ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov645

Impact of Anthropogenic Activities on the Physicochemical Properties of Soils in Some Selected Swamps in Kenema City, Eastern Sierra Leone

Human-Induced Changes in Swamp Soil Properties

Mamadu Bilal Bah[1]; Mark Fallah[2,3*]; Bockarie Momoh[1]

[1]Scienceworld Secondary School, Freetown, Sierra Leone
[2]Department of Medicine and Surgery, College of Medicine and Allied Health Sciences, University of Sierra Leone, Freetown, Sierra Leone
[3]Department of Nursing and Public Health, Maahad Aali College of Technology and Professional Courses, Freetown, Sierra Leone

Corresponding Author: Mark Fallah*

Publication Date: 2026/11/23

Abstract: Urban wetlands in Sierra Leone are cultivated intensively yet receive unregulated waste, and their soil response to these combined pressures remains undocumented. This study characterized residents' perceptions of swamp-based activities and the physicochemical status of cultivated soils in three inland valley swamps: Lekpetieh, Buwahun, and Kondebotihun, in Kenema City, Eastern Sierra Leone. Sixty residents (20 per swamp) completed a structured questionnaire, and nine composite soil samples (three per swamp; 0–20 cm depth) were analyzed for pH, electrical conductivity, texture, organic carbon, total nitrogen, available phosphorus, and exchangeable cations. Most respondents were female (63.3%) and aged 36–45 years (48.3%); all consumed swamp products despite widespread awareness of associated risks. Agriculture was the most recognized activity (95.0%), followed by open waste dumping (80.0%) and sand mining (63.3%). Respondents attributed soil pollution (96.6%), water pollution (100.0%), and soil erosion (94.4%) to these activities, yet simultaneously reported high yields (100.0%) and high-quality products (100.0%). Swamp water was used for laundering (96.7%), bathing (93.3%), and irrigation (91.7%) but rarely for drinking (11.0%). Soils were strongly acidic (pH 3.6–4.6 in KCl), sandy (70–75% sand), and low in soluble salts. Nutrient status was generally poor, with total nitrogen (0.15–0.28%), available phosphorus (6.8–8.3 mg/kg), and low exchangeable bases, whereas organic carbon was relatively high (2.9–3.2%). The swamps sustain livelihoods but carry environmental and health risks. Within the limits of the measured fertility parameters, nutrient depletion appears to be the principal constraint on productivity; however, because potentially toxic elements (e.g., Pb, Cd, Cr, Hg) were not analyzed, contaminant enrichment cannot be ruled out. Community sensitization, continued biomass return, and comprehensive monitoring of potentially toxic elements are recommended.

Keywords: *Anthropogenic Activities, Urban Swamp Soils, Soil Physicochemical Properties, Inland Valley Swamps.*

How to Cite: Mamadu Bilal Bah; Mark Fallah; Bockarie Momoh (2026) Impact of Anthropogenic Activities on the Physicochemical Properties of Soils in Some Selected Swamps in Kenema City, Eastern Sierra Leone. *International Journal of Innovative Science and Research Technology,* 11(11), 1115-1122. https://doi.org/10.38124/ijisrt/26nov645

I. INTRODUCTION

Around the world, people are moving to cities at an unprecedented rate; urban areas were already home to 54% of the global population in 2014. Cities occupy less than 2% of the Earth's land surface yet account for more than 80% of the world's urban and industrial waste, most of which is discharged, directly or indirectly, into surrounding soils and water bodies. Urban soils therefore carry a growing environmental load, and because their capacity to absorb and purify pollutants is finite, they can shift from being a sink to a source of contamination, with long-lasting consequences. The

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov645

physical, chemical, and biological alteration of soils by urbanization has accordingly drawn increasing attention since the 1990s [1]. Degraded urban soils not only lose their capacity to provide ecosystem services but also may compromise food safety, as research highlights potential health risks associated with crops grown in contaminated soils [2,3]. Recent work in urban Sierra Leone specifically shows that heavy metal concentrations in crop leaves and soil at urban and peri-urban farming sites can exceed regulatory limits [4,5]. Directly assessing such toxicological contamination, however, requires a comprehensive heavy metal suite (e.g., Pb, Cd, Cr, Hg); the present study focuses on the physicochemical fertility status of the soils, and the implications of this scope are addressed in the Discussion and Conclusion.

