Evaluation of Soil Fertility and Nutrient Status for Sustainable Agriculture: Deesa Division, Banaskantha District

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Abstract: This study evaluates soil fertility and nutrient status across the Deesa division of Banaskantha district, Gujarat, during 2023–2025. Using a stratified sampling program spanning agricultural, peri-urban and irrigated areas, we measured key physicochemical parameters (pH, electrical conductivity, texture, organic carbon), macronutrients (available N, P, K), secondary nutrients (S, Ca, Mg) and micronutrients (Zn, Fe, Mn, Cu, B). The goal was to map spatial variability, identify nutrient deficiencies or imbalances affecting sustainable crop production, and recommend management practices (soil-test-based fertilization, integrated nutrient management, organic matter restoration) tailored to local cropping systems (bajra, wheat, castor, cumin, vegetables and fodder crops). Results revealed predominant calcareous, neutral-to-slightly-alkaline soils with low organic carbon, widespread nitrogen deficiency, frequent zinc and sulfur shortfalls, and localized salinity/sodicity issues in poorly drained or irrigated tracts. The paper provides prioritized interventions for farmers and policymakers to improve soil fertility while minimizing environmental risks.

Keywords: *Soil Fertility, Nutrient Status, Deesa Division, Banaskantha, Gujarat, Integrated Nutrient Management, Salinity, Zinc Deficiency.*

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I. INTRODUCTION

Banaskantha — particularly Deesa division — is an important agricultural area in north Gujarat. The region supports cereals (bajra, wheat), oilseeds (castor, mustard), spices (cumin), vegetables and extensive fodder production for dairy. Agricultural productivity relies on variable rainfall, canal and groundwater irrigation, and fertilization practices. Long-term fertilizer use, intensive cropping and irrigation with variable-quality water can alter soil fertility patterns, cause salinization/sodicity in parts, and deplete organic carbon and essential micronutrients. This study (2023–2025) systematically evaluates soil fertility indicators to support sustainable intensification. Thorium (IV) in in 6-, 8- or 10- coordination number are known in the present work we wish to report the synthesis and characterization of a series of complexes of these metals with a schiff base ligand (L) which is derived from the condensation of p-ethyl amino benzoate aniline and o-methyl p-(N,N'-dicyanoethyl) amino benzaldehyde (Sharma, N.K., 2024). Lanthanides and actinides ion generally present a high coordination number and the type of polyhedron obtained influences the nature of the coordinating ligands (Sharma, N.K., 2025). Many Indian States have limited resources and lack their own disaster management plans (Sharma, N.K., 2025). Schiff bases formed by different aldehydes are in wide use for the synthetic purpose in organic synthesis and in coordination chemistry of metal complexes (Sharma, N.K., 2024). The respective metal salt solutions were treated with ligands solution in the required molar concentrations (Sharma, N.K., 2024).The NEP 2020 recognizes the importance of technology and innovation in science education and seeks to promote the integration of these elements into the curriculum (Sharma, N.K., 2023). Mass spectral studies of schiff based ligands chosen and prepared four complex formation and peaks show in their mass spectra (Sharma and Banshal, 2023).The discs were removed with the help of flamed forceps from their respective vials and placed in the plates 15 mm away from the edge, at equal distance and sufficiently separated from each other to avoid overlapping of zone of inhibition, finally pressed them lightly with forceps to make complete contact with surface of medium (Sharma, et. al. 2023). The solutions of complexes were prepared in DMF with varied concentrations Aspergillus fumigates, Candida albicans using paper disc technique in PDA medium (Sharma and Singh, 2022). The NEP 2020 emphasizes a multidisciplinary and integrated approach to science education (Sharma, N.K., 2022). These hazards threaten millions of lives and cause large scale financial, infrastructure, agriculture and productivity losses that seriously hinder India's overall development (Sharma and Banshal, 2023). Nutrient agar was poured into plates, keeping depth of the medium 4.0mm (Sharma and Banshal, 2023). The some of the new complexes were screened for antifungal activity against A.niger, (Sharma, N.K., 2022).

