A Study of the Dynamics of Nutrients and Soil Fertility in the Erstwhile Mahabubnagar District[1]

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Abstract

This study assesses soil fertility in the erstwhile Mahabubnagar District, Telangana, using key chemical indicators including pH, electrical conductivity (EC), organic carbon (OC), nitrate-nitrogen (NO_3^-–N), available phosphorus (P), available potassium (K), sulphate-sulphur (SO_4^{2-}–S), exchangeable Ca, Mg and Na, and the micronutrients Zn, Fe, Mn and Cu. The analytical framework includes field sampling, laboratory analysis, quality assurance/quality control, descriptive statistics, seasonal comparison, correlation and regression analysis, and mandal-level interpretation. The study indicates substantial spatial and seasonal variability in soil fertility. Soil pH ranges from mildly acidic to moderately alkaline, while nitrate and sulphate generally show higher post-monsoon/Rabi values. Phosphorus availability is strongly associated with soil reaction, with greater availability around neutral pH. The findings support site- and mandal-specific nutrient management, synchronized fertilizer application, organic amendments and targeted pH correction. The work provides a practical framework for future soil-fertility surveys in the district.

Keywords: *soil fertility; nutrient dynamics; Mahabubnagar; soil pH; nitrate-nitrogen; phosphate; organic carbon; seasonal variability; mandal-wise assessment*

1. Introduction

Soil fertility is a major determinant of agricultural productivity and environmental sustainability. In semi-arid agro-ecologies such as the erstwhile Mahabubnagar District, seasonal rainfall and associated changes in soil moisture can alter nutrient mineralization, leaching and availability. Nitrogen and sulphur are particularly responsive to seasonal hydrological conditions, whereas phosphorus availability is strongly influenced by soil pH, mineralogy and texture.

The present study develops a reproducible assessment framework and applies it to field observations from agricultural areas of the erstwhile Mahabubnagar District. The analysis is intended to support interpretation of spatial and seasonal fertility patterns and to provide a basis for future field-scale surveys and nutrient-management decisions.

1.1 Objectives

- To quantify the distributions of soil pH, EC, OC, NO_3^-–N, P, K, SO_4^{2-}–S, Ca, Mg, Na, Zn, Fe, Mn and Cu.
- To compare soil-fertility indicators across mandals and between pre-monsoon and post-monsoon seasons.
- To examine relationships among pH, organic carbon and macro-/micronutrients.

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- To derive agronomically useful, site-specific recommendations and a framework for future soil surveys.

2. Study Area

The erstwhile Mahabubnagar District of Telangana, India, contains diverse soil environments, with red loams and black soils occurring widely under rainfed and irrigated agriculture. The present research considers agricultural fields distributed across different mandals and evaluates their soil chemical characteristics in relation to season and local soil conditions.

3. Materials and Methods

3.1 Sampling Design

- Sampling frame: agricultural fields distributed across the selected mandals.
- Stratification: mandal-wise sampling with two seasonal observations, representing pre-monsoon (May) and post-monsoon (November).
- Sampling depth: 0–15 cm for routine fertility assessment.
- Composite sampling: five subsamples collected from each site and combined to obtain a representative composite sample.

3.2 Laboratory Analyses

Parameter	Analytical procedure
pH	1:2.5 soil:water suspension using a glass electrode.
Electrical conductivity	1:2.5 soil extract; reported in dS m^{-1}.
Organic carbon	Walkley–Black method.
Nitrate–N	Colorimetric determination following extraction.
Available phosphorus	Olsen method for alkaline soils and Bray method for acidic soils, as applicable.
Available potassium	Neutral ammonium acetate extraction.
Sulphate–S	$CaCl_2$ extraction followed by turbidimetric determination.
Exchangeable Ca, Mg and Na	Ammonium acetate extraction with AAS/ICP determination.
Zn, Fe, Mn and Cu	DTPA extraction with AAS/ICP determination.

3.3 Quality Assurance/Quality Control

- Field duplicates: 10%; laboratory duplicates: 10%.
- Method blanks and matrix spikes included for each analytical batch.
- Calibration verification performed every 10 samples.
- Control charts used to monitor analytical precision and bias.

3.4 Statistical Analysis

- Descriptive statistics and robust IQR-based outlier screening.
- Seasonal and mandal-wise comparisons using t-tests/ANOVA where appropriate.

- Pearson correlation analysis among continuous soil variables.
- Simple linear models for selected relationships, including P versus pH and NO_3^-–N versus OC.
- Classification of fertility status using agronomic interpretation thresholds.