Rapid urbanization is nowhere more pronounced than in Sub-Saharan Africa, where it is fundamentally reshaping wetlands. Urban expansion, which is driven by population growth, economic development, infrastructure, and migration, has been linked to biodiversity loss, water quality degradation, altered hydrology, and the outright destruction of urban wetlands [6,7]. At the same time, urban agriculture has expanded into these same wetlands, because inland valley swamps combine relatively secure water retention with fertile soils that sustain vegetable and rice production for urban households [8]. Wetlands have thus become increasingly important for irrigated crop production across West Africa, particularly as upland soils decline in fertility [8]. This dual pressure, both agricultural use and simultaneous waste loading, makes urban swamps ecologically vulnerable: human activities such as waste dumping, settlement, sand mining, and small-scale industries are major drivers of wetland soil degradation [9], and waste deposition in particular can enrich soils with nutrients while also introducing potentially toxic elements above permissible limits for agricultural use [10].

These concerns are acute in Sierra Leone, where swamp soils are characteristically acidic, rich in organic matter, and highly moisture-retentive [11], and where the government has prioritized the intensification of inland valley swamp cultivation to boost rice production, the country's staple food. In Kenema City, the country's third most populous city, extensive urban swamps, notably at Lekpetieh, Buwahun, and Kondebotihun, are farmed for rice, vegetables, and potatoes, but are also used for waste disposal, sand mining, settlement expansion, car washing, and local soap and textile industries. Yet, to our knowledge, no documented study in Sierra Leone has assessed the actual impact of these anthropogenic activities on the physicochemical properties of urban swamp soils, despite growing concern. It should be noted that the physicochemical assessment reported here addresses soil health and fertility, that is, acidity, salinity, organic carbon, and macro- and micronutrient status, rather than contamination in the toxicological sense, the evaluation of which requires a heavy metal suite not covered in this study; this distinction is important for interpreting the findings. Evidence from elsewhere on the continent cannot substitute for local data, because the physicochemical response of soils to anthropogenic inputs is site-specific [12].

This study therefore departs from existing practice by combining a socioeconomic assessment of residents' perceptions with the physicochemical analysis of soils in the three selected urban swamps of Kenema City. Specifically, the study aimed to determine the demographic characteristics of residents living around the swamps, identify the predominant anthropogenic activities, and determine the physical and chemical properties of the swamp soils. In doing so, it provides the first empirical baseline on the impact of human activities on urban swamp soils in Kenema City and generates evidence to guide urban planners, the Ministry of Agriculture, and environmental regulators in protecting these productive yet vulnerable landscapes.

II. MATERIALS AND METHODS

➢ *Study Area and Site Selection*

The study was conducted in Kenema District, Eastern Province, Sierra Leone, where three urban inland valley swamps; Lekpetieh, Buwahun, and Kondebotihun, were selected because they are among the most intensively cultivated swamps in the city and the most exposed to anthropogenic activities. Site selection followed two criteria: agricultural potential and proximity to residential areas.

➢ *Study Design*

The study was conducted in two stages. The first was an analytical phase involving environmental media sampling, sample preparation, and laboratory determination of soil physicochemical properties. The second was a descriptive cross-sectional survey of residents' knowledge, attitudes, and perceptions of the swamps, combining a structured questionnaire, on-the-ground observation, and unstructured interviews. The two-tier design was intended to triangulate residents' perceptions against quantitative soil data, since socioeconomic information alone is insufficient to characterize environmental problems [13].

➢ *Study Population and Sampling*

The study population comprised adult residents (aged 18 years and above) living within the catchment areas of the three selected swamps, with one respondent per household. A total of 60 respondents were interviewed, with 20 questionnaires administered in each of the three swamp sections to ensure equal representation across sections and to minimize selection bias. This sample size reflects the descriptive aims of the survey and the small, geographically defined catchment population, consistent with guidance that sample adequacy should be judged against the population and design of the study [14].

