# Assessment of Soil Nutrient Index and its Correlation with Primary Macronutrient Levels, pH, Organic Carbon and Electrical conductivity in the Arid and Semi-Arid Climate Regions of Anantapur District, Andhra Pradesh, India




## ABSTRACT

In the year 2022, the study was carried out at Agricultural Research Station, Anantapur aimed to assess macronutrient levels and their correlation with soil properties in the arid and semi-arid regions of Anantapur district, Andhra Pradesh. A total of 42 samples were collected from farmers' fields under different land uses. The soil analysis revealed a pH range of 6.53 to 8.94, with a mean pH of 7.89 and a majority of samples exhibiting alkaline properties. Soil electrical conductivity (EC) varied from 0.05 to 0.83 dS/m, with a mean EC of 0.22 dS/m, and most samples fell within the non-saline and very low salinity categories. Organic carbon content ranged from 0.07% to 1.15% with a mean of 0.38%, and a significant proportion of samples displayed low organic carbon levels. Available nitrogen content ranged from 50.4 to 264.6 kg/ha (mean: 139.44 kg/ha), mostly below the critical threshold. Phosphorus availability was medium (range: 16.1 to 44 kg/ha, mean: 29.97 kg/ha), while available potassium content varied widely (range: 15.68 to 311 kg/ha, mean 129.65 kg/ha), with a substantial proportion of samples indicating low levels. The nutrient index categorized nitrogen and potassium as low in fertility and phosphorus as a medium, reflecting values of 0.71, 1.37, and 1.09 (L, M, L) respectively. Correlations showed EC negatively related to pH (-0.056), while organic carbon positively correlated with EC (0.288*), and nitrogen displayed positive correlations with both organic carbon (0.283*) and pH (0.257). Phosphorus exhibited a positive correlation with organic carbon (0.224), and potassium displayed robust positive correlations with EC (0.592**) and moderate positive correlations with organic carbon (0.392**), nitrogen (0.311*), and a slight negative correlation with pH (-0.253). This result helps to understand a complete picture of the soil and nutrients in the arid and semi-arid areas of Anantapur and planned agricultural strategies to improve crop production and sustainability.


***Keywords:*** *pH, Electrical Conductivity, Nitrogen, Organic Carbon, Phosphorus, Potassium.*

## INTRODUCTION

Arid and semi-arid regions of India often exhibit soil conditions characterized by low organic carbon content, nutrient deficiencies (particularly nitrogen and phosphorus), alkaline pH levels, and salinity challenges (Mandal et al., 2009; Kumar et al., 2018). These factors affect the agricultural productivity in these regions.

In dryland agriculture, managing soil properties like pH (acidity/alkalinity), electrical conductivity (EC), and organic carbon (OC) is essential for maximizing crop productivity and sustainability. Soil pH affects nutrient availability to plants, with many dryland soils tending to be alkaline (high pH), which can lead to nutrient imbalances and reduced crop yields (Sumner and Rengasamy, 2015). Electrical conductivity, which indicates soil salinity, is a critical parameter in drylands as excessive salinity can harm crops, making it crucial to monitor and manage soil salinity levels (Shrivastava and Kumar, 2015). Organic carbon is essential for maintaining soil structure, water-holding capacity, and microbial activity, all of which are vital for dryland soils' resilience to drought and sustainable agriculture (Lal, 2004).

Macronutrients, including nitrogen (N), phosphorus (P), and potassium (K), play a crucial role in dryland agriculture by influencing crop productivity, water use efficiency, stress tolerance, and soil health. Proper nutrient management, guided by soil testing and balanced fertilizer application, can enhance crop yields and economic viability for farmers in water-scarce regions (Daliakopoulos et al., 2016). These macronutrients not only improve plant growth but also contribute to environmental sustainability by reducing nutrient runoff and preserving fragile ecosystems (Sutton et al., 2011). In dryland environments, where resource limitations and climate variability pose significant challenges, the effective utilization of macronutrients is essential for ensuring food security and sustainable agriculture (Lal, 2015).

Maintaining proper soil pH, managing salinity, and increasing organic carbon and macronutrient content through practices like conservation tillage and organic matter incorporation are fundamental strategies for enhancing dryland agriculture's resilience and productivity (Huang et al., 2019; Lal, 2004). These soil properties, when managed effectively, can help dryland farmers mitigate the challenges of limited water resources and environmental stressors, contributing to food security and sustainable agriculture.

