹ with a mean of 19.51 mgkg⁻¹ and standard deviation of 5.32 (SE±1.07). This mean is also rated as low. In the lower slope section of the catenae however, Pb is extremely high with values that range from 90.75 to 3505.50 mgkg⁻¹ with a mean value of 1326.33 mgkg⁻¹ and standard deviation of 986.20 (SE±239.01).

In all the units, Pb decreases with increasing soil depth (see Table 2), suggesting that surface horizons of the soils is higher Pb values except for the middle slope unit which is much higher values in the sub surface horizons than in the surface. This can be attributed to effect of erosion and deposition by water during irrigation. Hence, the upper slope with low moisture content is much lower values of extractable Pb in the soil. This finding is consistent with the report of Bhattachariya *et al.*, (2008). The result shows that increased levels of Pb in the soils may decrease soil productivity resulting in phytotoxicity and reduced nutrient uptake by plants. Also, Jordao *et al.*, (2006) noted that cultivation of crops on contaminated soils represents a potential risk and a source through which vegetable tissues can accumulate heavy metals.

Table 2: Heavy Metal Distribution in The Soils of Gadabiyu Irrigation Area for Catena 'A'

Location	Horizon/depth cm	Pb	Cd	Ni	Cr	Co
MU1 (Upland) upper slope	Ap 0 – 16	13.43	ND	21.18	16.63	6.40
N8.61257	AB 16 – 48	12.43	ND	15.78	12.93	2.60
E6.919432	Bt1 48 – 67	14.95	ND	2.53	12.75	1.70
Alt.= 85m	Bt2 67 – 106	9.80	ND	13.68	2.53	2.40
	C1 106 – 153	8.50	ND	4.10	6.20	0.90
	C2 153 – 175	10.18	ND	2.73	3.11	0.30
	C3 173+	3.78	0.13	2.92	3.78	2.70
	Augered (0 - 15)	14.33	ND	13.33	11.70	ND
	Augered (15 - 30)	12.62	ND	3.16	5.98	ND
	Mean	11.06	-	8.60	8.40	1.90
	Std.Dev	7.12	-	2.44	2.11	1.01
	SE±	0.84	-	0.31	0.23	0.03
MU2 (Backswamp) Middle slope	Ap1 0 – 11	23.88	0.05	21.79	13.30	4.77
N8.610845	Ap2 11 – 27	15.43	ND	18.46	16.32	4.25
E6.918897	Bt1 27 – 42	16.80	ND	9.80	18.05	5.78
Alt.= 85m	Augered (0 - 15)	20.11	ND	13.90	4.28	2.18
	Augered (15 - 30)	21.32	ND	8.71	5.34	2.15

			<i>Mean</i>	19.51	-	14.46	9.06	3.83
			<i>Std.Dev</i>	5.32	-	4.72	1.23	1.42
			<i>SE±</i>	1.07	-	1.38	0.07	0.50
MU3 (levee)	Lower	Ap1	0 – 16	3505.50	ND	48.88	24.70	18.25
N8.606472		Ap2	16 – 34	1742.50	ND	39.33	19.18	20.20
E6.9139		Bt	34 – 58	1942.50	ND	27.63	15.70	4.40
Alt.= 78m		C1	58 – 79	779.75	ND	29.00	17.43	0.90
		C2	79 – 92	787.78	ND	14.78	4.11	10.25
		C3	92+	90.75	ND	4.17	3.28	0.75
		Augered (0 - 15)		1772.10	ND	31.22	13.27	16.72
		Augered(15 - 30)		989.76	ND	23.18	12.63	5.66
		<i>Mean</i>		1326.33	-	27.27	10.70	9.64
		<i>Std.Dev</i>		986.20	-	12.53	4.35	6.22
		<i>SE±</i>		239.01	-	7.11	0.84	2.17

NB: Pb = lead, Cd = cadmium, Ni = nickel, Cr = chromium, Co = cobalt, ND not detected

Source: Fieldwork (2018)

NICKEL

Nickel (Ni) in the upper slope unit range from 2.53 to 21.18 mgkg⁻¹ with a mean of 8.60 mgkg⁻¹ and standard deviation of 2.44 (SE±0.81). These values are rated as being moderate. In the middle slope, Ni range from 8.71 to 21.78 mgkg⁻¹ with a mean of 14.46 mgkg⁻¹ and standard deviation of 4.72 (SE±1.38). In the lower slope unit, Ni range from 4.17 to 48.88 mgkg⁻¹ with a mean of 27.27 mgkg⁻¹ and standard deviation of 12.53 (SE±7.11). These values are rated as being moderate.