➢ *Research Instrument and Data Collection*

A standardized, structured questionnaire was used. The questionnaire was validated by 5 experts from the Department of Chemistry, and Public Health, Njala University. Section A covered respondents' demographic characteristics; Sections B and C covered the principal livelihood and income-generating activities in the area, including activities carried out in or near the swamps (agriculture, waste dumping, sand mining, and waste types); and the remaining sections assessed knowledge, attitudes, and behaviour regarding anthropogenic activity,

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov645

swamp utilization, water use, and health and sanitation. Questionnaires were administered face-to-face in one-on-one interviews over a six-week period in 2022, with the researcher guiding each respondent and recording answers; one questionnaire was completed per interviewee. Interviews were conducted in English and the local language.

➢ *Survey Data Analysis*

Survey responses were entered into the Statistical Package for the Social Sciences (SPSS, version 16.0) and summarized as frequencies, percentages, tables, and charts using Microsoft Office Excel.

➢ *Soil Sampling and Preparation*

Soil samples were collected from the three swamps at nine sampling points (three per swamp, representing the upper, middle, and lower reaches; coordinates recorded with a Garmin GPSMAP eTrex 10 handheld receiver). Different agricultural land-use types, rice, vegetable, and potato, were identified in each swamp. At each sampling point, samples were taken at the boundaries and in the center of the cultivated area to a depth of 20 cm and composited into a single sample. Land-use history was established through field observations and interviews with local farmers. Samples were placed in labeled polythene bags [10], transported to the laboratory, air-dried, crushed, and passed through a 2 mm sieve before analysis, following standard preparation for the determination of physicochemical properties in wetland soils [8].

➢ *Soil Physicochemical Analyses*

Soil reaction (pH): Ten grams of air-dried (2 mm) soil was weighed into a cup, 10 mL of distilled water was added, and the mixture was stirred thoroughly for 30 s. The suspension was allowed to stand for 30 min at 20–25 °C, and pH was read with a pH meter after 30–60 s, following the standard water-suspension procedure for soil pH [9]. Soil pH was also measured in 1 M KCl using the same protocol to estimate exchangeable acidity.

Electrical conductivity and texture. EC was measured with a conductivity meter [8], and texture (sand, silt, and clay) was determined by sedimentation using a hydrometer.

Exchangeable cations (K, Ca, and Mg): Exchangeable potassium, calcium, and magnesium were extracted with 1 N ammonium acetate: 5 g of air-dried (2 mm) soil was placed in a 50 mL extraction vessel, 25 mL of 1 N ammonium acetate was added, and the mixture was shaken on a reciprocating shaker for 5 min at 150 rpm, centrifuged for 5 min, and filtered; cations in the filtrate were determined with a flame photometer [9].

Total nitrogen: Total nitrogen was determined by the Kjeldahl digestion and distillation procedure: 1.0 g of soil and 10 mL of distilled water were placed in a Kjeldahl flask with 0.7 g of copper sulfate, 1.5 g of potassium sulfate, and 30 mL of concentrated sulfuric acid; the mixture was digested gently at 150 °C and then at 300 °C until clear, cooled, and made up with 50 mL of deionized water. The digest was distilled with 25 mL of 0.05 M H_2SO_4, 30 mL of 10 M NaOH, and 0.2 g of Devarda's alloy; after approximately 30 min of distillation, the distillate was titrated with 0.1 M NaOH [8].

Available phosphorus: Available P was determined by the Bray-1 method: 2 g of soil was extracted with 14 mL of extraction solution in a 125 mL conical flask and filtered; 3 mL of the filtrate was mixed with 3 mL of the combined colour reagent in a test tube, allowed to stand for approximately 30 min, and measured with a spectrophotometer [8].

Organic carbon. Organic carbon was determined by the Walkley–Black dichromate oxidation method: 0.5 g of air-dried (2 mm) soil was digested with potassium dichromate and concentrated sulfuric acid in a 500 mL conical flask, 50 mL of deionized water was added, and, after cooling, the excess dichromate was titrated with ferrous ammonium sulfate [8].

