

DISTRIBUTION OF MICROPLASTIC CONTAMINANTS IN THE SOIL ENVIRONMENT OF SOME RURAL COMMUNITIES IN BOKKOS LOCAL GOVERNMENT AREA, PLATEAU STATE, NIGERIA

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Microplastic contamination of soils poses an emerging threat to soil function and food security, yet data from rural, smallholder-farming regions of north-central Nigeria remain scarce. This study assessed the abundance and aerial distribution of microplastics in soils across three land-use types, farmland, residential areas, and roadsides, in seven rural communities of Chikam, Kuba, Kunet, Mai Katako, Mbar, Ndar, and Tadin of Bokkos Local Government Area, Plateau State, Nigeria. Composite topsoil samples (0–15 cm) were processed by density separation and peroxide digestion, and microplastic particles were enumerated and expressed as particles per kilogram of dry soil. Microplastics were detected in all twenty-one composite samples, with mean abundances of $16,690 \pm 20,391$, $24,039 \pm 18,943$, and $15,126 \pm 14,647$ particles kg^{-1} in farmland, residential, and roadside soils, respectively, with the wide magnitude of the standard deviation indicative of the heterogeneous distribution of microplastics among the land use types. A one-way ANOVA indicated no significant differences in abundance among land-use types ($p = 0.626$), whereas community identity was the dominant source of variability, with the community of Ndar alone contributing 42.2% of the cumulative regional burden. A source-proximity gradient analysis showed a strong, statistically significant correlation between farmland and roadside abundance ($r = 0.988$, $p < .001$) and a significant linear relationship between a composite proximal-source index (residential and roadside soils) and distal farmland abundance ($R^2 = 0.812$, $p = 0.006$), suggesting substantial transport of microplastics from settlement and road corridors into adjoining cultivated land. These results indicate that rural agricultural soils in Plateau State are measurably and spatially linked to nearby anthropogenic plastic sources, which may have implications for soil health.

Keywords: microplastics, agricultural soil, spatial distribution, source-proximity gradient

1.0 Introduction

Society's failure to understand how plastics degrade soil and human health has created a vicious cycle. Because the public remains unaware of these long-term impacts, manufacturers face no pressure to stop producing mass quantities of plastic household shopping bags, which eventually litter the environment (Auta, et al., 2026). This lack of awareness extends to rural agriculture. Local farmers frequently view plastic gathered from dump sites as biochemically inert, leading them to dump plastic waste across active farmlands without restriction or monitoring (Ubong et al., 2025). This widespread ignorance of environmental chemistry has escalated soil contamination from a localized nuisance into a severe ecological crisis across most rural settlements (UNEP, 2021). Without functional waste management systems, plastic deposits continue to accumulate at an exponential rate (Ekwe et al., 2024).

The core threat of plastic lies in its durability. Over extended periods, physical fragmentation, ultraviolet (UV) radiation, mechanical weathering, and microbial action break large plastic items down into smaller fragments (Willmer, 2023). This degradation yields microplastics (MPs)—particles smaller than 5 mm that accumulate rapidly in agricultural ground, where soils retain them at rates up to 23 times higher than in marine environments (UNEP, 2021).

In developing nations like Nigeria, backyard waste burning, open dumping, and discarded single-use low-density polyethylene (LDPE) water sachets drive the microplastic crisis (Alichio et al., 2026). The Bokkos Local Government Area (LGA) is particularly vulnerable to this pollution due to its intense focus on producing crops like Irish potatoes, maize, and vegetables. Because these rural communities lack sanitary landfills and formal recycling programs, residents rely entirely on open-air dumpsites. Consequently, local soils face direct, continuous exposure to microplastics. The contamination spreads through indiscriminate dumping, the use of municipal solid waste as fertilizer, the degradation of agricultural films, and the use of polluted streams and ponds for dry-season irrigation. Once in the ground, microplastic debris physically disrupts the soil matrix. It lowers water-holding capacities, alters bulk density, reduces structural stability, and skews essential nutrient cycles, creating hostile conditions for vital soil organisms (Sajjad et al., 2022). Despite these clear hazards, researchers have not yet gathered baseline data on the abundance, polymer types, and spatial distribution of microplastics in Bokkos. Without a formal soil assessment, structural soil damage, declining crop yields, and the risk of toxins entering the human food chain will remain unaddressed.

