SOIL QUALITY EVALUATION IN RANGELAND SOILS IN RELATION TO HEAVY METALS POLLUTION

Avaliação da Qualidade de Faixas de Solos Relacionadas à Contaminação por Metais Pesados

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Abstract

Heightened anthropogenic activities at the study site necessitated this investigation on soil quality. A transect soil survey technique was used to link sampled points from an open dumpsite towards the river valley. Three minipedons were dug and sampled per location and collected samples were used for various laboratory analyses. Results showed that soils of the dumpsite (OB1) had the highest soil quality morphological index (SQMI) value of 3.82, indicating best quality while the least SQMI was found in the ranch (SQMI = 1.27). The SQMI had significant correlations with OM (organic matter) (r=0.82; p=0.001; n=72), clay (r=65; p=0.01; n=72), pH(r=0.58; p=0.01; n=72) and bulk density (r=0.71; p=0.05; p=0.05; n=72). Although there were positive correlations between SQMI and copper and cadmium, heavy metals were poor predictors of SQMI, indicating that soil quality evaluation by SQMI assesses mainly soil physical fertility.

Keywords: Land; Soil; Bioaccumulation; Biotoxicity; Soil quality; Morphological index.

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Resumo

O aumento das atividades antropogênicas, no local de estudo, culminou com a necessidade de investigar a qualidade do solo. A técnica de transecto (corte no solo) foi utilizada para ligar pontos amostrais de um depósito de lixo a céu aberto até o vale de um rio. Três pequenas áreas foram demarcadas, escavadas e delas foram coletadas amostras para análises laboratoriais. Os resultados mostraram que o solo do depósito de lixo (OB$_1$) tinha melhor índice morfológico de qualidade do solo (SQMI = 3,82) que os valores encontrados num outro local determinado (SQMI = 1,27). O SQMI teve uma correlação significativa com OM (material orgânico) (r=0,82; p=0,001; n=72), com a argila (r=65; p=0,01; n=72), com o pH (r=0,58; p=0,01; n=72) e com a densidade (r=0,71; p=0,05; p=0,05; n=72). Embora exista correlação entre o SQMI, o cobre e o cádmio, metais pesados foram fracos indicadores deste parâmetro, mostrando que a avaliação da qualidade do solo por SQMI resulta principalmente em apontar para a fertilidade do solo.

Palavras-chave: Terra; Solo; Bioacumulação; Biotoxicidade; Qualidade do solo; Índice morfológico.

Introduction

The quality of soils determines their capacity to function well for any intended use. The current popularity of soil quality concept reflects the growing awareness that soil is an important component of the earth biosphere especially in the production of food and fibre (1). Soil quality decline implies degradation of soil resource which is the temporary or permanent lowering of the productive capacity of soil caused by overgrazing, deforestation, inappropriate agricultural practices, over-exploitation of fuel wood leading to desertification and other problems (2). Oldeman *et al.* (3) reported that 35% of Africa soils are lightly degraded, while 65% are extremely degraded. Intensive use of soil without equivalent inputs results in decline in agro-ecosystems through soil erosion and loss of soil microbes (4). This situation is heightened because of the diminution of organic matter and consequent degradation of soil properties (5). In addition to long and intensive cultivation without appropriate inputs, over-grazing impoverishes soil properties (6, 7).

Waste disposal activities of man have also resulted to soil quality decline. Wastes, especially solid wastes contain diverse materials many of which have toxic and hazardous constituents (8). Leachates from these hazardous wastes may include heavy metals that enter the soil system. In some circumstances, the heavy metals are transported to surface and ground waters (9). Heavy metals inputs have been found in site soils where wastes were used as soil amendments (10). Pasture and crop plants act as vehicles for transferring these heavy metals and other toxic constituents in the soil into the food chain. However, the mobility of metals from solid to solution in the soils is mainly controlled by sorption-desorption, chelation, precipitation-dissolution, and oxidation-reduction processes of the metals in soils (11). Plants absorb heavy metals from the soil as well as from aerial deposits on leaves, fruits and stems (12). Some plants accumulate these toxic metals in their above-ground tissues where they constitute serious health and environmental problems not only because of the toxicity to crop plants but also because of the potentially dangerous health effects to man and grazing animals (13).