Available iron and zinc were determined using the DTPA-extraction method. Ten grams of air-dried (2 mm) soil was extracted with 20 mL of DTPA solution in a 125 mL conical flask, shaken for 15 min at 180 rpm, and filtered through Whatman 42 filter paper; iron and zinc in the filtrate were determined by EDTA titration, and results were reported as DTPA-extractable "available" values.

Exchangeable aluminium. Exchangeable acidity and aluminium were determined by 1 N KCl extraction: 10 g of air-dried (2 mm) soil was extracted with 25 mL of 1.0 N KCl in a 100 mL beaker, stirred, allowed to stand for 30 min, and filtered; the soil was leached with 10 aliquots of 10 mL of 1 N KCl to a total volume of 125 mL. The filtrate was titrated with 0.1 N NaOH using phenolphthalein to the first permanent pink endpoint to determine exchangeable acidity; 10 mL of 1 N KF was then added and the solution titrated with 0.1 N HCl to determine exchangeable aluminium.

Analytical scope. The analytical suite was deliberately restricted to fertility-related parameters, namely pH, electrical conductivity, texture, organic carbon, total nitrogen, available phosphorus, exchangeable cations, and DTPA-extractable iron and zinc. Potentially toxic elements such as lead, cadmium, chromium, and mercury were not determined, because the primary objective of the study was a fertility-oriented physicochemical baseline of the swamp soils. This omission is a recognized limitation, and its implications for interpreting the findings are stated explicitly in the Discussion and Conclusion.

➢ *Laboratory Data Analysis*

Laboratory data were entered into Microsoft Office Excel. Descriptive statistics, means and coefficients of variation, were computed. Swamp means were compared using analysis of variance at $p = 0.05$, following standard practice for the statistical evaluation of wetland soil data [9]. Where significant differences were detected, pairwise mean separation was performed using the Bonferroni post-hoc procedure, which controls the family-wise Type I error rate, and means were ranked in ascending order with alphabetical notations. Figures were produced with GraphPad Prism.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov645

➢ *Ethical Considerations*

Before each interview, respondents were informed that: all data would be treated with strict confidentiality; they could withdraw at any point; they could decline to answer any question; their names would not appear in any report unless they expressly requested otherwise; the data would be used primarily for academic research, with recommendations shared with relevant stakeholders; and no compensation would be provided for participation. Informed consent was obtained from all participants, both in writing and verbally. Ethical approval was waived by the ethical committee of Njala University as no sensitive information was collected.

III. RESULTS AND DISCUSSIONS

➢ *Demographic Characteristics of Respondents*

The demographic profile of the 60 respondents is summarized in Table 1. Females constituted 63.3% of the sample. Most respondents (48.3%) were aged 36–45 years, followed by those aged 26–35 years (26.7%) and above 45 years (25.0%). Formal education was widespread: 26.7% had attained secondary level, 23.3% tertiary, 18.3% technical/vocational, and 16.7% primary, while only 3.3% had no formal education. With respect to religion, Muslims made up 63.3% of respondents.

Table 1 Demographic Characteristics of Respondents (n = 60)

Variable	Category	Frequency	Percent
Age (years)	26–35	16	26.7
	36–45	29	48.3
	Above 45	15	25
	Total	60	100
Sex	Male	22	36.7
	Female	38	63.3
	Total	60	100
Education	None	2	3.3
	Primary	10	16.7
	Secondary	16	26.7
	Technical/vocational	11	18.3
	Tertiary	14	23.3
	Quranic	7	11.7
	Total	60	100
Religion	Christianity	22	36.7
	Islam	38	63.3
	Total	60	100

The predominance of female respondents is consistent with the national census of Sierra Leone, which recorded more females than males, while the youthful profile of the sample echoes the country's demographic structure, in which people under 35 years accounted for 80% of the national population in the 2015 census [15]. The low proportion of tertiary-educated respondents may be attributable to high early-stage school dropout rates [16].