2.0 Materials and Methods

2.1 Study Area

This study took place in Bokkos Local Government Area (LGA), Plateau State, north-central Nigeria. The area is a rural agrarian zone situated on the Jos Plateau, characterized by smallholder crop farming, scattered residential settlements, and a network of untarred and semi-tarred roads connecting remote communities to local markets. We purposefully selected seven communities that accurately reflect the LGA's overall settlement and land-use patterns: Chikam, Kuba, Kunet, Mai Katako, Mbar, Ndar, and Tadin. These sites capture the region's primary land-use mosaic—specifically active farmlands, residential compounds, and roadside corridors. These three zones serve as the main human interfaces where plastic debris enters the local environment.

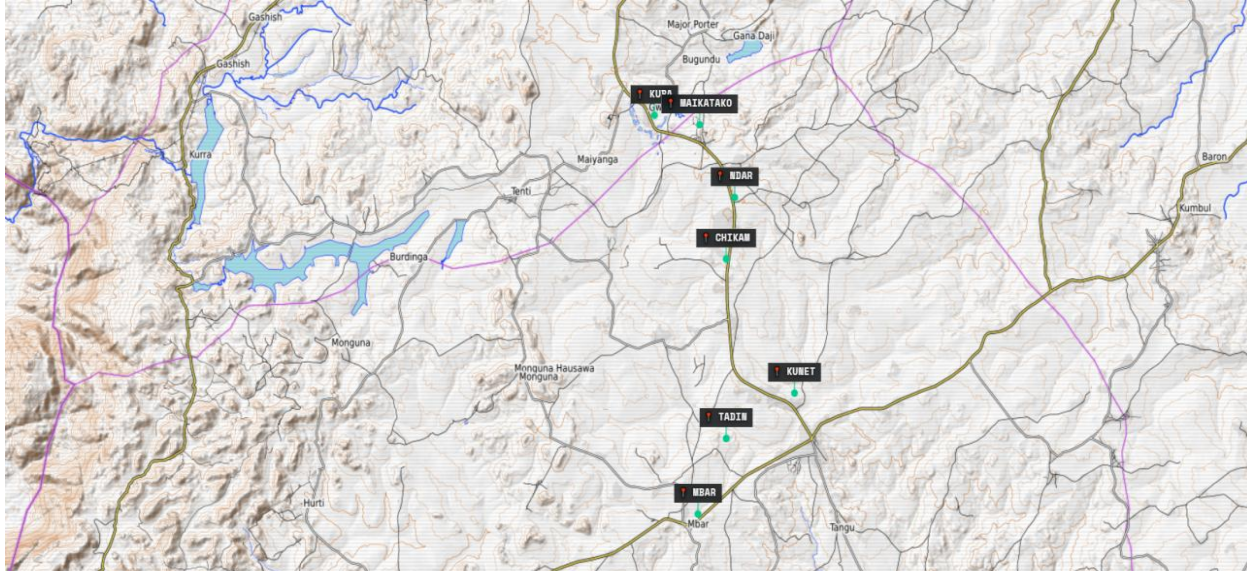


Figure 1. Map of the rural communities studied in Bokkos LGA, Plateau State

2.2 Sample Collection

Field teams collected surface soil samples from a depth of 0–5 cm using a stainless-steel auger. At each sampling location, we scooped 500 g of soil into clean, labeled paper envelopes for transport to the laboratory. To facilitate spatial analysis and mapping of microplastic distribution, we recorded the geographical coordinates of every sampling point using a handheld GPS device. Once in the lab, the soil samples were air-dried at room temperature and passed through a 2 mm mesh sieve to remove stones and large organic debris. The sieved soil was then stored in airtight glass jars prior to analysis.