Thus, soil quality decline is an aftermath of anthropogenic activities. Earlier, Zinck (14) attributed degradation of soils to increased human population and consequent pressure on soils for many conflicting uses. Evaluation of soils to ascertain their health status is therefore necessary. Soil quality evaluation exercise generates land information necessary for promoting food security (15) by implementing agricultural development programmes (16). Andrews *et al.* (17) remarked that soil quality concept depends on inherent capabilities, intended uses and management goals. Soil survey is specifically a relevant tool for generating soil and soil-related data for improved understanding of landscape processes (18, 19). Information from soil survey report helps in modeling soil, vegetation, hydrology and grazing activities of animals (20). Hanson *et al.* (21) noted that detailed inventories on agroecosystem and processes enhance sustainable rangelands. It is often argued that spatial heterogeneity in soil quality exists as a result of differential use of areas by grazing animals (22; 23) that integrated crop-livestock systems improve sustainable use of soils (24). Evaluation studies such as this will go a

length in improving the predictability of such scientific assertions. Currently, there are a wide variety of crop and livestock models but substantial work remains in combining these into robust systems models that can account for the major interactions within crop-livestock system (25).

Based on the foregoing and on the fact that there is a causal nexus between land, population, poverty and degradation especially in an excruciating humid tropical agro-environment, it becomes necessary to investigate rangelands for the purpose of accumulating useful soil and soil-related data for their sustainable management.

The major aim of this study was to investigate soil quality of rangeland soils of a peri-urban community of Obinze in Imo state southeastern Nigeria by using a numerical soil quality index.

Materials and Methods

Site selection and characterization

Obinze is a military settlement lying between latitudes $5^o10^'$ and $5^o25^'$ North and longitudes $6^o45^'$ and $7^o00^'$ East. Obinze is a peri-urban community at a distance of about 25 kilometres away from the metropolitan city of Owerri, southeastern Nigeria. Although, it is a military settlement, the site is a home for nomads especially from northern part of the country who settle around the barracks with their herds of animals especially cattle. These animals are grazed on surrounding rangelands. Consequently, the vegetation of the rangelands tend to be more of derived savanna than rainforest as a continuous grazing. The major geological material of the site is Coastal Plain Sands (Benin formation) of the Oligocene-Miocene era (26). Obinze is a lowland area (27). It is a humid tropical environment. The average annual rainfall is about 2400 mm with 3 months of dryness. Temperatures are high and change only slightly during the year (27-29°c). Crop farming is mainly practiced at subsistence level with traditional slash and burn system. Mixed cropping is prominent and soil fertility regeneration is by bush fallow. Cassava-maize mixtures are common while plantains and bananas are planted at waste dumpsites and abandoned pit latrines.

Field studies

A transect was established from an open waste dump site, 100 metres away from the Army Barracks in Obinze towards the Otamiri River in Imo state. Beginning from the dumpsite to the last sampled location was a distance of 350 metres. In all, 8 sampled points were established as OB_1, OB_2, OB_3, OB_4, OB_5, OB_6, OB_7 and OB_8 and are described in Table 1.