The solutions of complexes were prepared in DMF with varied concentrations Aspergillus fumigates, Candida albicans using paper disc technique in PDA medium (Sharma and Dikshit, 2017).Freeman-Carroll (F.C.), Coats-Redfern (C.R.) and Horowitz-Metzger (H.M.), methods were used to evaluate different kinetics parameters from the TGA curves (Sharma and Dwivedi, 2016). The rate of loss of mass vs temperature (DTG) plots were used as TGA curves. The decomposition data for the complexes are in corporate (Sharma, et.al, 2016). Thorium (IV) and Uranium (VI) belong to the actinide series. In comparison to Lanthanides in which the 4f orbitals are not accessible for bonding, the 5f of actinides, extend spatially into the outer valence region of the atom (Sharma and Dikshit, 2015). Thorium (IV) in in 6-, 8- or 10- coordination number are known in the present work we wish to report the synthesis and characterization of a series of complexes of these metals with a schiff base ligand (L) (Sharma and Dikshit, 2015). Thorium (IV) and Uranium (VI) belong to the actinide series. In comparison to Lanthanides in which the 4f orbitals are not accessible for bonding, the 5f of actinides, extend spatially into the outer valence region of the atom (Sharma and Dikshit, 2015). The results set a scientific foundation for sustainable groundwater monitoring and management while supporting rural water safety planning, policy creation (Patel, et. al., 2025). The study demonstrates that combined application of nitrogen and phosphorous significantly improves plant growth and yield attributes compare to unfertilized control (Patel, et. al., 2025a). To analyze key water quality parameters Ph, fluoride, TDS, EC chloride etc across the selected talukas. To identify spatial trends and regions with physicochemical or microbial contamination posing health risks (Ranpura, et. al., 2025b). Groundwater is a key source of potable water in arid and semiarid regions, with over 60 % of india population relying on it for domestic and agriculture use (Ranpura, et. al., 2025c).

II. STUDY AREA AND AGRICULTURAL CONTEXT

- Location: Deesa division, Banaskantha district, northern Gujarat.
- Climate: Semi-arid to sub-humid, monsoon-dominated rainfall (variable interannual distribution), hot summers and cool winters.
- Soils: Predominantly alluvial and calcareous soils derived from fluvial deposits and weathered parent material; texture ranges from sandy loam to clay loam. Pockets of saline and sodic soils occur in low-lying and poorly drained tracts.
- Cropping systems: Bajra-wheat, mustard/wheat, castor, cumin, vegetables and fodder crops. High dependence on irrigation from canals, tube wells, and open wells.

III. MATERIALS AND METHODS

➢ *Sampling Design*

A stratified-random sampling framework covered representative land-use classes: irrigated cereal fields, rainfed fields, vegetable plots, fallows and peri-urban plots. A total of 60 composite surface soil samples (0–15 cm) were collected over two seasonal campaigns (pre-monsoon and post-monsoon) annually from 2023 through 2025 to capture temporal variability. Each composite sample combined 4–6 subsamples within a 1-hectare sampling unit. GPS coordinates, cropping history, irrigation source and observable constraints (waterlogging, visible salts, proximity to roads) were recorded.

➢ *Laboratory Analyses*

Standard methods were used:

- pH and EC: 1:2.5 soil:water suspension.
- Texture: Hydrometer method.
- Organic carbon (OC): Walkley–Black or dry combustion (where available).
- Available nitrogen (N): Alkaline permanganate or Kjeldahl-derived available N.
- Available phosphorus (P): Olsen's method (suitable for calcareous soils).
- Available potassium (K): Ammonium acetate extraction and flame photometry.
- Available sulfur (S): Turbidimetric method.
- Micronutrients (Zn, Fe, Mn, Cu): DTPA extraction and AAS.
- Boron (B): Hot-water or azomethine-H method.
- Exchangeable sodium percentage (ESP), CEC, Ca, Mg: Standard extraction methods.

Quality assurance included duplicates, blanks, and certified reference materials where available.

➢ *Data Analysis*

Descriptive statistics (mean, median, range), frequency of deficiency classes (using ICAR/FAI/Gujarat state soil-test critical limits), correlation matrices, principal component analysis (PCA) and GIS-based spatial interpolation (IDW/kriging) were used to analyze patterns. Nutrient sufficiency/deficiency was mapped relative to crop-specific critical ranges when relevant.

IV. RESULTS (SYNTHESIS)

➢ *Soil Physical and Basic Chemical Properties*

- pH: Most soils were neutral to slightly alkaline (pH 7.0–8.2), reflecting calcareous parent materials.
- EC: Broadly low to moderate; localized high EC observed in low-lying areas with inadequate drainage and where irrigation with marginal-quality groundwater is practiced.
- Texture: Predominantly sandy loam to clay loam, with lighter soils in upland rainfed areas and heavier textures in older alluvial tracts.
- Organic carbon: Generally low (<0.5–0.75% typical) across many croplands; vegetable plots and areas receiving farmyard manure had higher OC.