2.3 Microplastic Extraction and Quantification

To isolate microplastics from the sieved soil fractions, we used density separation in a saturated saline solution following the protocol outlined by Scopetani et al. (2020), followed by wet peroxide oxidation to digest any remaining organic matter. The resulting floating fraction was vacuum-filtered onto gridded filter paper. We then examined the filters under a stereomicroscope to visually identify suspected microplastic particles based on established morphological criteria. Finally, we weighed the dried filter paper and calculated particle concentration using the following formula:

$$\text{Microplastic abundance (particles/kg)} = \frac{\text{Number of microplastic particles}}{\text{Weight of dry soil(kg)}}$$

2.4 Statistical and Spatial Analysis

We calculated descriptive statistics to summarize microplastic abundance across the seven communities, categorized by land-use type. To evaluate differences in microplastic abundance among the three land-use categories, we applied both a parametric one-way analysis of variance (ANOVA) and a non-parametric Kruskal–Wallis H-test. We also used Pearson correlation coefficients to examine pairwise associations between land-use categories, testing whether microplastic levels in one zone co-varied with levels in another across the study sites.

A source-proximity gradient analysis helped characterize the spatial distribution of the contamination relative to its likely entry points. We designated residential and roadside soils as proximal (near) anthropogenic source zones, given their direct exposure to domestic waste, burning residues, and traffic emissions. Conversely, farmland soils served as distal (distant) receptor environments, which sit further from direct inputs and rely on secondary transport mechanisms like surface runoff, wind deposition, and agricultural turning. All statistical operations were executed in Python 3 using NumPy and SciPy (v1.x) libraries with a significance threshold of $\alpha=0.05$. All figures were generated using Matplotlib.

3.0 Results and Discussion

3.1 Statistical Evaluation of Land Use

A one-way ANOVA revealed no statistically significant difference in mean microplastic abundance among the three land-

use types, $F(2,18) = 0.48$, $p = .626$. Non-parametric testing supported this outcome: the Kruskal–Wallis test yielded $H = 1.55$, $p = .462$, while the community-blocked Friedman test showed $\chi^2 = 2.00$, $p = .368$. At the LGA scale, these numbers indicate that land-use category alone does not dictate microplastic loading. Instead, localized, community-level factors appear to drive contamination intensity far more than specific land-use divisions.

The spatial distribution of microplastic contamination relative to its likely point(s) of introduction was characterised using a source-proximity gradient analysis. Residential and roadside soils were treated as proximal anthropogenic source zones because they directly receive domestic waste handling, burning residues, and traffic-derived particulate inputs, whereas farmland soils were treated as distal receptor environments situated further from these direct inputs and subject to secondary transport via runoff, aeolian deposition, and agricultural redistribution. All statistical analyses were performed on Python 3 using the NumPy and SciPy (v1.x) libraries, with a significance threshold of $\alpha = 0.05$; figures were generated using Matplotlib.

3.1.1 Microplastic Abundance across Communities and Land-use Types

Microplastic particles were detected in all twenty-one composite soil samples, confirming widespread contamination across the study area irrespective of land-use type or community, and these values are presented in Table 1.

Table 1. Mean Microplastic abundance (particles kg^{-1} dry soil) across farmland, residential, and roadside soils in seven communities of Bokkos LGA.

Land-use Type	Chikam	Kuba	Kunet	Mai Katako	Mbar	Ndar	Tadin
Farmland	5,170	8,880	8,750	10,740	8,890	62,700	11,700
Residential	10,260	16,070	10,500	38,820	35,820	54,100	2,700
Roadside	11,290	9,320	6,130	9,770	9,770	48,100	11,500

The distribution of the microplastics across the seven communities showed Ndar Community to have the highest particles in all the soil types, followed by Maikatako and Mbar. The mean microplastic abundance spread was highest in residential soils ($24,039 \pm 18,943$ particles kg^{-1}), followed by farmland ($16,690 \pm 20,391$ particles kg^{-1}) and roadside soils ($15,126 \pm 14,647$ particles kg^{-1}). On a cumulative basis, residential land use accounted for the largest proportion of the total microplastic burden recorded across the study area (43.0%), compared with farmland (29.9%) and roadsides (27.1%). All three land-use types exhibited very high coefficients of variation (79–122%), indicating substantial inter-community heterogeneity that exceeded the variability attributable to land-use type alone.