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TABLE 1: Description of sampled sites

Location	Distance Barracks (m)	Human Influence	Vegetation
OB_1	100	Open dump site	Luxuriant grasses (*Panicum maximum etc) Caloprogonium mucunoides* and relics woody shrubs.
OB_2	150	End of dumpsite	Grasses (*Panicum maximum,Sida acuta, Imperata cyclindrica and Acioa barteri*
OB_3	200	Ranch	Very few grasses (*Panicum maximum, Axonopus compressus*).
OB_4	250	Weedy arable farm	Cassava-dominated plus grasses (*Panicu,m maximum, Axonopus compressus* and pteridophytes.
OB_5	300	Open field(1)	Imperata-dominated plus *Panicum maximum*
OB_6	350	Open field(2)	Sparsely grassed with Imperata and Panicum interspersed with woody shrubs
OB_7	400	Military range(1)	Suppressed grasses (*Panicum maximum, Axonopus compressus)*
OB_8	450	Military range(2)	Shrub-dominated grassy vegetatio

Sampling was done at an equidistance of 50 metres. Three minipedons were dug in each sampling location giving a total of 24 minipedons for the study. Each minipedon had 3 layers at predetermined depths of 0-10 cm, 10-20 cm and 20-30 cm and this is necessary for soil quality evaluation using soil quality morphological index (SQMI) as recommended by Seybold *et al.* (28). They stated that SQMI is used to assess near-surface soil attributes quantitatively for the estimation of soil quality. These depths are necessary in the computation of SQMI as they represent SRI 0-10, SRI 10-20 and SRI 20-30 where SRI is the structure-rupture resistance. Soil samples were collected from the bottommost layer upwards to avoid contamination and a total of 72 soil samples were collected.

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TABLE 2: Texture-weighting class criteria for SQMI

Texture class	Criteria
A	Sand, loamy sand
B	Not A and clay is < 18%
C	18-40% clay
D	≥ 40% clay

SQMI = soil quality morphological index.

Table 3: Criteria for placement of structure class in the SQMI

Structure class	Criteria
1	All structures with common or many stress surfaces irrespective of other features, massive, platy with firm or stronger horizontal rupture resistance, all weak structure except granular, moderate very coarse prismatic, all columnar.
2	All structures with few stress surfaces irrespective of other features, weak, granular, moderate very coarse and coarse blocky, coarse and medium prismatic, platy with friable horizontal rupture resistance, strong very coarse and coarse prismatic.
3	No stress surfaces; moderate medium blocky; very fine, fine medium prismatic; platy with very friable horizontal rupture resistance; strong very coarse and coarse blocky.
4	No stress surfaces, moderate granular, moderate very fine and fine blocky; strong fine.
5	No stress surfaces, strong granular, strong very fine through medium blocky and very fine prismatic.

The texture weighting class, structure class and rupture resistance class for each layer was described (29). Texture weighting class was based on the percentage of clay. Soil structure was determined by type, grade and size of structural units. The higher the SQMI the better and SQMI value lies between 0 and 100 (29). Rupture-resistance class was estimated by combining texture-weighting class and moist rupture-resistance (Table 2, 3, 4).

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TABLE 4: Rupture resistance classes for the SQMI

Texture class	Loose	Very friable	Friable	Firm	Very firm & stronger
A	2	3	3	2	1
B	3	4	3	2	1
C	4	5	3	2	1
D	5	5	4	1	1

Leaves of *Panicum maximum* growing on the soils were used for the study. The leaves were harvested at their succulent stage of development in all the sampled points. The leaf samples were oven-dried at 80ºC for 24 hours after washing and later ground with the aid of a blender. Coning and quartering technique was used to obtain sub-samples of dried plant materials for analysis. The ground samples were placed in clean glass bottles and oven-dried again at a temperature of 65ºC for 24 hours in readiness for heavy metals analysis.