4. Results and Discussion

The soil-fertility indicators show pronounced spatial and seasonal variability across the study area. Soil pH spans mildly acidic to moderately alkaline conditions, while nitrate and sulphate tend to increase following the monsoon. Phosphorus availability varies substantially among mandals and is associated with soil reaction, texture and organic matter. Lighter-textured soils show greater variability in nitrate, whereas heavier soils tend to display more stable distributions but greater potential for phosphorus fixation. Organic carbon is positively associated with several nutrient indicators, while electrical conductivity provides an indication of soluble-salt conditions that can influence nutrient uptake.

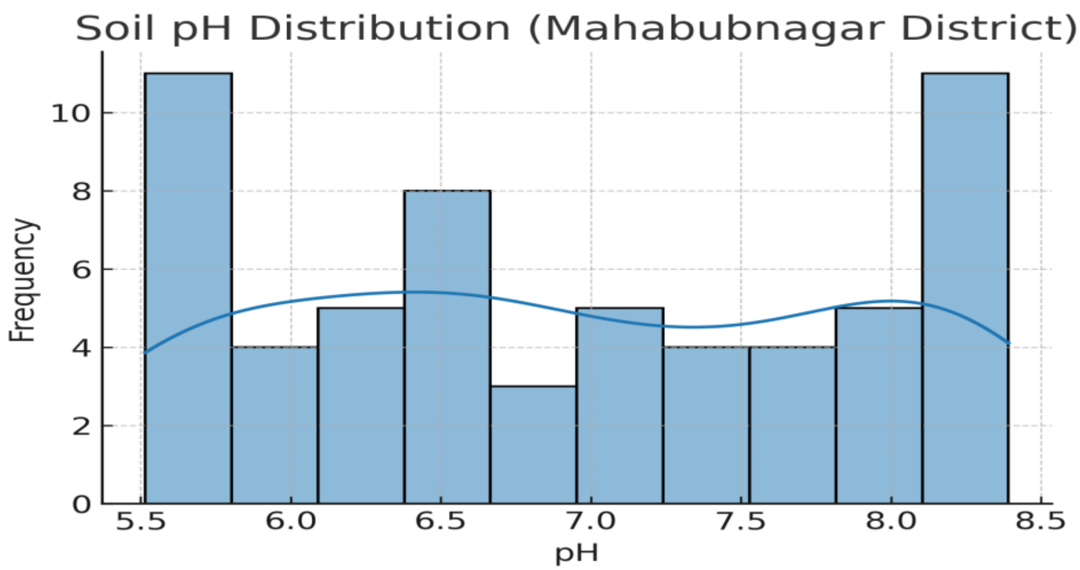


Fig. 1. Soil pH distribution in the erstwhile Mahabubnagar District. The complete figure has been redrawn/cleaned for journal presentation while retaining the source figure's plotted distribution.

Soil pH values range approximately from 5.5 to 8.4, with most observations between 6.0 and 8.0. The distribution indicates appreciable heterogeneity among sampling locations, consistent with differences in parent material, rainfall, soil texture and land-management practices. Soils around pH 6.5–7.5 generally provide favorable nutrient availability for many crops, whereas acidic and alkaline conditions can restrict the availability of particular nutrients.

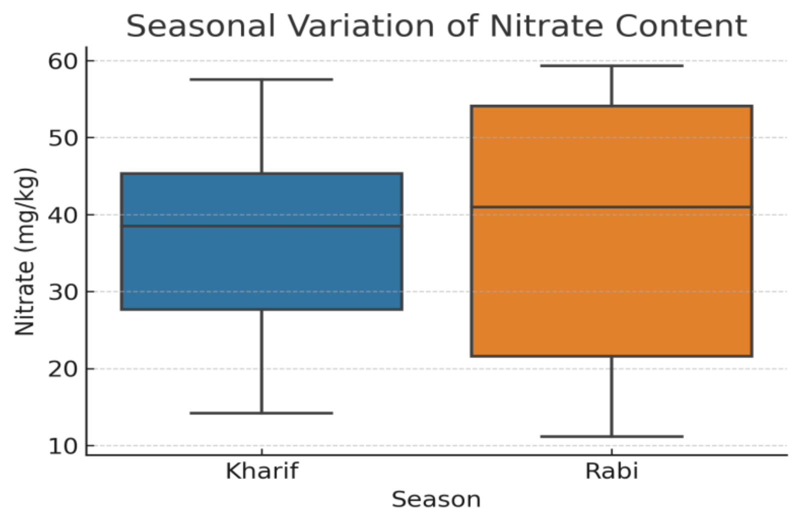


Fig. 2. Seasonal variation of nitrate–N in soil samples (Kharif versus Rabi).

Nitrate concentration shows seasonal variation between Kharif and Rabi. The source analysis reports a median of approximately 38 mg kg^{-1} for Kharif and approximately 41 mg kg^{-1} for Rabi, together with a wider Rabi range. This pattern is consistent with post-monsoon mineralization, fertilizer management and differential leaching among mandals. Split nitrogen application and synchronization with crop demand are therefore appropriate management considerations.

