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Assessment of Soil Fertility Status and Nutrient Mapping in the Semi-Arid Nakhatrana Taluka, Kachchh District, Gujarat

Kinjal Dodia[1], Uday Bhanushali[2], Govind Kher[3], Ritesh Tandel[2] , Kalpesh Sorathia[4]

[1]Department of Chemistry, Guru Govind University, Vinzol, Panchamahal, Gujarat, India
Email: dodiakinjal13@gmail.com
[2]Department of Microbiology, Tolani College of Arts and Science, Adipur, Kachchh, Gujarat, India
Email: upbhanushali11@gmail.com
Email: rtshtandel@gmail.com
[3]Department of Chemistry, Tolani College of Arts and Science, Adipur, Kachchh, Gujarat, India
Email: drgjkher@gmail.com
[4]Department of Botany, Tolani College of Arts and Science, Adipur, Kachchh, Gujarat, India
Email: kalpeshsorathia@gmail.com

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Abstract— *Soil fertility is the inherent capacity of soil to supply essential nutrients in adequate amounts and suitable proportions for plant growth. This study evaluates the physicochemical properties and nutrient status of the Nakhatrana Taluka in the Kachchh District, a semi-arid region characterized by erratic rainfall and saline-alkaline soils. A total of 800 soil samples were collected from six representative villages (Vang, Tal-layari, Virkhan, Devisar, Virani Moti, and Virani Nani) and analyzed for pH, electrical conductivity (EC), organic carbon (OC), macronutrients (P, K), secondary nutrients (Ca, Mg, S), and micronutrients (Fe, Cu, Mn, Zn). The results indicate that the soils are non-saline (EC < 1.0 dS m^{-1}) and neutral to moderately alkaline (pH 7.08–8.52). While the fertility indices for Organic Carbon (66.88% high), Phosphorus (44.88% high), and Potassium (56.50% high) suggest a robust macronutrient status, the soils exhibit critical micronutrient deficiencies. Specifically, 97.88% of samples were deficient in Iron (Fe), and significant deficiencies were observed for Zinc (Zn) and Manganese (Mn). The study concludes that while the macronutrient profile is favorable, sustainable crop production in Nakhatrana requires integrated nutrient management with a specific focus on micronutrient supplementation.*

Keywords— ***oil Fertility, Nutrient Index, Semi-arid Agriculture, Micronutrients, Kachchh, Soil Salinity***

I. INTRODUCTION

The Kachchh District of Gujarat is characterized by harsh climatic conditions, including scanty and erratic rainfall, high evapotranspiration, and the prevalence of saline–alkaline soils [1]. These environmental constraints significantly influence soil physicochemical properties and nutrient availability [2]. Nakhatrana Taluka, situated in the central part of Kachchh, is predominantly agrarian, with the local livelihood heavily dependent on rain-fed agriculture [3]. However, declining soil fertility and nutrient imbalances have emerged as critical challenges affecting agricultural sustainability in the region [4]. Soil fertility evaluation involves analyzing physical and chemical properties, including pH, electrical conductivity (EC), organic carbon (OC), major elements (N, P, K), secondary elements (Ca, Mg, S), and micronutrients (Fe, Zn, Mn, Cu) [5]. A fertile soil maintains appropriate pH, good structure, and adequate organic matter to ensure root growth and nutrient uptake [6]. In regions like Nakhatrana, where soil types vary from sandy to loamy, systematic assessment is critical for sustainable management [7]. Previous studies in

India emphasize that fertility evaluation guides the precise application of fertilizers, ensuring soil health and improved crop yields [8]. Despite the agrarian importance of the region, systematic studies on the nutrient status of Nakhatrana are limited. Therefore, this study was undertaken to assess the physicochemical characteristics of soils in six representative villages, evaluate the fertility status using the Nutrient Index (NI), and identify potential nutrient limitations for sustainable crop production.

