Comprehensive Soil Analysis and Nutrient Evaluation for Agricultural Optimization in Sinor Taluka

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Abstract: ***This study evaluates key soil properties—pH, electrical conductivity (EC), organic carbon, and nutrient levels—across four villages in Sinor Taluka, Vadodara, Gujarat, to guide sustainable farming practices. Laboratory analysis revealed slightly alkaline soils (pH 7.6–7.8), which may restrict nutrient availability, particularly phosphorus. EC levels were low to moderate (0.19–0.49 dS/m), with Chhanbhoi showing higher salinity risks. Organic carbon content was suboptimal, signaling the need for compost or green manure to enhance fertility. While macronutrients (N, P, K) were generally adequate, micronutrients such as zinc and manganese were at borderline levels in certain areas, requiring targeted supplementation. Based on these findings, we recommend cultivating pH-tolerant crops (e.g., wheat, barley, cotton), improving organic matter, and using targeted nutrient management to improve yields and soil health. These strategies can optimize agricultural productivity while ensuring long-term sustainability.***

Keywords: Soil fertility, nutrient management, sustainable farming, salinity, crop suitability

1. Introduction

Soil is a cornerstone of agricultural productivity and plays an integral role in crop growth. Variations in its properties—such as texture, organic matter content, nutrient levels, and pH—can have profound impacts on both crop yield and farming practices. In rural areas, particularly villages, soil characteristics often differ significantly due to a mix of local environmental conditions, agricultural techniques, and historical land use. In the present study, of the four villages, Barkal Village has a red-colored, textured soil. While anandi and chhanbhoi has black soil texture.

Conducting soil analysis is crucial, as it provides farmers with essential data to make informed decisions about soil management, irrigation, and fertilizer applications, enhancing productivity overall. A key parameter in soil health assessment is electrical conductivity (EC), which evaluates salt and nutrient concentrations in the soil. Agricultural soils generally require a pH range between 6 and 8 for optimal nutrient availability, whereas acidic soils with pH levels below 6 pose challenges like reduced nutrient availability, toxic ion buildup, and nutrient imbalances [1]. Techniques for measuring EC offer insights into these aspects. Excessively high EC can damage plant roots and hinder microbial activity, while extremely low EC reflects inadequate nutrients. Factors influencing EC include farming practices, irrigation methods, land use changes, and fertilizers, as well as intrinsic characteristics like soil mineral content, climate, and texture [2]. Maintaining EC within the optimal range of 0.8–1.8 (not exceeding 2.5) is essential for healthy plant growth [3]. Understanding and regulating EC levels is fundamental to fostering sustainable agriculture and reducing greenhouse gas emissions.

Micronutrient deficiencies in crops are becoming more common owing to factors like intensive cropping, soil erosion, nutrient leaching, acidic soil liming, and reduced use of organic manures in favor of purer chemical fertilizers [4]. In India, declining soil fertility is a major factor driving these deficiencies, which negatively affect human and animal health as well as agricultural output. Essential micronutrients for crops, including boron, copper, iron, manganese, molybdenum, and zinc, are critical for plant growth and development. Deficiencies manifest through symptoms like chlorosis, interveinal chlorosis, and stunted growth, depending on the nutrient and soil condition. Addressing these issues often involves applying specialized fertilizers like sodium borate for boron or zinc sulfate for zinc. Even micronutrients such as nickel and cobalt, required in trace amounts, play vital roles for certain plants [5].

Macronutrients are equally significant for plant growth. Nitrogen, phosphorus, and potassium support key processes like respiration, protein synthesis, cell membrane formation, and water balance. Deficiencies may result in issues such as chlorosis, hindered growth, and delayed flowering. Structural nutrients, such as carbon, hydrogen, and oxygen, are pivotal for energy generation and the structural integrity of plants [6]. These elements comprise a large portion of plant dry weight and are indispensable for overall health. Secondary nutrients, including calcium, magnesium, and sulfur, contribute to regulating soil acidity, synthesizing chlorophyll, and aiding root and seed development. Lacking these nutrients can result in stunted growth, brittle leaves, and premature leaf drop [7].

This study focuses on analyzing soil properties across various villages in Sinor Taluka, Vadodara, Gujarat. The findings aim to deliver tailored recommendations for enhancing soil quality, boosting crop yields, and promoting sustainable agricultural practices.