Laboratory analyses

Soil particle size distribution was determined by hydrometer method according to the procedure of Gee and Bauder (30). Bulk density was determined by the method of Blake and Hartge (31). Exchangeable basic cations and total exchangeable acidity were measured according to the method described by Thomas (32) and these exchangeable cations (calcium, magnesium, potassium, sodium, aluminium and hydrogen) were summed to give effective cation exchange capacity (ECEC). Base saturation (Bsat) was calculated as total exchangeable bases (TEB) divided by ECEC multiplied by 100%. Aluminium saturation (Alsat) was similarly computed as exchangeable aluminium divided by ECEC multiplied by 100%. Soil pH was estimated electrometrically using the procedure of Hendershot *et al.* (33). Total carbon was obtained by wet oxidation method (34). Spectrophotometric analyses of soil samples were carried out after pre-extraction of cations with dithionite-citrate carbonate according to the procedure of Hesser (35) as follows: Two and half grams of each soil sample was weighed into a beaker and the same quantity of sodium dithionite was added. This was prepared by adding 88.23 g of sodium citrate to 21.02 g of citric acid in a two-litre flask and made to mark with distilled water to give exactly 0.15 M sodium citrate and 0.05 M citric acid essential for this extraction. The beaker was shaken overnight in a shaking machine and later filtered with Whatman no. 42 filter paper. Twenty-five milliliters of the extract were pipetted into a 200 ml beaker and 5 ml of 30% H_2O_2 was added after which the beaker was covered with watch glass. The sample was allowed to cool. Then, 10 ml of HNO_3-H_2SO_4 acid mixture was added in a fume chamber with the sample again digested for 3 hours 30 minutes until the extract became clear. The extract was allowed to cool and diluted with distilled water and made to 100 ml in a volumetric flask. Concentrations of Nickel, Vanadium, Copper and Cadmium in the extract were determined using Perkin Elmer Model 2280/2380 Atomic Absorption Spectrophotometer. Readings were taken at 316.30 µm for Nickel, 228.90 µm for Vanadium, 422.7 µm for Copper Cadmium.

For the plant material, 1 g was weighted into 50 ml beakers, followed by the addition of 10 ml of 6 M HCl (analytical grade). The beakers containing the samples for different sampled points were covered and heated for 15 minutes, followed by the additions of 1 ml HNO_3. The digestion was performed at 95ºC until about 4 ml was left in the beaker. Then, a further 1 ml of 6 M HCl was added, swirled and 10 ml of water added. The beakers with their contents were heated again on the steam bath to complete dissolution. On cooling, the solution was filtered through a Whatman no. 541 filter paper into a 50 ml volumetric flask and made

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to mark with water (36). Mineralization blanks were carried out using the same procedure but without plant materials. Thereafter, concentrations of heavy metals in the extracts were analyzed using Perkin Elmer Moder 2280/2380 Atomic Absorption Spectrophotometer and readings recorded.

Statistical analyses

Coefficient of variation, correlation and computer-based step-wise regression analyses were performed on the soil and plant data according to the procedure of Little *et al.* (37).

Results and discussion

Soil quality

Results of SQMI are shown in Table 5 with soils of the open dumpsite (OB$_1$) having the best quality (SQMI=3.82), followed by arable farm (OB$_4$) (SQMI=3.06) and least quality value recorded in the ranch (OB$_3$) (SQMI=1.27).

TABLE 5: Mean values of sqmi. Variability and variability rating

Location	SQMI	SD	CV(5)	Rating
OB$_1$	3.82	0.50	13	Slight variation
OB$_2$	2.63	0.80	30	Moderate variation
OB$_3$	1.27	0.12	9	Slight variation
OB$_4$	3.06	0.70	22	Moderate variation
OB$_5$	1.39	0.20	14	Slight variation
OB$_6$	1.42	0.15	10	Slight variation
OB$_7$	1.58	0.19	12	Slight variation
OB$_8$	2.72	0.62	22	Moderate variation

SQMI = soil quality morphological index, SD = standard deviation,
CV = coefficient of variation. * Rating was according to Aweto (38).