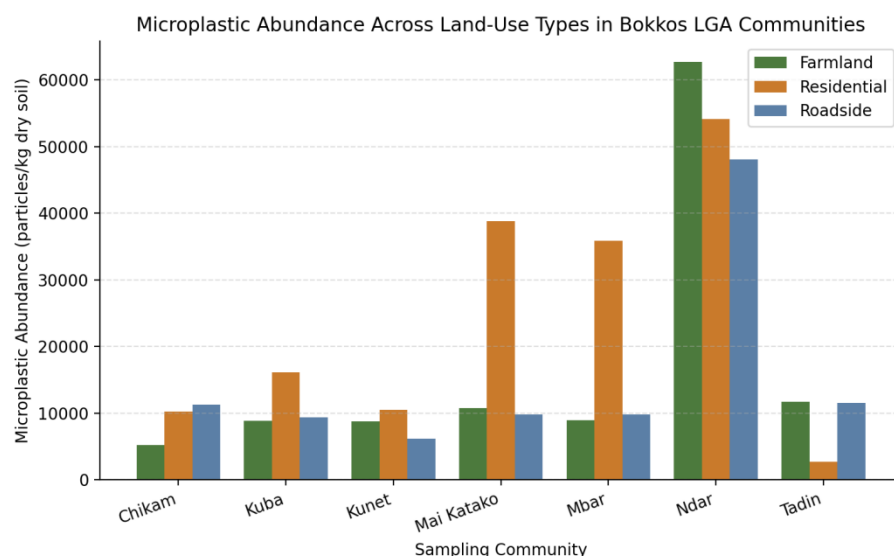


Figure 2. Microplastic abundance (particles kg^{-1}) across farmland, residential, and roadside soils in the seven sampled communities of Bokkos LGA.

A one-way ANOVA found no statistically significant difference in mean abundance among the three land-use types ($F(2,18) = 0.48$, $p = .626$). This result was corroborated by the non-parametric Kruskal–Wallis test ($H = 1.55$, $p = .462$) and the community-blocked Friedman test ($\chi^2 = 2.00$, $p = .368$), indicating that, at the LGA scale, land-use category alone was not a strong determinant of microplastic loading; instead, contamination intensity was driven predominantly by community-level factors rather than by land-use type.

The microplastic levels recorded across these Bokkos LGA communities range from 2,700 to 62,700 particles kg^{-1} across all three land-use types, placing them in the upper tier of values reported for global agricultural and rural soils. For context, Büks and Kaupenjohann (2020) analyzed 23 global soil studies and identified a median concentration of 1,076 particles kg^{-1} , with most agricultural and horticultural sites tracking below 13,000 particles kg^{-1} . The average farmland abundance in this study—16,690 particles kg^{-1} —surpasses that common agricultural benchmark, though it remains well below the extreme global maximum of 690,000 particles kg^{-1} identified in the same report. Similarly, En-Nejmy et al. (2024) compiled data from 62 global sites and found abundances ranging wildly from 0 to 3,573,000 particles kg^{-1} . This wide variation emphasizes that soil microplastic loads are highly site-specific. They depend on local waste management, settlement proximity, and specific agricultural inputs rather than any universal baseline.

Comparable microplastic data remain scarce within Nigeria. The country's north-central geopolitical zone is especially under-represented, as most regional research focuses on aquatic systems rather than terrestrial or atmospheric matrices (Emole et al., 2026). However, researchers have documented roadside soil contamination in other parts of the country. Mgbemena et al. (2024), for example, found heavy microplastic loads along major road corridors in Rivers State (Port Harcourt and Elele), blaming tire abrasion, littering, and broken waste management systems—a source profile that matches the roadside contamination found in Bokkos. This study expands on those findings by demonstrating, for the first time in Plateau State, that roadside and settlement-derived plastics do not stay confined to their immediate source zones. Instead, they are statistically linked to elevated contamination in neighboring farmland soils.