2. Experimental Methodology

The soil samples were meticulously collected following the standardized quadrat method, ensuring a systematic and representative approach to capture the diverse soil conditions across the study area. Each sample was carefully sealed in sterile polythene bags to prevent contamination and preserve its natural composition during transportation to the laboratory. Adhering to stringent scientific protocols, the samples underwent a thorough and detailed analysis to assess their chemical properties. Drawn randomly from four strategically selected villages, these offered a reliable representation of all 41 villages within Sinor Taluka, Vadodara, Gujarat. The laboratory evaluation was exhaustive, focusing on key chemical parameters crucial for evaluating soil health and fertility. These included pH levels, electrical conductivity, and essential nutrients such as nitrogen, phosphorus, and potassium, as well as vital micronutrients like zinc, boron, manganese, and copper. Each parameter was analyzed with precision to deliver reliable insights into the soil's quality and agricultural potential.

3. Result and Discussion

Parameter	Simdi	Anandi	Barkal	Chhanbhoi	Standard/Typical Value	Interpretation
pH	7.8	7.6	7.8	7.8	6.0-7.5 (most crops)	Slightly alkaline in all villages.
EC (dS/m)	0.19	0.34	0.31	0.49	< 2.0 (generally)	Low to moderate salinity, Chhanbhoi approaching higher levels.
Organic Carbon (%)	0.35	0.4	0.75	0.36	> 1.0 (ideal)	Low to moderate, Barkal is the best, but still low.
P (ppm)	21.28	17.69	22.176	17.248	15-30 (medium range)	Adequate, but Anandi and Chhanbhoi are on the lower side of adequate.
N (kg/ha)	380	420	550	388	280-560 (medium range)	Generally adequate, Barkal is high.
K (kg/ha)	114.688	157.248	102.816	153.664	120-300 (medium range)	Generally adequate, but some are on the lower side.
Zn (ppm)	1.516	1.621	1.501	1.07	0.5-5.0 (adequate)	Adequate, but Chhanbhoi is at the lower end.
B (ppm)	1.035	1.162	1.122	0.964	0.5-1.0 (adequate)	Generally adequate, but very close to the top range.
Fe (ppm)	2.395	3.472	1.965	6.233	5-50 (adequate)	Adequate, but Chhanbhoi is significantly high.
Mn (ppm)	2.467	1.924	1.728	1.038	2-50 (adequate)	Adequate, but Chhanbhoi is at the lower end.
Cu (ppm)	0.665	0.62	0.938	0.676	0.2-3.0 (adequate)	Adequate.

pH: The slightly alkaline soil pH observed across all four villages, deviating from the optimal acidic to neutral range (6.0-7.5) preferred by most crops, presents a significant challenge [8]. This alkalinity directly impacts nutrient availability, potentially reducing the uptake of essential micronutrients like phosphorus, iron, zinc, manganese, and copper, even if current micronutrient levels appear adequate. Notably, the risk of phosphorus fixation is heightened, meaning that despite potentially high phosphorus values, plants may struggle to absorb it efficiently due to the pH. To mitigate these effects, consistent pH monitoring is crucial, and soil amendments such as sulfur application should be considered, particularly when cultivating pH-sensitive crops. Given these conditions, crops like alfalfa, barley, cotton, sugar beet, cabbage, cauliflower, asparagus, and spinach are recommended, as they tolerate alkaline soils. Conversely, acid-loving crops such as blueberries, potatoes, and tea should be avoided to ensure optimal growth and yield.

Electrical Conductivity: Electrical conductivity (EC), a measure of soil salinity, was found to be generally low to moderate across the studied villages, indicating a low risk of salinity stress and making the soil safe for all crops. However, Chhanbhoi exhibited the highest EC value, suggesting potential salinity issues that necessitate diligent monitoring and the implementation of appropriate irrigation and drainage practices to manage salt accumulation. Given the generally low EC, these soils are ideal for cultivating a wide range of crops, including vegetables, cereals, and legumes, ensuring healthy growth and optimal yields [9].