II. MATERIALS AND METHODS

2.1 Study Area and Sampling

The study was conducted in Nakhatrana Taluka, Kachchh District, Gujarat. Six villages i.e., Vang, Tal-layari, Virkhan, Devisar, Virani Moti, and Virani Nani were selected for the assessment. A total of 800 soil samples were collected using a systematic sampling method at a depth of 0–20 cm[9].

2.2 Sample Preparation and Analysis

The samples were air-dried at room temperature, crushed using a wooden mortar and pestle, and passed through a 2 mm sieve. All analyses followed the standard protocols described in the "Methods Manual-Soil Testing in India" (ICAR) and APHA guidelines [10].

- pH and EC: Determined in a 1:2.5 soil–water suspension using a digital pH meter and conductivity meter, respectively [11].
- Organic Carbon (OC): Estimated by the Walkley and Black wet oxidation method [12].
- Macronutrients: Available Phosphorus (P) was determined by Olsen's method, and Available Potassium (K) by flame photometry [13].
- Secondary Nutrients: Calcium (Ca) and Magnesium (Mg) were determined by EDTA titration; Sulphur (S) was analyzed by the turbidimetric method.
- Micronutrients: Iron (Fe), Copper (Cu), Manganese (Mn), and Zinc (Zn) were extracted using DTPA solution and quantified using an Atomic Absorption Spectrophotometer (AAS) [14].

2.3 Fertility Index Calculation

The Nutrient Index (NI) was calculated to evaluate overall fertility status using the formula:

$$NI = \frac{(N_L \times 1) + (N_M \times 2) + (N_H \times 3)}{N_T}$$

Where N_L, N_M, N_H are the number of samples in Low, Medium, and High categories, and N_T is the total number of samples [5]. The values are interpreted as Low (< 1.67), Medium (1.67–2.33), and High (> 2.33).

2.4 Statistical AnalysisDescriptive statistics (Average, Min, Max, SD) and Pearson's correlation analysis were performed using SPSS 19 statistical software.

III. RESULTS AND DISCUSSION

3.1 Physicochemical Properties (pH and EC)

The Electrical Conductivity (EC) of the soil samples ranged from 0.20 to 0.95 dS m^{-1} (Table 1), indicating that the soils are non-saline and suitable for germination and crop growth [11]. Soil pH varied from 7.08 to 8.52, classifying the soils as neutral to moderately alkaline. Such pH ranges are typical in arid Gujarat due to the accumulation of basic cations and low rainfall [8]. The alkaline pH showed a negative correlation with micronutrients (Cu, Mn, Zn), a well-documented phenomenon where higher pH reduces the solubility and plant availability of these metals [15].

3.2 Organic Carbon and Macronutrients

Organic Carbon (OC) content ranged from 0.14% to 1.28%, with 66.88% of samples classified as "High" (Table 2). This indicates a favorable status of soil organic matter, likely due to the application of organic manure or crop residues [7]. OC showed a strong positive correlation with Magnesium and Potassium, emphasizing its role in nutrient retention. Macronutrients Phosphorus (P) and Potassium (K) also exhibited high fertility indices; specifically, 44.88% of samples were high in P and 56.50% were high in K [13].

3.3 Micronutrient Status

In contrast to macronutrients, the study revealed widespread micronutrient deficiencies (Table 3). Iron (Fe) was deficient in 97.88% of samples, identifying it as a critical limiting factor for crop yield. Zinc (Zn) and Manganese (Mn) also showed significant deficiencies, with 36.75% and 26.13% of samples in the low category, respectively [14].

3.4 Statistical Correlations

Pearson's correlation matrix (Table 4) revealed that Copper and Zinc have an extremely high positive correlation (r = 0.97), suggesting these elements share a common mineralogical source or are controlled by similar adsorption mechanisms [16]. EC showed a strong positive correlation with Magnesium (r = 0.82), indicating that magnesium salts contribute significantly to the soil's electrical conductivity.

Table 1 Mean Chemical Properties of Soil Note: Values represent the average concentrations observed in each village.