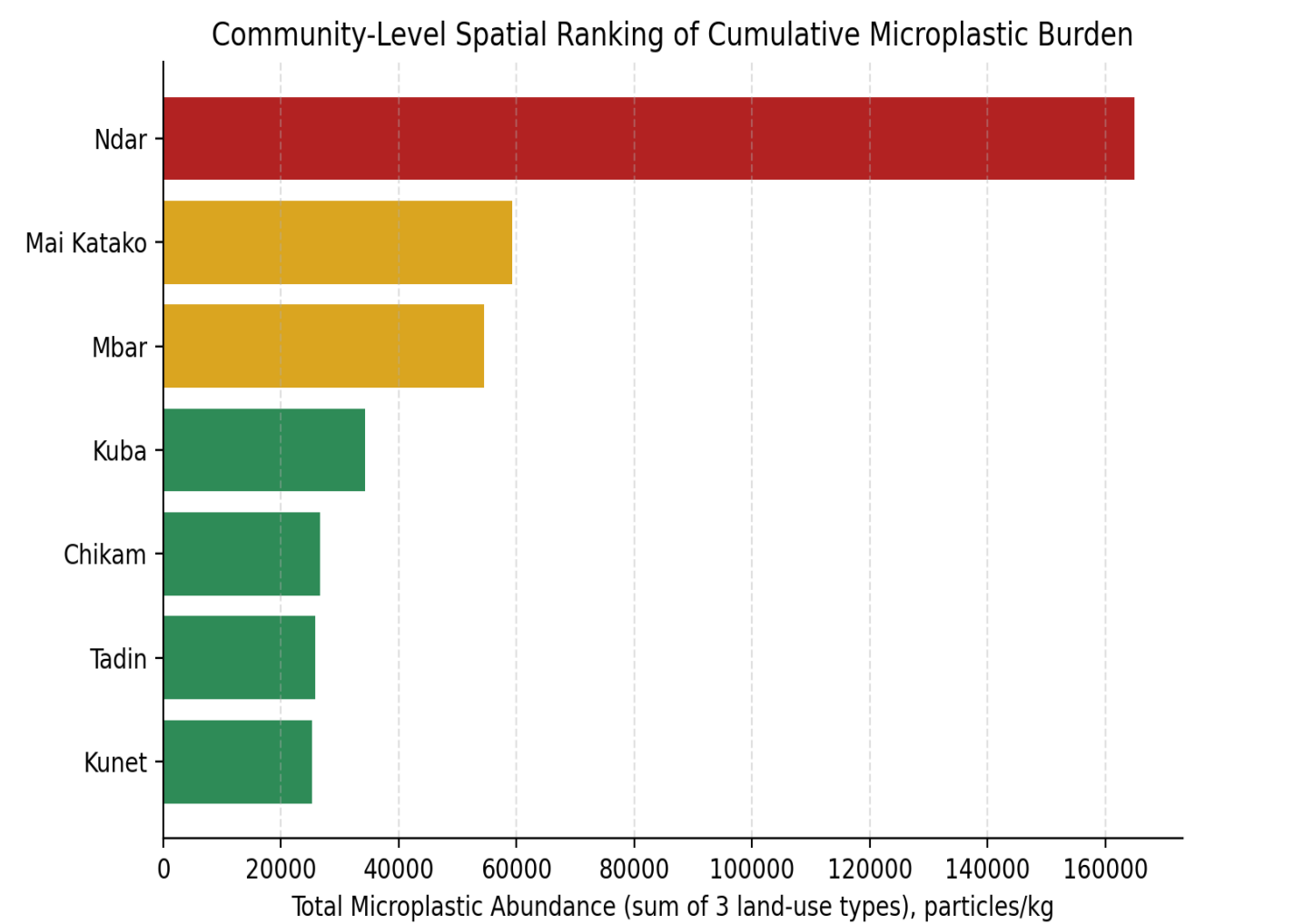


Figure 3. Community-level spatial ranking of cumulative microplastic burden (sum of farmland, residential, and roadside abundances) across Bokkos LGA.