Slight variations in soil quality were encountered in OB$_1$, OB$_3$, OB$_5$, OB$_6$ and OB$_7$. High SQMI values of the open dumpsite could be attributed to high organic matter content and consequent improvement of the physical properties of soil especially soil structure. The soil organic matter content is a major contributing factor in aggregation and aggregate stability of soils with low exchangeable sodium percentage (39). In soil quality evaluation by SQMI, soil structure is a major variable evaluated because it facilitates soil properties such as infiltration, porosity, moisture availability to plants and susceptibility to soil erosion (40). The least SQMI value recorded in

OB$_3$ (SQMI=1.27) is indicative of total breakdown of unstable soil aggregates resulting in the collapse of soil pores and consequent production of finer particles and microaggregates resulting in seal formation.

Soil properties

Soil properties studied are shown in Table 6. Soils were sandy, extremely to strongly acidic and of low effective cation exchange capacity (ECEC). Bulk density values were high except in the dumpsite. Base saturation was low (<50%) except in soils of the dumpsite having 58%. Conversely aluminium saturation (Alsat) was high

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except in soils of the dumpsite (Alsat = 32%). Organic matter content of the site was generally low although high in soils of the dumpsite (4.21%). These soil properties influenced SQMI values as in Table 5. Naturally soils are sandy being derived from Coastal Plain Sands and this condition interacted with the excruciating humid climate to set in motion pedogenic processes of leaching, elluviation, illuviation and rapid mineralization of organic matter. Grazing and cultivation activities may have contributed to decline in organic matter and increase in bulk density of soils. A bulk density of 1.64 Mgm^{-3}) obtained in the ranch can be explained by the stocking density of cattle.

TABLE 6: Mean values of selected soil properties in the study site

Loc.	Sand %	Silt %	Clay %	BD (Mgm^{-3})	ECEC (cmolkg^{-1})	Bsat %	Alsat %	pH (KCl)	OM %
OB$_1$	82	4	14	1.28	9.12	58	32	5.3	4.21
OB$_2$	86	6	8	1.32	6.35	48	42	5.0	3.06
OB$_3$	86	8	6	1.64	2.68	26	65	3.5	2.92
OB$_4$	88	8	4	1.54	6.63	49	46	5.1	2.26
OB$_5$	75	2	3	1.58	4.32	36	62	3.8	1.94
OB$_6$	94	2	4	1.56	4.36	37	61	3.8	1.96
OB$_7$	88	2	10	1.62	3.24	30	64	4.0	1.88
OB$_8$	86	3	11	1.61	3.26	34	62	4.1	2.02

BD = Bulk density, ECEC = effective cation exchange capacity, Bsat = base saturation, Alsat = aluminium saturation, OM = organic matter.

Table 7 shows the distribution of heavy metals in soils of the site. Nickel values ranged from 7.8±80.62 mgkg^{-1} to 24.38±6.00 mgkg^{-1}. Others were distributed as follows: Vanadium (0.16±0.01-2.06±0.4 mgkg^{-1}), Cadmium (0.1+0.01-5.2+1.00 mgkg^{-1}) and copper (28.24±4.1-76.21±5.71 mgkg^{-1}).

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TABLE 7: Distribution of heavy metals in soils of study site (mean $\pm$sd)

Location	Nickel	Vanadium	Copper	Cadmium
OB_1	24.38$\pm$6.00	2.06$\pm$0.04	76.21$\pm$5.71	5.2$\pm$1.00
OB_2	21.22$\pm$5.31	1.18$\pm$0.01	44.05$\pm$6.64	3.1$\pm$1.00
OB_3	15.14$\pm$6.12	0.90$\pm$0.01	32.55$\pm$5.16	2.6$\pm$1.00
OB_4	12.33$\pm$2.01	0.20$\pm$0.01	28.24$\pm$4.11	0.5$\pm$0.08
OB_5	8.26$\pm$1.22	0.22$\pm$0.01	33.29$\pm$6.10	0.3$\pm$0.02
OB_6	9.14$\pm$2.61	0.16$\pm$0.01	34.46$\pm$7.12	0.3$\pm$0.01
OB_7	10.30$\pm$1.84	0.21$\pm$0.01	35.28$\pm$5.14	0.1$\pm$0.01
OB_8	7.88$\pm$0.62	0.18$\pm$0.01	38.33$\pm$4.13	0.2$\pm$0.01

