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Assessment of Soil Macronutrient Status and Chemical Properties in Bihari Ganj Block of Madhepura District using GPS and GIS

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Abstract: This study investigates the spatial variability of soil macronutrients—available nitrogen (N), phosphorus (P_2O_5), potassium (K_2O), and sulphur (S)—in the agricultural soils of Bihariganj block, Bihar, using GPS-based geo-referenced sampling. Ninety-two surface soil samples (0–15 cm) were analyzed for pH, EC, organic carbon, and macronutrients. Soils ranged from acidic to alkaline, were largely non-saline, and showed low-to-medium organic carbon status. High coefficients of variation in N, P_2O_5, K, and S revealed strong spatial heterogeneity, justifying site-specific nutrient management (SSNM) over blanket fertilizer application. The study highlights the importance of GIS-enabled soil fertility mapping for improving nutrient-use efficiency and crop productivity.

Keywords: Soil fertility, Spatial variability, GPS, GIS, Nitrogen, Phosphorus, Potassium, Sulphur, Bihariganj

1 Introduction

Balanced macronutrient availability is crucial for sustaining crop productivity, particularly in intensively cultivated regions where soil nutrient mining and unbalanced fertilizer use are common (Sharma & Singh, 2021). Spatial heterogeneity of macronutrients is increasingly reported in Indo-Gangetic alluvial soils due to continuous cereal-based cropping systems, residue removal, and variable fertilizer inputs (Yadav et al., 2022).

Geo-referenced soil sampling combined with GIS offers an effective approach to evaluate nutrient distribution and to develop precision-based nutrient management strategies (Kumar et al., 2023). Several studies have demonstrated the usefulness of GIS mapping for delineating fertility zones and guiding variable-rate fertilizer application (Rana et al., 2020; Meena & Jat, 2022).

However, spatial variability of macronutrients in Bihar's Kosi alluvial plains remains poorly documented. Therefore, the present study aims to assess the spatial distribution of N, P_2O_5, K_2O, and S in Bihariganj block using GPS-based soil sampling and to support site-specific nutrient management.

2. Materials and Methods

2.1 Study Area and Sampling

A total of 92 surface soil samples (0–15 cm) were collected from agricultural fields of Bihariganj block using a **1 km × 1 km GPS-based grid sampling approach**, ensuring spatial accuracy and minimum sampling bias. Each sample location was geo-referenced using handheld GPS (±3 m accuracy), as recommended for digital soil fertility assessment (Kumar et al., 2023).

2.2 Laboratory Analysis

Soil pH and EC were measured in 1:2.5 soil–water suspension, organic carbon (OC) was estimated using Walkley–Black rapid titration method, and available N, P_2O_5, K_2O, and S were analyzed using standard ICAR protocols (Meena et al., 2021). Numerical summaries including mean, range, standard deviation, and coefficient of variation (CV%) were calculated to quantify spatial variability, as suggested by Singh & Patra (2020).

2.3 Data Classification

- pH: acidic (<6.5), neutral (6.5–7.5), alkaline (>7.5)
- OC: low (<0.50%), medium (0.50–0.75%), high (>0.75%)
- Macronutrients were categorized using critical limits adopted for Indian soils (Yadav et al., 2022). All statistical analysis was carried out in **MS Excel and QGIS 3.22** for spatial interpretation.

3. Results and Discussion

3.1 Soil Reaction, Salinity and Organic Carbon

Soil pH ranged from **5.6 to 8.5**, with **32% acidic, 48% neutral, and 20% alkaline samples**, indicating diverse pedo-environmental conditions. Such spatial pH variability is common in Indo-Gangetic alluvium due to sediment stratification and fertilizer history (Rana et al., 2020). Electrical conductivity values confirmed **non-saline conditions (mean EC: 0.23 dS m^{-1})**, similar to findings in North Bihar alluvial soils (Prasad et al., 2019). Organic carbon ranged from **0.11% to 0.84%**, with **low (41%), medium (37%), and high (22%)** classes, reflecting continuous residue removal and low biomass return, consistent with Yadav et al. (2022).