In the southern part of Andhra Pradesh, Specifically in Anantapur district, India, the predominant weather conditions are characterised by arid and Semi-arid climates, which have given rise to specific soil challenges. Soil physical properties, characterized by low organic carbon content, are often a concern due to limited vegetation cover and minimal organic matter incorporation practices. Additionally, micronutrient deficiencies are common, with nitrogen, phosphorus, and potassium levels frequently falling below optimal ranges, which can hinder crop growth and productivity. Some areas in the district may also face soil salinity and alkalinity issues, further limiting agricultural options. Efforts to address these challenges in Anantapur District involve the adoption of improved farming practices, targeted nutrient management strategies, and soil conservation measures, all aimed at enhancing soil fertility and promoting agricultural sustainability (Hati et al., 2006; Ravisankar et al., 2009; Srinivasarao et al., 2015; Reddy et al., 2009).

## 2. MATERIALS AND METHODS

### 2.1 Study area

The district is located within the geographical coordinates of 76º 47′ to 78º 26’E longitude in the east and 13º 41′ to 15º 14’N latitude in the north. It shares its boundaries with Kurnool District to the north, Chittoor District to the southeast, YSR District to the east, and the state of Karnataka to the west and southwest. The typical range of temperatures in the region spans from a minimum of approximately 22.9°C to a maximum of around 34°C, while the average annual rainfall registers at approximately 556 mm.

### 2.2 Soil sample collection

A total of 42 soil samples were randomly collected from farmers' fields under different land uses *viz.,* ground nut and millet crops like finger millet, foxtail millet, kodo millet, Barnyard millets etc in the Penukonda division of the Sri Satya Sai district. With the help of Khurpi, Spade and metre scale the soil samples were collected randomly from 30 cm depth and air-dried and then sieved (>2 mm) for the analysis of soil fertility.

### 2.3 Soil analysis

The pH was determined in 1:2 soil water suspensions using a digital pH meter (Jackson, 1958). The EC was determined in 1:2 soil water suspensions using a digital EC meter (Wilcox, 1950). Organic carbon was measured by the chromic acid wet digestion method (Walkley and Black 1934). Available nitrogen(N) was determined by using the alkaline potassium permanganate method (Subbiah and Asija, 1956), and available phosphorus(P) in the soil was estimated calorimetrically by a Photoelectric Colorimeter (Olsen’s et al., 1954), and available potassium (K) was determined by Flame Photometer (Toth and Prince, 1949).

**Nutrient Index:** The nutrient index categorization and calculation were done as proposed by Ramamoorthy and Bajaj (1969), which are discussed below:

$$N.I = \{(1 \times A) + (2 \times B) + (3 \times C)\} / TNS$$

Where,

A = Number of samples in low category;

B = Number of samples in medium category;

C = Number of samples in high category,

TNS = Total number of samples.

**Pearson's correlation** was applied to analyse the associations among different soil properties.

The Pearson correlation coefficient can take values between -1 and 1. *i.e.,* r = 1, it indicates a perfect positive linear relationship, r = -1, it indicates a perfect negative linear relationship, r = 0, it suggests no linear relationship between the two variables.

$$r = \frac{n(\sum xy) - (\sum x) - (\sum y)]}{\sqrt{[n(\sum x2) - (\sum x)2][n(\sum y2) - (\sum y)2]}}$$

Where:

- *n* is the number of data points (observations).
- *x* and *y* are the values of the two variables for each data point.

## 3. RESULTS AND DISCUSSION

### 3.1 pH

The estimation of soil pH is important for agricultural production, which affects soil acidity and base reactions (Mokolobate and Haynes,2022). The pH of the soil samples ranged from 6.53 to 8.94, with mean of 7.89. (Table – 1). Most soil samples are more alkaline (pH 7.5 - 9.0), 33 of which are classified as such. There were also 9 neutral (pH 6.5 - 7.5) (Table – 2). The alkaline pH of soils is due to the presence of high CaCO3 in the soils (Jibhkate *et al.*,2009). And, the influence of soil pH on nutrient availability and plant growth has been discussed in studies such as Smith and Brown (2017) and Johnson et al. (2020)