➢ *Anthropogenic Activities and Swamp Utilization*

Respondents' awareness of the activities carried out in the swamps is shown in Figure 1. Almost all respondents (95%) confirmed that the swamps are used for agriculture, 80% confirmed open waste dumping, and 63.3% confirmed sand mining, although 29.3% were unaware of sand mining. The swamps are thus utilized for multiple purposes simultaneously, and the intensity of concurrent uses indicates considerable anthropogenic influence on these ecosystems.

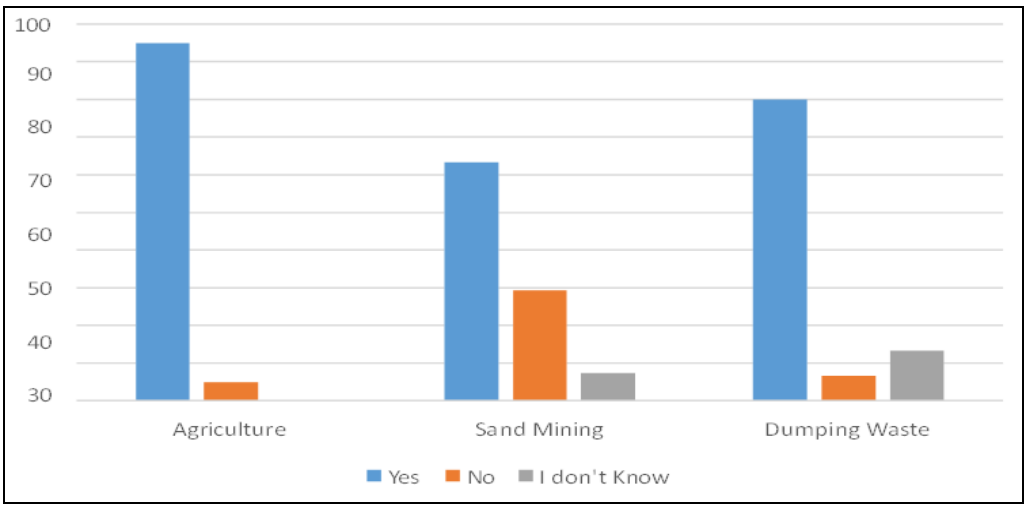

Fig 1 Respondents' Awareness of Activities Carried out on the Swamps.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov645

These activities carry risks to humans and the environment. When asked to identify specific effects, respondents overwhelmingly associated the activities with soil pollution (96.6%), water pollution (100.0%), air pollution (100.0%), and soil erosion (93.4%). Interestingly, all respondents simultaneously attributed high yields (100.0%) and high-quality products (100.0%) to the same activities, reflecting a dual perception of the swamps as both a livelihood asset and an environmental hazard. The widespread practice of dumping, in particular, is known to alter soil nutrient status and introduce potentially toxic elements into cultivated soils [10]. It should be emphasized, however, that benchmarking these perceived risks against empirical thresholds, such as the WHO/FAO maximum permissible limits for soil and vegetables, was not possible in this study because potentially toxic elements were not analyzed; such benchmarking is recommended once heavy metal data become available.

Table 2 Respondents' Perceptions of the Effects of Anthropogenic Activities on the Inland Valley Swamps (%)

Statement	Yes	No
Soil pollution	96.6	3.4
Water pollution	100	0
Air pollution	100	0
Soil erosion	94.4	5.6
High-quality products	100	0
High yields	100	0

➢ *Utilization of Swamp Water Resources*

Responses on the uses of swamp water are summarized in Figure 2. Water from the swamps is generally not used for drinking; only 11% of respondents reported using it for that purpose, while the majority indicated that they did not know whether it was potable. In contrast, the water is widely used for laundering (96.7%), bathing (93.3%), and irrigation (91.7%). The dominant domestic and agricultural uses of swamp water, combined with its rejection as a drinking source, suggest that residents already perceive the water as compromised, a perception consistent with the pollution burden they attribute to the swamps.