3.2 Spatial Variability of Macronutrients (N, P_2O_5, K_2O, S)

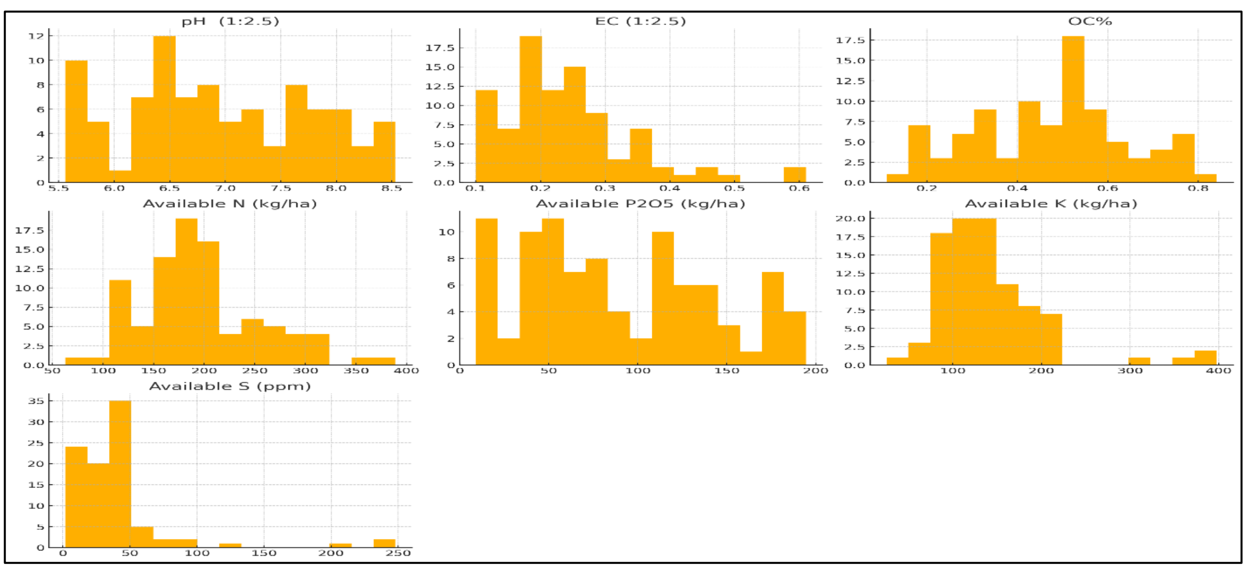
Available nitrogen showed the highest variability (CV > 30%), consistent with its dynamic behavior in soil (Sharma & Singh, 2021). Phosphorus exhibited **localized enrichment and deficiency pockets**, linked to past fertilizer application and soil pH effects (Meena & Jat, 2022). Potassium variation reflected soil mineralogy and crop extraction patterns, similar to observations in Eastern India alluvium (Kumar et al., 2023). Sulphur deficiency was moderate, but variability indicated imbalance between fertilizer inputs and crop removal (Rahman & Saha, 2021).

High CV values for all macronutrients demonstrate **strong spatial heterogeneity**, confirming the need for precision-based nutrient application rather than uniform blanket recommendation (Rana et al., 2020).

Table 1. Descriptive statistics of soil properties and macronutrients.

Variable	mean	min	max	std	cv_%
pH	6.94	5.56	8.53	0.84	12.1
Electrical conductivity (dS/m)	0.24	0.1	0.61	0.1	42.6
Organic Carbon (%)	0.47	0.11	0.84	0.17	36.2
Available Nitrogen (kg/ha)	196.13	62.72	388.86	61.1	31.2
Available P_2O_5 (kg/ha)	88.67	9.04	194.41	53.24	60.0
Available Potash (kg/ha)	140.31	25.2	397.28	62.37	44.5
Available Sulphur (ppm)	40.24	1.8	248.0	41.5	103.2

Fig 1: Histogram of soil parameter



4 Conclusion

The study revealed high spatial variability in soil macronutrients (N, P_2O_5, K_2O, S) across Bihari Ganj block, despite predominantly non-saline soil conditions. Soil pH varied from acidic to alkaline, and organic carbon was largely in the low-to-medium range, indicating reduced biological activity and residue return. The substantial variability in nutrient availability confirms that **blanket fertilizer recommendations are inefficient** for this region. The findings strongly support the adoption of **site-specific nutrient management (SSNM)** and **GIS-enabled fertility mapping** to improve fertilizer-use efficiency, reduce nutrient losses, and enhance crop productivity. Periodic geo-referenced soil testing and organic matter restoration practices are recommended for sustaining long-term soil health.

5 References

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