The results showed that the open dump site with the best soil quality (SQMI=3.82) had the highest concentration of heavy metals in the study site. This tends to prove that SQMI is a little subjective and measures physical and not chemical fertility and quality of soils. Again, the presence of these heavy metals in all the sampled points confirms that heavy metals are naturally occurring in soils) (41). The values nickel, copper, vanadium and cadmium were 12.8$\pm$3.2, 5.2$\pm$0.4, <.0.2 and <0.2 mgkg^{-1} respectively in the Obiobi/Obirikom communities of Rivers state Nigeria (42). The variability in the surface concentrations of these metals could be related to source of heavy metal, hydrodogical and lithological properties of soils of respective sites. Except in minipedons located on and around the open dump site, others had heavy metal concentrations below the critical level recommended by FEPA (43). In the leaves of P. maximum, heavy metals distribution was as follows: Nickel (0.002$\pm$0.001-0.018$\pm$0.003 mgkg^{-1}), copper (1.22+0.2-6.32$\pm$0.2 mgkg^{-1}) and cadmium (0.1$\pm$0.01-0.9$\pm$0.03 mgkg^{-1}) as indicated in Table 8. Soil properties influence soil quality hence may have affected uptake of heavy metals by *Panicum maximum*. In a similar study, Lee (44) reported that cadmium uptake by rice was influenced by soil properties particularly clay and soil pH. However high levels of these metals in the soil may produce high concentrations in P. maximum (45). Nonetheless bioavailability and uptake of heavy metals by plants may relate to the age and part of the plant. Wang and Liao (46) reported that uptake of heavy metals increases as plant grows, then falls as the crop reaches maturity.

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TABLE 8: Distribution of heavy metals in leaves of Panicum maximum (mean ±sd)

	Heavy metals (mgkg⁻¹)			
Location	Nickel	Vanadium	Copper	Cadmium
OB_1	0.018±0.003	0.088±0.003	6.32±0.2	0.9±0.03
OB_2	0.012±0.003	0.042±0.01	4.16±0.3	0.6±0.04
OB_3	0.009±0.003	0.033±0.02	3.42±0.1	0.6±0.03
OB_4	0.006±0.002	0.028±0.02	2.42±0.2	0.4+0.01
OB_5	0.003±0.001	0.026±0.01	2.46±0.2	0.4±0.01
OB_6	0.003±0.002	0.021±0.01	1.38±0.1	0.1±0.01
OB_7	0.002±.001	0.023±0.01	2.02±0.1	0.1±0.01
OB_8	0.003±.001	0.019±0.01	1.22±0.2	0.1±0.01

Relationship between SQMI and soil properties

Soil quality morphological index had significant correlation with clay (r=0.65; p=0.01; n=72), bulk density (r=-0.71; p=0.05; n=72), ECEC(r=0.55; p=0.05; n=72), Bsat (r=0.42; p=0.05; n=72), Alsat (r=-0.53; p=0.05; n=72), pH (r=0.58; p=0.01, n=72) and OM (r=0.82; p=0.001; n=72) as shown in Table 9.

TABLE 9: Correlation coefficients between SQMI and selected soil properties (n = 72)

Soil property	Correlation coefficient(r)	Level of significance
Sandy	-0.26	NS
Silt	0.31	NS
Clay	0.65	**
BD	-0.71	*
ECEC	0.55	*
Bsat	0.42	*
Alsat	-0.53	*
pH	0.58	**
OM	0.82	***

*** = significant at p = 0.001, *** = significant at p = 0.01,
* = significant at p = 0.05, NS = not significant

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These results indicate the role of organic matter, clay and pH in determining the quality of tropical soils. High positive significant correlation between SQMI and OM stresses the relevance of the latter in improving soil structure (47). Earlier, Scharpenseel and Miehlich (48) noted that OM relates to all forms of soil fertility-physical, chemical and biological. In soils of open dump sites, high SQMI and OM values were recorded and in these soils were the highest concentrations of heavy metals, suggesting possible complexation of these biotoxic metals by OM.