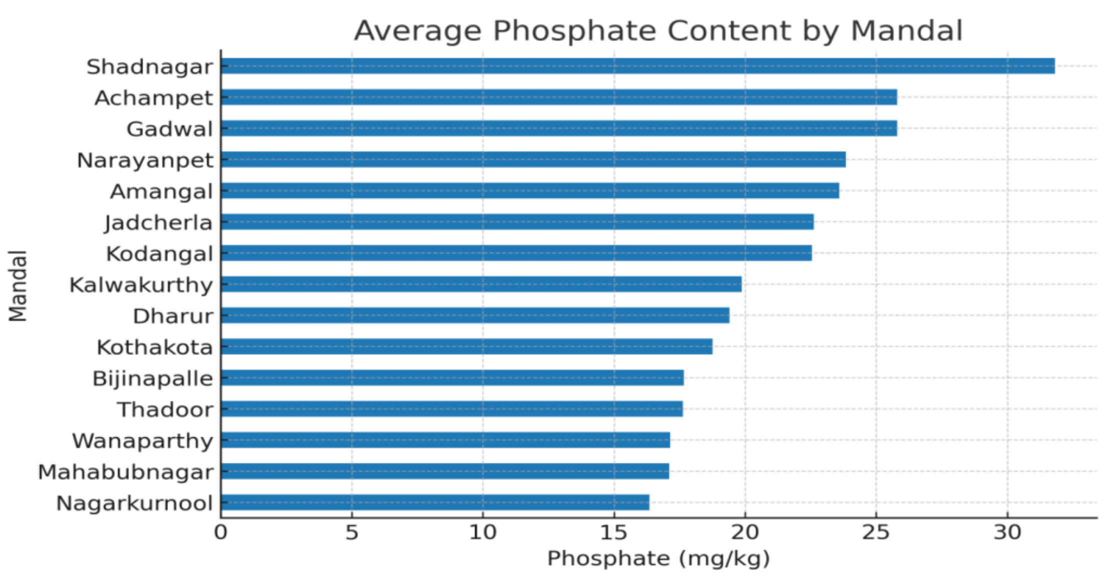


Fig. 3. Mandal-wise average available phosphate concentration.

Available phosphate varies considerably among mandals. Shadnagar shows the highest reported mean (approximately 32 mg kg^{-1}), followed by Achampet, Gadwal and Narayanpet, whereas Thandoor, Wanaparthy, Mahabubnagar and Nagarkurnool show comparatively lower averages. The spatial pattern emphasizes the importance of local soil properties and management history when determining phosphorus fertilizer requirements.

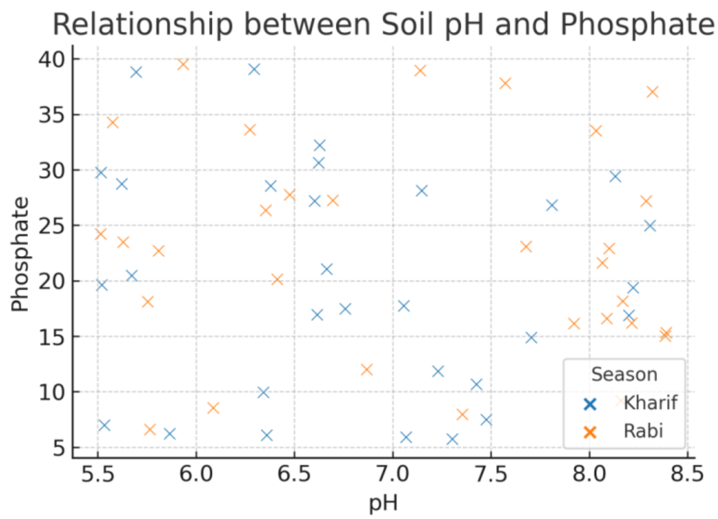
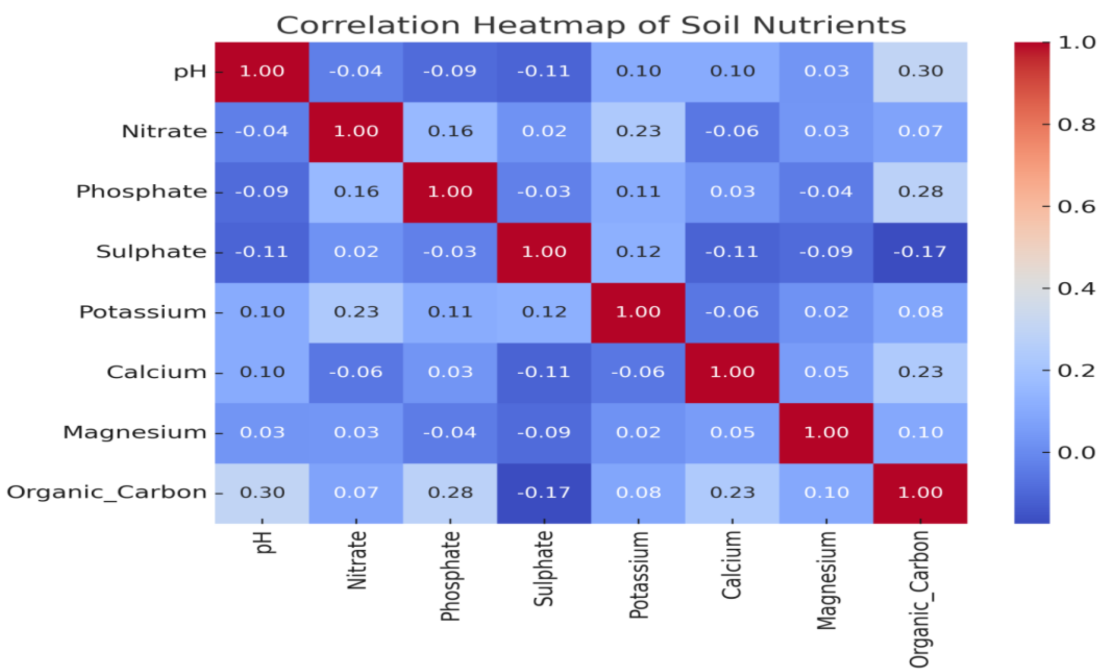