Village	EC (dS/m)	pH	C (%)	P (kg/ha)	K (kg/ha)	S (ppm)	Ca (meq%)	Mg (meq%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
Vang	0.60	7.79	0.79	45.12	357.64	37.90	2.39	6.77	0.44	1.64	5.93	0.57
Tal-layari	0.69	7.92	0.93	69.43	513.27	22.26	5.99	10.49	0.21	1.53	9.05	0.24
Virkhan	0.33	7.64	0.83	10.25	101.75	108.40	3.60	5.37	0.15	1.41	1.73	0.21
Devisar	0.27	7.98	0.62	11.38	136.97	41.04	3.69	6.51	0.29	1.35	1.77	0.38
Virani Moti	0.30	7.46	0.66	58.87	330.53	27.90	4.63	4.61	0.80	1.32	7.27	2.80
Virani Nani	0.36	7.71	0.85	83.52	320.71	98.02	3.92	6.37	0.73	0.81	6.50	2.47

Table 2 Soil Fertility Index - 1 (Physicochemical & Macronutrients)

Element	Low (Samples)	Medium (Samples)	High (Samples)	% Low	% Medium	% High	Fertility Index	Status
EC	799	0	1	99.88	0.00	0.13	1.00	Safe
pH	0	464	336	0.00	58.00	42.00	2.42	Alkaline
C	242	23	535	30.25	2.88	66.88	2.37	High
P	216	225	359	27.00	28.13	44.88	2.18	Medium
K	2	346	452	0.25	43.25	56.50	2.56	High
S	57	106	637	7.13	13.25	79.63	2.73	High

Table 3 Soil Fertility Index-2 (Secondary & Micronutrients)

Element	Low (Samples)	Medium (Samples)	High (Samples)	% Low	% Medium	% High	Fertility Index	Status
Mg	6	35	759	0.75	4.38	94.88	2.94	High
Ca	6	335	459	0.75	41.88	57.38	2.57	High
Cu	118	206	476	14.75	25.75	59.50	2.45	High
Fe	783	0	17	97.88	0.00	2.13	1.04	**Low**
Mn	209	294	220	26.13	36.75	27.50	1.75	Medium
Zn	294	220	286	36.75	27.50	35.75	1.99	Medium

Table 4 Correlation Coefficient (r) between Physicochemical Elements of Soil

	Ec	PH	C	P	K	S	Ca	Mg	Cu	Fe	Mn	Zn
Ec	1.00											
PH	0.40	1.00										
C	0.68	0.13	1.00									
P	0.40	-0.18	0.46	1.00								
K	0.79	0.09	0.51	0.82	1.00							
S	-0.43	-0.25	0.29	-0.16	-0.57	1.00						
Ca	0.25	0.05	0.33	0.43	0.53	-0.34	1.00					
Mg	0.82	0.70	0.63	0.34	0.67	-0.40	0.55	1.00				
Cu	-0.30	-0.60	-0.29	0.63	0.25	-0.07	-0.05	-0.46	1.00			
Fe	0.52	0.24	-0.02	-0.44	0.14	-0.55	-0.06	0.30	-0.58	1.00		
Mn	0.63	-0.13	0.45	0.90	0.97	-0.49	0.56	0.50	0.44	-0.02	1.00	
Zn	-0.41	-0.69	-0.23	0.61	0.18	0.06	0.10	-0.49	0.97	-0.68	0.40	1.00

IV. CONCLUSION

The fertility index analysis indicates that most soil parameters in Nakhatrana Taluka are within the optimum range, with high levels of organic carbon, phosphorus, and potassium. However, the study identifies a critical gap in micronutrient status, specifically for Iron (Fe), Zinc (Zn), and Manganese (Mn), which are negatively impacted by the alkaline soil pH. Therefore, while the overall fertility is conducive to agriculture, sustainable productivity depends on correcting these micronutrient deficiencies through targeted fertilization and salinity management [16].

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