The trend in the distribution of Ni in the soil shows that Ni decreases with increase in soil depth within the profiles. The decrease, however, does not follow a regular pattern. Also, the lower slope position had higher values of Ni indicating effect of erosion and deposition of materials that moved from higher elevations, thus giving higher concentration in lower or depressed units. This result agrees with finding by Okoli *et al.*, (2017), they studied some coastal plain soils and reported higher values were found at the surface horizons than in the subsurface which they attributed to the agricultural activities practiced in the area. However, Ayodele and Mohammed, (2011) had noted that Ni is generally not distributed uniformly throughout most profiles.

CHROMIUM

Chromium (Cr) in the upper slope soil units range from 2.53 to 16.63 mgkg⁻¹ with a mean of 8.40 mgkg⁻¹ and standard deviation of 2.11 (SE±0.23). In the middle slope soil unit, Cr ranged from 4.28 to 18.50 mgkg⁻¹ with a mean of 9.06 mgkg⁻¹ and standard deviation of 1.23 (SE±0.07).

In the lower slope unit, Cr ranged from 3.28 to 24.70 mgkg⁻¹ with a mean of 10.70 mgkg⁻¹ and standard deviation of 4.34 (SE±0.84). In all the soil units, Cr was higher in the surface soil horizons than on the sub-surface soils.

This finding agrees with Okoli *et al.*, (2017) and could be attributed to deposition and affinity to soil organic matter in soils. The relatively higher values on the lower slope positions indicate effect of irrigation and accumulation as a result of erosion and movement in water.

COBALT

The abundance of Cobalt (Co) in the soil of the upper slope section range from 0.30 to 2.78 mgkg⁻¹ with a mean of 1.90 mgkg⁻¹ and standard deviation of 1.01 (SE±0.03). In the middle slope, Co range from 2.18 to 5.78 mgkg⁻¹ having a mean value of 3.83-1 and standard deviation of 1.42 (SE±0.50). For the lower slope unit, the values for Co within the profile range from 0.75 to 20.20 mgkg⁻¹ with a mean value of 9.64 mgkg⁻¹ and standard deviation of 6.22 (SE±2.17), these values are rated as being high.

Cobalt was lower in the upper slope position where irrigation was never practiced. In the middle and lower slope sections however, Co increased significantly. This finding agrees with Ayorinde and Dallatu (2017) and is attributed to erosion consequent of irrigation practice in the area. Distribution within the profile showed that cobalt in the profiles decreased with profile depth.

Table 3: Heavy Metal Distribution in the Soils of Gadabiyu Irrigation Area For Catena 'B'

Location	Horizon/depth cm	Pb	Cd	Ni	Cr	Co
MU1 (Upland) upper slope	Ap 0 – 19	21.22	ND	20.88	18.07	2.03
N8.612515	AB 19 – 68	14.67	ND	18.53	13.34	3.12
E6.920833	Bt1 68 – 103	10.89	ND	13.22	13.09	2.93
Alt.= 96m	Bt2 103 – 152	9.85	ND	13.64	ND	1.96
	C1 152 – 181	9.93	ND	6.85	5.22	1.33
	C2 181 – 200	9.67	ND	3.27	1.96	1.07
	Augered (0 - 15)	14.63	ND	14.06	15.72	3.75
	Augered (15 - 30)	13.45	ND	13.43	12.13	3.22
	Mean	13.04	-	12.99	9.94	2.32
	Std.Dev	3.93	-	5.69	6.64	0.95
	SE±	1.39	-	2.01	2.35	0.34
MU2 (Backswamp) Middle slope	Ap1 0 – 17	20.22	ND	21.95	14.045	4.59
N8.610763	Ap2 17 – 41	17.23	ND	20.18	15.27	5.22
E6.920262	Bt1 41 – 67	16.00	ND	10.77	18.00	5.79
Alt.= 85m	Bt2 67 – 76	16.71	ND	16.51	17.96	6.04
	Augered (0 - 15)	19.26	ND	13.91	10.12	2.02
	Augered (15 - 30)	21.75	ND	10.96	14.31	2.34
	Mean	18.53	-	15.71	14.95	4.73
	Std.Dev	2.24	-	4.69	2.93	1.62
	SE±	0.91	-	1.91	1.20	0.72
MU3 (levee) Lower slope	Ap1 0 – 20	437.34	ND	39.44	18.46	19.21
N8.60633	Ap2 20 – 44	1032.51	ND	39.07	16.40	19.26
E6.915265	Bt 44 – 72	947.22	ND	30.39	16.08	5.31
Alt.= 78m	C1 72 – 98	738.49	ND	25.81	14.53	1.11
	C2 98 – 117	659.43	ND	10.22	3.54	8.66
	C3 117+	186.52	ND	4.01	3.00	0.92
	Augered (0 - 15)	895.77	ND	37.52	17.87	15.44
	Augered (15 - 30)	746.16	ND	30.96	15.27	14.29
	Mean	705.43	-	27.18	13.14	10.53