3.1.2 Spatial Distribution and Hotspots

Cumulatively, the microplastic burden varied more than six-fold across the study area, ranging from 25,380 particles kg⁻¹ in Kunet to 164,900 particles kg⁻¹ in Ndar. Ndar alone accounted for 42.2% of the total microplastic load collected across all seven communities and land-use types combined (390,980 particles kg⁻¹), establishing it as a definitive contamination hotspot. Mai Katako (59,330 particles kg⁻¹; 15.2% of total) and Mbar (54,480 particles kg⁻¹; 13.9%) formed a secondary tier of moderately elevated contamination. Meanwhile, Chikam, Kunet, and Tadin recorded low, broadly uniform cumulative burdens ranging from 25,380 to 26,720 particles kg⁻¹.

3.1.3 Source-Proximity Gradient Analysis

Pearson correlation analysis revealed a strong, significant positive association between farmland and roadside microplastic abundance across the seven communities ($r = 0.988$, $p < 0.001$). This indicates that farmland soils near communities with heavy roadside pollution are themselves disproportionately contaminated. Conversely, the link between farmland and residential abundance did not reach statistical significance ($r = 0.707$, $p = 0.076$), and the correlation between residential and roadside abundance was similarly non-significant ($r = 0.689$, $p = 0.087$). This distinction suggests that residential inputs follow a contamination pathway separate from the farmland–roadside transport system. Combining residential and roadside abundances into a single proximal-source index yielded a highly significant linear relationship when regressed against distal-receptor farmland abundance:

Farmland = 1.19xProximal-Source Index - 6,585

This model ($R^2 = 0.812$, $p = 0.006$) indicates the contribution of residential and roadside sources to proximal anthropogenic contamination and shows that roughly 81% of the variance in farmland microplastic loading is from these sources (Hopke,

2016). This strong relationship aligns with a source-to-receptor transport gradient, where microplastics deposited near roads and settlements progressively migrate into adjoining cultivated soils.

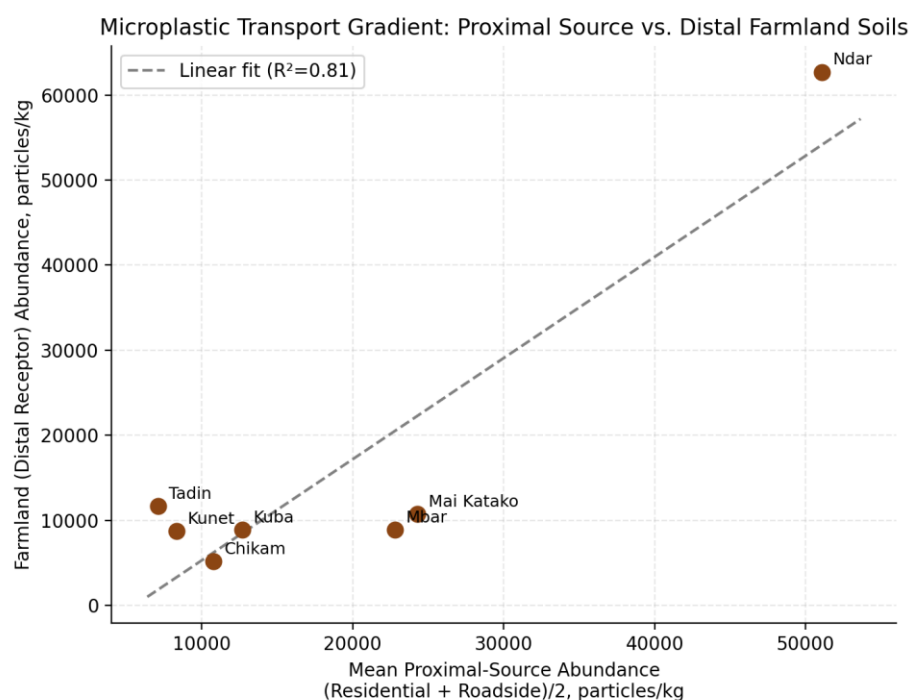


Fig. 4: Source-proximity transport gradient showing the relationship between proximal anthropogenic source abundance (mean of residential and roadside soils) and distal farmland microplastic abundance across seven communities in Bokkos LGA.