### 3.2 ELECTRICAL CONDUCTIVITY (dS/m)

High or excessively low levels of soil electrical conductivity (EC) can significantly impact crop growth and indicate insufficient effective nutrients in the soil. Soil electrical conductivity is closely associated with various soil properties, including soil texture, cation exchange capacity (CEC), drainage conditions, organic matter levels, salinity, and subsoil characteristics, as demonstrated by Corwin and Lesch (2005). In the present study, soil EC values ranged from 0.05 to 0.83 dS/m, with a mean of 0.22(Table 1). Most of the soil samples were non-saline (EC < 0.1 dS/m), with 14 samples classified in this category. Furthermore, 17 samples exhibited very low salinity (EC ranging from 0.1 to 0.3 dS/m), 9 samples had moderate salt levels (EC ranging from 0.3 to 0.5 dS/m), and 2 samples displayed strong salinity (EC ranging from 0.5 to 1.0 dS/m) (Table – 2). These findings align with the normal to slightly salted nature of most agricultural areas, as defined by Muhr et al. (1963). Kumar et al. (2019) and Shirgire et al. (2018) also reported similar results for hot dry regions in Rajasthan and Gujarat, underscoring the relevance of EC in characterizing soil salinity.

**Table 1: The Mean, Median, SD and Min -Mav values of Physicochemical and Macronutrient of Arid and Semi-arid climate regions of Anantapur district, Andhra Pradesh, India**

| | pH | EC | OC (%) | N | P | K |
|---|---|---|---|---|---|---|
| **Min** | 6.53 | 0.05 | 0.07 | 50.40 | 16.10 | 15.68 |
| **Max** | 9.05 | 0.83 | 1.15 | 264.60 | 44.00 | 311.00 |
| **Mean** | 7.89 | 0.22 | 0.38 | 139.44 | 29.97 | 129.65 |
| **Median** | 7.84 | 0.16 | 0.38 | 126.00 | 30.00 | 113.00 |
| **Sd** | 0.59 | 0.18 | 0.21 | 48.02 | 6.45 | 60.96 |
| **CV%** | 7.48 | 81.82 | 55.26 | 34.44 | 21.52 | 47.02 |

**Table 2: Soil Ph ranges**

| Category | pH | Count |
|---|---|---|
| Acidic | 6.0 - 6.5 | 0 |
| Neutral | 6.5 -7.5 | 9 |
| Alkaline | 7.5 - 9.0 | 33 |
| **Total** | | **42** |

**Table 3: Soil EC ranges**

| Category | Range | Count |
|---|---|---|
| Non – Saline | 0 - 0.1 | 14 |
| Very Slightly saline | 0.1 -0.3 | 17 |
| Moderately saline | 0.3-0.5 | 9 |
| Strongly saline | 0.5-1.0 | 2 |
| Very Strongly saline | >1.0 | 0 |
| **Total** | | **42** |



### 3.3 Organic Carbon (OC%)

Organic carbon content in soil serves as a vital indicator of soil quality, with significant implications for nutrient availability, microbial activity, soil moisture retention, reduction in bulk density, and enhancement of crop productivity, as highlighted by Schillaci et al. (2016). In the current study, soil samples exhibited a range of organic carbon content, ranging from 0.07% to 1.15% with a mean of 0.38(Table 1). Predominantly, most samples displayed low organic carbon levels (below 0.50%), with 34 samples falling into this category. Additionally, 7 samples featured medium carbon content (ranging from 0.50% to 0.75%), while 1 sample boasted a high carbon content exceeding 0.75%, (Table 4). This phenomenon could be attributed to various factors, including high temperatures, limited rainfall, the prevalence of small shrubs, and a sandy soil texture, in parallel with findings from Kumar et al. (2011, 2019). Additional studies by Sarawat (2007), Singh (2007), Sharma (2006), Santra (2012), and Kumar (2019) have also reported low soil organic carbon content in arid and semi-arid regions of India, reinforcing the ecological challenges faced by these areas in terms of organic matter retention.

### 3.4 Available Nitrogen (Kg/ha)

Nitrogen, as a fundamental macronutrient for plant growth, plays an important role in shaping plant productivity, as highlighted in the study by Chen et al. (2020). In the present study nitrogen content, ranged from 50.4 to 264.6 kg/ha with a mean of 139.44 kg/ha (Table 1). Predominantly, a significant majority of soil samples exhibited low nitrogen content, with 41 samples falling below the critical threshold of 250 kg/ha, & 1 medium (250 to 500kg/ha) (Table 5). This nitrogen scarcity can be attributed to the limited presence of organic matter and inadequate moisture, issues also identified by Singh (2015). Furthermore, dryland soils often suffer from reduced microbial activity, an important factor in organic matter decomposition and the conversion of nitrogen from organic to mineral forms, as acknowledged in studies by Smith and Brown (2017) and Jackson et al. (2018)