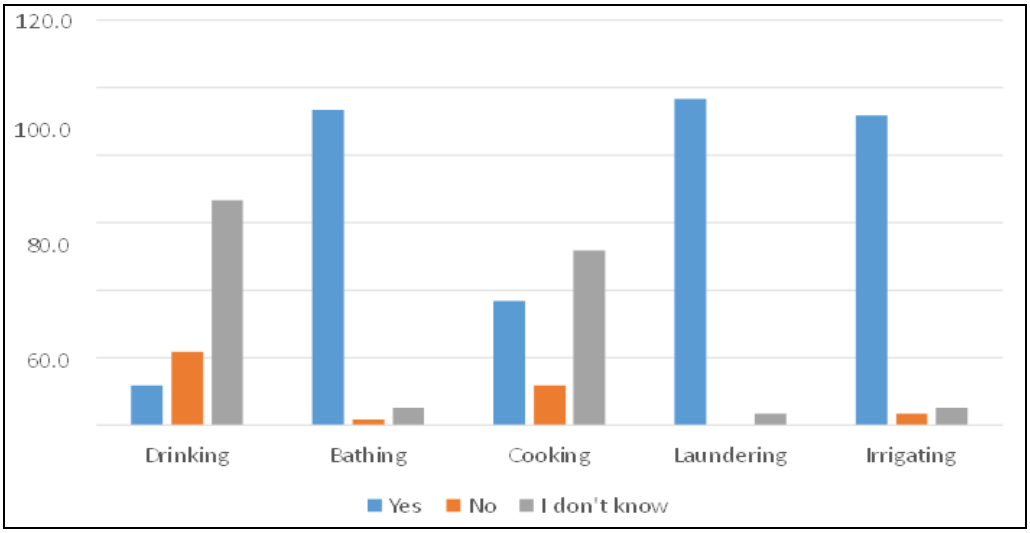

Fig 2 Respondent Response on the of Swamp Water

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➢ *Soil Physical Properties*

The physical properties of the soils are presented in Table 3. Soil reaction in potassium chloride ranged from pH 3.6 at Buwahun to pH 4.6 at Kondebotihun, while pH measured in water was identical (5.1) across all sampling sites. The soils are therefore strongly acidic throughout. This acidity is consistent with the accumulation of organic acids such as carbonic acid, an end product of organic matter decomposition [17], and with the tropical climate, high rainfall, and acidic parent materials typical of the region [18]. Acidic swamp soils have likewise been reported elsewhere in Sierra Leone [11], and the strongly acidic reaction observed here is consistent with the leached, highly weathered inland valley soils of West Africa generally, for which a mean pH of 5.3 has been reported across the region [19], as well as with

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov645

strongly acidic conditions (pH ≈ 4.9) documented at urban sites within the sub-region [20]. Notably, this contrasts with the alkaline reaction (pH 7.6–9.1) commonly recorded in the urban soils of temperate cities such as Szeged, Hungary [21]; the comparison underscores the site-specificity of urban soil chemistry, which is best judged against tropical rather than temperate baselines.

Electrical conductivity was low, ranging from 12 µS/cm at Kondebotihun to 14.2 µS/cm at Lekpetieh, with no significant difference among swamps, reflecting the low quantities of soluble salts in the soils. Texturally, all soils were sandy (70–75% sand), with low silt (10–12%) and clay (14–17%) contents, consistent with the coarse-fragment enrichment and fine-fraction depletion commonly associated with disturbed urban soils [22].

Table 3 Physical Properties of Soils from the three Swamps

Location	pH	pH (H_2O)	EC (µS/cm)	Sand (%)	Silt (%)	Clay (%)
Lekpetieh	3.8	5.1	14.2	75	11	14
Buwahun	3.6	5.1	13.5	70	12	17
Kondebotihun	4.6	5.1	12	75	10	15