Std.Dev	279.71	-	13.36	6.23	7.57
SE±	98.89	-	4.72	2.20	2.68

NB: Pb = lead, Cd = cadmium, Ni = nickel, Cr = chromium, Co = cobalt, ND not detected

Source: Author's Fieldwork (2018).

Analysis of Variance for Properties Across Different Topographic Units

Analysis of variance for Pb showed that there is significant difference ($p < 0.05$) in the Pb content of the soils across the different slope positions in the two catenas studied. The test of homogeneity also showed that the variation in the distribution was not homogenous all across the different units. This implied that the values were highly variable.

The result for ANOVA shows that there is significant difference ($p < 0.05$) in the distribution of Ni in the soils across the different slope sections of the two catenas. While the values for Ni in Toposequence 'A' were not homogeneous, the result for Ni in Toposequence 'B' is homogenous in their trend.

The result of analysis of variance for Chromium shows that there is no significant difference ($p > 0.05$) in the values recorded across the different slope position in both the catenas studied. Also, the test of homogeneity shows that the values obtained for chromium is homogeneous across the different slope units of the area.

The analysis of variance shows that there is significant difference ($p < 0.05$) in the distribution of cobalt across the different slope sections of the two catenas. Test of homogeneity showed that the values is not homogenous in all the units studied (Table 3 and 4)

Table 4: Summary of ANOVA Analysis for Catena 'A'

S/N	Property	Calculated F	Significant Value	Alpha Level	Significance Difference	Test Significance Value Of Homogeneity	Description Of Homogeneity
1	Pb	13.138	.000	0.05	S	.001	S
2	Ni	7.485	.004	0.05	S	.233	NS
3	Cr	1.585	.231	0.05	NS	.804	NS
4	Co	3.932	.040	0.05	S	.000	S

Table 5: Summary of ANOVA Analysis for Catena 'B'

S/N	Property	Calculated F	Significant Value	Alpha Level	Significance Difference	Test Significance Value Of Homogeneity	Description Of Homogeneity
	Pb	42.039	.000	0.05	S	.001	S
	Ni	5.324	.015	0.05	S	.037	S
	Cr	.733	.494	0.05	NS	.203	NS
	Co	6.336	.008	0.05	S	.000	S

Source: Author's Fieldwork (2018).

Conclusion and Recommendation

In all the units studied, Pb was decreasing with increase in soil depth suggesting that surface horizons of the soils had higher Pb values except for the middle slope unit which is much higher values in the sub surface horizons than in the surface. This can be attributed to effect of erosion and deposition by water during irrigation. Hence, the upper slope with low moisture content had much lower values of extractable Pb in the soil.

The trend in the distribution of Ni in the soil showed that Ni decreased with increase in soil depth within the profiles. The decrease however, did not follow a regular pattern. Also, the lower slope position had higher values of Ni indicating effect of erosion and deposition of materials that moved from higher elevations, thus giving higher concentration in lower or depressed units.

Cobalt was lower in the upper slope position where irrigation was never practiced. In the middle and lower slope sections however, Co increased significantly.

Generally, this study reveals that shows that there is significant difference ($p < 0.05$) in the Pb, Ni and Co content of the soils across the different slope positions in the two catenas studied. Therefore, periodic test of soil within the area is highly recommended. This will ensure sustainable soil quality and suitability control. It is important to include this aspect in all plans for irrigation and sustainable soil quality management.

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