Organic Carbon: Organic carbon (OC), a critical indicator of soil health and fertility, was found to be generally low to moderate across the studied villages, with Barkal exhibiting the highest, though still below ideal, levels, indicating a potential limitation to soil productivity. This low OC directly impacts soil properties by reducing water holding capacity, diminishing nutrient retention, and negatively affecting beneficial microbial activity. To mitigate these adverse effects and enhance soil health, it is strongly recommended to increase OC levels through the addition of organic matter. Specifically, incorporating compost or farmyard manure (FYM) at a rate of 5-10 tons per hectare, cultivating green manure crops like sunn hemp or dhaincha, and utilizing mulching techniques to retain moisture and improve organic matter content are effective strategies. These practices will improve soil structure, fertility, and overall health, leading to enhanced agricultural productivity [10].

Macronutrients: Macronutrients, vital for plant growth, display varied levels across the villages, impacting agricultural practices. Phosphorus, crucial for root development, is adequately present in Simdi and Barkal, but lower in Anandi and Chhanbhoi, necessitating phosphorus fertilization because alkaline soils restrict its availability; incorporating organic matter and regular soil testing are essential. Nitrogen, a key component of proteins, is generally high, particularly in Barkal, requiring careful management to prevent excess vegetative growth through balanced NPK application. Potassium, vital for water balance, is at medium levels, suggesting potential potassium fertilization with KCl or K_2SO_4, especially for high-potassium crops, and organic matter incorporation to enhance availability [11]. The generally high nitrogen levels (380-550 kg/ha), exceeding the ideal 200-400 kg/ha range, necessitate reduced nitrogen-heavy fertilizers to prevent excess vegetative growth [12]. Phosphorus levels (17-22 ppm) are medium to high, but alkaline pH reduce s uptake, suggesting the use of phosphorus-solubilizing bacteria or foliar sprays. Potassium levels (102-157 kg/ha), though medium, may require K_2O application (40-60 kg/ha) for high-potassium crops [13]. Overall, tailored fertilization strategies and organic matter management are crucial to address specific nutrient imbalances and optimize crop productivity.

Micronutrient: The soil analysis across the four villages shows generally adequate micronutrient levels, but with important local variations requiring specific management. While zinc (Zn) levels are sufficient in Simdi, Anandi, and Barkal, Chhanbhoi shows borderline adequate Zn that may need supplementation through soil application of $ZnSO_4$ (25 kg/ha) or foliar spray (0.5% $ZnSO_4$ + lime) to prevent deficiencies [14]. Boron (B) levels are currently adequate in all locations but approach the upper threshold, requiring monitoring to prevent potential toxicity if soil pH increases. Iron (Fe) concentrations are appropriate in three villages but elevated in Chhanbhoi, where Fe-EDTA foliar spray (0.5%) should be used if chlorosis appears [15]. Manganese (Mn) is sufficient in most areas but marginal in Chhanbhoi, suggesting possible $MnSO_4$ application (10-15 kg/ha) if deficiency symptoms like interveinal chlorosis occur [16]. Copper (Cu) levels are adequate across all villages and only need routine monitoring.

Crop Recommendations: For general crop recommendations in alkaline soils with low organic carbon (OC) and medium potassium (K), suitable field crops include wheat, barley, mustard, and chickpea (which tolerate pH 7.5–8.0), as well as cotton (which has moderate K demand and benefits from added sulfur (S) for fiber quality). For vegetables, consider spinach, cauliflower, onion, and okra (which are pH-tolerant), while tomatoes require extra K and Zn. Among pulses and oilseeds, soybean and groundnut are good options. For fodder crops, sorghum and pearl millet are ideal due to their drought and pH tolerance.

4. Conclusion

the soil analysis conducted across the villages in Sinor Taluka, Vadodara, Gujarat reveals crucial insights for enhancing agricultural practices and improving crop yields. The slightly alkaline soil pH presents a significant challenge, impacting nutrient availability and requiring consistent monitoring. Electrical conductivity levels indicate low to moderate salinity, except for Chhanbhoi, which necessitates diligent monitoring and appropriate irrigation and drainage practices. Organic carbon levels, though generally low to moderate, indicate a potential limitation to soil productivity, highlighting the need to increase organic matter through effective strategies like compost incorporation and mulching techniques. Macronutrient and micronutrient levels across the villages require tailored fertilization and specific management to address nutrient imbalances and optimize crop productivity. Overall, the findings provide tailored recommendations for crop cultivation, emphasizing the importance of pH-tolerant crops, organic matter incorporation, and precise nutrient management to foster sustainable agricultural practices.

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