Table 10 shows different combinations of independent variables in SQMI modelling. Predictors in $SQMI_{(c)}$, namely ECEC, OM and sand gave the best relationship with minimal coefficient of alienation (1-r^2) value of 0.22, followed by predictors in $SQMI_{(f)}$ and $SQMI_{(a)}$ combinations with OM gave good predictions. These results further confirm the role of organic matter in tropical soil fertility and quality. Good relationships in $SQMI_{(a)}$ is indicative of the role of physical properties in soil quality determination while the highest prediction in SQMI reveals possibility of best soil qualities being achieved by considering both physical and chemical factors in the modelling.

TABLE 10: Regression models of SQMI and soil properties (n = 72)

Dependent variable	Model	r^2
$SQMI_{(a)}$	Y=30.09+0.26(clay)-0.43(sand)+4.21(silt)-0.21(BD)	0.58**
$SQMI_{(b)}$	Y=1.69+0.45(ECEC)+ 2.1(Bsat)-0.89+1.24(pH)	0.55*
$SQMI_{(c)}$	Y=3.68+1.26(ECEC)+2.88(OM)-0.38(sand)	0.78**
$SQMI^{(d)}$	Y=0.99+0.28(pH)-4.25(Alsat)	0.16^{NS}
$SQMI_{(e)}$	Y=29.25+1.22(clay)-3.21(OM)+0.82(ECEC)	0.46*
$SQMI_{(f)}$	Y=1.45+1.31(sand)-1.11(silt)+0.22(clay)+6.2(OM)	0.62**
$SQMI_{(g)}$	Y=0.96-0.26(silt)+2.26(CLAY)+0.33(OM)	0.56**
$SQMI_{(h)}$	Y=1.77+1.24(sand) +1.31(BD)-0.23(pH)	0.21^{NS}

**=significant at p =0.01, *=significant at p=0.05 NS= not significant.

Relationship between SQMI and heavy metals

Tables 11 and 12 represent relationships between SQMI and heavy metals. There were significant positive correlations between SQMI and copper (r=0.42; p=0.05; n=72) and cadmium (r=0.61; p=0.05; n=72).

TABLE 11: Correlation coefficients between SQMI and selected heavy metals (n = 30)

Heavy metal	Correlation coefficient (r)	Level of significance
Nickel	-0.32	NS
Vanadium	-0.28	NS
Copper	0.42	*
Cadmium	0.61	*

* = Significant at p=0.05, NS = not significant.

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TABLE 12: regression models of SQMI and heavy metals (n = 30)

Dependent variable	Model	r^2
$SQMI_{(1)}$	Y=0.45+0.26 (copper)	0.17
$SQMI_{(2)}$	Y=2.23-0.30(cadmium)	0.37
$SQMI(_{3)}$	Y=1.16+7.28(copper)-1.71 (cadmium)	0.41
$SQMI(_{4)}$	Y=1.03-1.14(Nickel)+2.18(vanadium)	
	-6.21(copper)-0.13 (c0.13(cadmium)	0.26

Conclusion

Soils of the study site varied in quality with least soil quality being recorded on the ranch (OB_3). Soil OM had tremendous impact on the soil quality although other soil properties especially clay, pH and bulk density contributed. Heavy metals were present in all sampled points but in greater proportion in dump sites. Soils with the best SQMI had the highest level of heavy metals concentration. Copper and cadmium increased with rise in SQMI values while the reverse was the case in Nickel and Vanadium.

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