Figure 4 illustrates this source-proximity transport gradient, charting the relationship between proximal anthropogenic source abundance and distal farmland microplastic levels across the seven communities in Bokkos LGA. The ordinary least-squares linear fit is represented by the dashed line ($R^2 = 0.81$, $p = .006$). The absence of an overall land-use effect, paired with strong community-level clustering and significant regression results, indicates that plastic pollution in Bokkos LGA is dictated by a community's total exposure to plastic inputs rather than land-use classification. These contaminants disperse across adjacent land zones through shared local transport mechanisms. The tight farmland–roadside correlation ($r = 0.988$) points to known near-road transport pathways. These include wind-driven re-suspension of tire and litter fragments, rainy-season surface runoff washing roadside debris into adjacent fields, and the physical turning of soil through informal roadside farming and plowing. Weber et al. (2022) demonstrated a similar pattern in a longitudinal study of agricultural fields, showing that microplastics from a defined point source become redistributed across a farming landscape over time via tillage and erosion.

In contrast, the weaker, non-significant correlations involving residential zones suggest that domestic waste—derived from backyard burning, dumping, and degrading household items—remains spatially confined. Because this domestic waste follows a more localized deposition pattern, it does not consistently co-vary with wider roadside or farmland loads across the LGA. This difference is vital for mitigation: while roadside microplastics act as a mobile, diffuse contaminant that threatens distant cultivated soils, residential pollution represents isolated point sources requiring targeted, community-specific waste management.

Finding microplastics in every single farmland sample has serious implications for Bokkos LGA, where smallholder farming is the primary livelihood and food source. Agricultural soil plastic accumulation is known to damage soil structure, disrupt microbial communities, and reduce crop yields, threatening food security in affected ecosystems (En-Nejmy et al., 2024). Because the sampled soils are actively cultivated, this clear source-to-receptor pathway from settlements into fields raises real concerns about microplastic uptake into food crops. This potential dietary exposure risk for local populations requires immediate empirical investigation through crop and produce sampling.

Ndar stands out as a severe spatial outlier, contributing nearly half (42.2%) of the entire study's microplastic burden. This massive deviation suggests a localized, community-specific driver rather than a regional trend. It likely stems from proximity to an unmanaged dumpsite, a bustling local market generating heavy packaging waste, or highly concentrated informal trash burning. Because Ndar's high plastic concentrations occurred uniformly across its farmlands, residential areas, and roadsides, the pattern reflects a community-wide point source. This outlier effect also explains the high coefficients of variation (79–122%) seen across all three land-use categories, proving that researchers must report community-level statistics alongside aggregate means to prevent localized hotspots from skewing the broader data.

4.0 Conclusion

This study quantified microplastic abundance using visual stereomicroscopic counting after density separation and peroxide digestion. While this aligns with common screening protocols in Nigerian microplastic research, visual identification cannot confirm polymer types and can lead to misclassifying ambiguous particles. Future studies should use attenuated total reflectance Fourier-transform infrared (ATR-FTIR) spectroscopy to validate particle identities, determine polymer compositions, and track sources more accurately.

Additionally, because this assessment looked only at soil, it cannot confirm whether microplastics have moved into local drinking water or crops. Given the source-to-receptor gradient identified here, testing soil, groundwater, surface water,

and local food crops together is the next logical step to map human exposure risks in rural Plateau State. Finally, this cross-sectional study captured only a single snapshot in time. Repeated seasonal sampling is highly recommended to determine how the agricultural calendar and weather patterns alter this microplastic transport gradient over the course of the year.

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