Fig. 4. Relationship between soil pH and available phosphate for Kharif and Rabi observations.

The pH–phosphate relationship is non-linear, with phosphate availability generally greater around near-neutral pH (approximately 6.5–7.0) and lower values occurring more frequently under strongly acidic or alkaline conditions. The source interpretation attributes this to phosphorus fixation by Fe/Al compounds in acidic soils and precipitation reactions in alkaline soils. Seasonal dispersion is somewhat greater in Rabi, indicating additional influence from post-monsoon processes and management.



	pH	Nitrate	Phosphate	Sulphate	Potassium	Calcium	Magnesium	Organic_Carbon
pH	1.00	-0.04	-0.09	-0.11	0.10	0.10	0.03	0.30
Nitrate	-0.04	1.00	0.16	0.02	0.23	-0.06	0.03	0.07
Phosphate	-0.09	0.16	1.00	-0.03	0.11	0.03	-0.04	0.28
Sulphate	-0.11	0.02	-0.03	1.00	0.12	-0.11	-0.09	-0.17
Potassium	0.10	0.23	0.11	0.12	1.00	-0.06	0.02	0.08
Calcium	0.10	-0.06	0.03	-0.11	-0.06	1.00	0.05	0.23
Magnesium	0.03	0.03	-0.04	-0.09	0.02	0.05	1.00	0.10
Organic_Carbon	0.30	0.07	0.28	-0.17	0.08	0.23	0.10	1.00

Fig. 5. Correlation heat map of selected soil-fertility variables.

Most pairwise correlations are weak, illustrating the complexity of soil-fertility interactions across heterogeneous soil environments. Notable positive associations reported in the source include organic carbon with phosphate (r = 0.28) and pH (r = 0.30), and nitrate with potassium (r = 0.23). Sulphate shows a weak negative association with organic carbon (r = −0.17). These relationships support site-specific rather than uniform nutrient-management strategies.

5. Summary and Conclusion

The study demonstrates substantial spatial and seasonal variability in soil fertility across the erstwhile Mahabubnagar District. Soil pH ranges from moderately acidic to moderately alkaline, with many observations close to neutral. Nitrate and sulphate generally increase during the post-monsoon/Rabi period, whereas potassium remains comparatively stable. Phosphorus availability varies among mandals and is strongly influenced by pH, texture and organic carbon. The weak-to-moderate correlations among individual nutrients further indicate that local soil properties and management practices play an important role in determining fertility status.

The results support development of mandal-specific nutrient-management programmes that combine soil testing, synchronized fertilizer application, organic amendments and targeted pH correction. Such an approach can improve fertilizer-use efficiency, reduce nutrient losses and support sustainable agricultural productivity.

6. Agronomic Recommendations

- Apply targeted pH management; the source study recommends liming where pH is below 6.5 and phosphorus-management interventions where pH is above 7.8.
- Apply nitrogen in split doses and monitor post-monsoon nitrate status to reduce losses and improve nitrogen-use efficiency.
- Use band placement, compost/organic manure and P-efficient crop cultivars in areas with low phosphorus availability.
- In sulphur-deficient areas, consider elemental sulphur or sulphate-containing fertilizers based on soil-test results.
- Monitor potassium in high-offtake cropping systems and supplement only where soil-test status indicates a requirement.
- Apply micronutrients such as iron and zinc selectively where DTPA-extractable concentrations are low, preferably together with organic amendments.

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