EC = electrical conductivity

➢ *Soil Chemical Properties*

The chemical properties of the soil samples are summarized in Table 4. In general, the soils were poor in all macronutrients. Total nitrogen ranged from 0.15% at Lekpetieh to 0.28% at Kondebotihun. Nitrogen losses are minimal under the anoxic conditions of the swamps compared with upland ecologies, since mineralization proceeds slowly via anaerobic pathways [23]. Available phosphorus ranged from 6.8 mg/kg at Buwahun to 8.3 mg/kg at Kondebotihun; these low values likely result from phosphorus fixation by the alumino-silicate clays that predominate in Sierra Leonean soils [24], and are consistent with contemporary evidence that African cropland soils show among the highest rates of phosphorus depletion globally, largely owing to limited fertilizer inputs [25]. Potassium (0.026–0.028 cmol/100 g), calcium (0.29-0.42 cmol/100 g), and magnesium (0.18-0.32 cmol/100 g) exhibited similar low values.

Table 4 Chemical Properties of Soils from the three Swamps

Location	Nitrogen (%)	Phosphorus (mg/kg)	Potassium (cmol/100 g)	Carbon (%)	Calcium (cmol/100 g)	Magnesium (cmol/100 g)
Lekpetieh	0.15	7.2	0.028	3.2	0.32	0.3
Buwahun	0.19	6.8	0.026	2.9	0.29	0.32
Kondebotihun	0.28	8.3	0.028	3.1	0.42	0.18

In contrast to the macronutrients, organic carbon was relatively high (2.9–3.2%) at all locations, attributable to organic matter accumulation under anoxic conditions, where microbial decomposition is extremely slow [26]. This indicates that the studied swamps currently function as carbon sinks. The overall pattern, low nutrient status with elevated organic carbon, is characteristic of waterlogged wetland soils and mirrors the fertility profile reported for other West African valley-bottom swamps [27], while more recent assessments of inland valley agriculture in the sub-region likewise emphasize that production remains limited by biophysical constraints and management practices [28]. Taken together, the results indicate that poverty of the soils in available nutrients is the principal constraint on productivity evident from the measured fertility parameters. However, because potentially toxic elements (e.g., Pb, Cd, Cr, Hg) were not analyzed, the possibility of contaminant enrichment cannot be excluded: studies of urban agriculture and dumpsite soils across West Africa, including Freetown, frequently report metal concentrations at or above regulatory limits [4,5], and tropical dumpsite soils have been shown to exceed safe thresholds for elements such as cadmium and lead [29,30]. The present findings should therefore be interpreted as a physicochemical fertility assessment, not as evidence of the absence of toxic contamination.

IV. CONCLUSION

Residents of the three swamps are highly knowledgeable about the inland valley swamps and the activities carried out in them; most are long-term adult residents, well educated (more than 80% had some schooling, with females representing over 60% of respondents), and primarily engaged in agriculture with petty trading as the main alternative income. Respondents are aware that dumping and other activities harm the environment and their livelihoods, yet swamp water remains widely used for domestic purposes, though not for drinking. Physicochemical analysis showed the soils are generally poor in nutrients, with organic carbon as the notable exception, even though parameter values were still higher than those typical of most upland soils in Sierra Leone. It must be stressed that, because the analytical suite focused on macro- and micronutrients, the current dataset cannot confirm or refute toxic contamination of the soils; the finding that nutrient depletion constrains productivity should therefore not be read as evidence that contaminant enrichment is absent. This is a significant limitation of the study design, and it is particularly relevant given that urban cropping and dumpsite soils elsewhere in Sierra Leone and West Africa have been shown to exceed regulatory limits for some heavy metals. Relevant authorities should sensitize residents on the hazards of polluted inland valley swamps; the practice of

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26nov645

returning biomass to the swamps should be continued to build fertility and reduce element toxicity while the dumping of toxic wastes is discouraged; and further studies should prioritize a comprehensive heavy metal suite (e.g., Pb, Cd, Cr, Hg) in the soils, crops, and water of the study area, benchmarked against WHO/FAO permissible limits, alongside objective water-quality assessment.

ACKNOWLEDGMENT

We give special thanks to Publish4Impact Sierra Leone and the Sierra Leone Clinical and Biosciences Reserachers for their unwavering support for this work. Additionally, the authors thank the local community members for their invaluable cooperation during the soil sampling and data collection process.

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