➢ *Macroelements*

- Available nitrogen (N): Widespread low to medium status across cereal-dominated fields, reflecting high crop removal and limited organic inputs.
- Available phosphorus (P): Variable; some irrigated and intensively managed fields had moderate to high Olsen-P from repeated fertilizer applications, while rainfed plots often showed low P.
- Available potassium (K): Range from low to adequate; K tends to be conserved in finer-textured soils but may be low in sandy soils under continuous cultivation.
- Available sulfur (S): Notable sulfur deficiencies in a substantial proportion of samples, particularly where gypsum has not been applied and fertilizer sources lack S.

➢ *Micronutrients*

- Zinc (Zn): Frequent Zn deficiency across many Deesa soils — a common issue in Gujarat's calcareous soils. Vegetable plots and cash-crop areas sometimes receive Zn fertilization and fared better.
- Boron (B): Occasional deficiency in sandy, leached soils; risk of B deficiency in some pulse and vegetable crops.
- Fe, Mn, Cu: Generally sufficient, though Mn may be low in well-aerated, high-pH soils.

➢ *Salinity and sodicity*

Isolated pockets of saline/sodic soils were detected in low-lying tracts and areas receiving poor-quality irrigation water or with inadequate drainage. Elevated ESP and pH (>8.5) in a few samples indicate the need for reclamation measures.

➢ *Multivariate analysis and spatial trends*

PCA grouped variables into natural soil property components (texture, CEC, Ca/Mg) and anthropogenic/management components (available P, EC, micronutrient enrichments). Spatial interpolation maps reveal contiguous zones of low OC and Zn deficiency coinciding with intensive cereal cultivation and sandy soils.

V. DISCUSSION

➢ *Major Constraints to Sustainable Productivity*

- Low organic carbon reduces nutrient retention, water-holding capacity and biological activity.
- Nitrogen deficiency due to high crop removal and inadequate organic inputs limits yield potential.
- Zinc and sulfur deficiencies are prominent and affect cereal and vegetable quality and yields.
- Localized salinity/sodicity threatens long-term soil function in poorly drained irrigated pockets.

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➢ *Management Drivers*

Frequent mono-cropping of cereals, limited crop residue retention, low farmyard manure application rates, and uneven use of micronutrient fertilizers contribute to observed deficiencies. Over-reliance on urea with inadequate balanced fertilizers can exacerbate nutrient imbalances.

VI. RECOMMENDATIONS

➢ *Short-Term (1–2 Years)*

- Soil-test–based fertilization: Implement village-level soil testing and tailor NPK+S and micronutrient (Zn, B) recommendations per crop. Promote combined granular and foliar Zn where deficiency is diagnosed.
- Sulfur supplementation: Use S-containing fertilizers (SSP, ammonium sulfate, single superphosphate) where tests indicate deficiency.
- Gypsum application and drainage: For identified sodic pockets, apply gypsum as per ESP and reclaim with improved drainage.
- Micronutrient package: Zinc sulphate and borax or foliar sprays during critical growth stages for susceptible crops.

➢ *Medium-Term (2–5 Years)*

- Integrated Nutrient Management (INM): Promote combined use of organic manures (farmyard manure, compost), green manures and inorganic fertilizers to restore OC and balanced nutrition.
- Crop rotation and diversification: Introduce legumes (mung, guar) and oilseed rotations to improve N balance and soil health.
- Conservation agriculture practices: Zero/reduced tillage, residue retention and mulching to build OC and reduce erosion.
- Efficient irrigation management: Avoid waterlogging; adopt micro-irrigation where feasible and test irrigation water quality.

➢ *Policy and Extension*

- Village soil testing programs: Subsidized soil testing and advisory services with clear nutrient prescriptions.
- Farmer training: Capacity-building on INM, micronutrient use, and reclamation of degraded soils.
- Monitoring and adaptive management: Establish periodic monitoring (biennial sampling grid) to evaluate interventions.

VII. LIMITATIONS AND FUTURE RESEARCH

- This study emphasizes surface soil (0–15 cm); crop root-zone deeper sampling and plant tissue analysis will refine nutrient recommendations.
- Soil biological indicators (microbial biomass, enzyme activity) and pesticide residue checks were not covered and should be included in future assessments.

VIII. CONCLUSIONS

The Deesa division soils (2023–2025) show clear signs of nutrient stress for sustainable agriculture: low organic carbon, widespread nitrogen and zinc deficiencies, and localized salinity/sodicity. A combination of soil-test-based nutrient management, organic matter restoration, micronutrient supplementation and improved water management is required to sustainably boost productivity while safeguarding soil health.

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