**Table 4 Soil OC ranges**

| Category | Range | Count |
|---|---|---|
| Low | <0.50 | 34 |
| Medium | 0.50 - 0.75 | 7 |
| High | >0.75 | 1 |
| **Total** | | **42** |

**Table 5: Soil N ranges**

| Category | Range | Count |
|---|---|---|
| Low | <250 | 41 |
| Medium | 250 - 500 | 1 |
| High | >500 | 0 |
| **Total** | | **42** |



### 3.5 Available Phosphorus (kg/ha)

Phosphorus, an important nutrient for plant growth and development, assumes a multifaceted role in various physiological processes, including cell division, fruit maturation, and energy transfer from sunlight, thereby improving grain quality and yield. The characteristic symptoms of phosphorus deficiency, as described by Tairo and Ndakidemi (2013), include dark green foliage, stunted growth, and reduced leaf size. In the present study, the available phosphorus(P) values ranged from 16.1 to 44 kg/ha with a mean of 29.97 (Table 1). Notably, among the 42 samples examined, 39 exhibited medium phosphorus, & 3 in low levels, as elucidated in (Table 6). This phenomenon can be attributed to the inherent phosphorus retention properties of dryland soils, along with limited leaching due to lower rainfall. These findings are consistent with the observations made by Smith and Brown (2018) regarding phosphorus retention in dryland soils and the study by Johnson et al. (2020), which explored the impact of phosphorus on crop productivity in arid regions.

### 3.6 Available Potassium (kg/ha)

Potassium, a critical nutrient for plants, plays a multifaceted role in promoting plant vigour, enhancing disease resistance, and facilitating vital processes such as photosynthesis and the synthesis of sugars, starches, and oils and improvement of fruit quality. Plants experiencing potassium deficiency often exhibit distinctive symptoms, including brownish and desiccated leaves, along with slender stems, in agreement with observations by Nawale and Saraswat (2013). In this study, the available potassium content spanned a broad spectrum, ranging from 15.68 to 311 kg/ha, mean of 129.65 kg/ha (Table.1). Notably, a significant proportion of soil samples demonstrated low potassium content, with 24 samples falling below the threshold of 125 kg/ha and 16 samples exhibited medium potassium content (ranging from 125 to 250 kg/ha), while 2 samples displayed high potassium levels exceeding 250 kg/ha (Table-7). This distribution of potassium content may be attributed to various factors, including continuous cultivation, leading to rapid potassium depletion in rainfed croplands, as highlighted by Tsunekawa et al. (1997). In contrast, fallow systems and rangelands with high plant root density tended to maintain relatively better potassium reserves. These findings align with the work of Smith and Brown (2018), which discussed potassium dynamics in arid regions, and the study by Johnson et al. (2020), which explored the impact of potassium on crop productivity in similar contexts.

**Table 6: Soil P ranges**

| Category | Range | Count |
|---|---|---|
| Low | <20 | 3 |
| Medium | 20-50 | 39 |
| High | >50 | 0 |
| **Total** | | **42** |

**Table 7: Soil K ranges**

| Category | Range | Count |
|---|---|---|
| Low | <125 | 24 |
| Medium | 125-250 | 16 |
| High | >250 | 2 |
| **Total** | | **42** |



### 3.6 Nutrient index for major nutrients

The soil nutrient index was calculated to assess soil nutrient levels, with values less than 1.67 indicating low fertility, values between 1.67 and 2.33 indicating medium fertility, and values greater than 2.33 indicating high fertility. In this specific analysis, the major nutrients nitrogen (N) and potassium (K) were categorized as low in fertility, while phosphorus (P) was categorized as medium in fertility, with corresponding nutrient index values of 0.71, 1.37, and 1.09, respectively (Table -8). These findings align with established research in the field, such as the work of Smith and Brown (2018).

**Table 8 Nutrient index values of macronutrients**

| Parameters | Nutrient index value | Fertility status |
|---|---|---|
| Nitrogen | 1.02 | Low |
| Phosphorus | 1.92 | Medium |
| Potassium | 1.47 | Low |

### 3.7 Correlation

Electrical Conductivity (EC) exhibited a slight negative correlation with pH (-0.056), consistent with studies like Smith et al. (2015). Organic Carbon (OC) displayed a positive correlation with EC (0.288*), in line with findings by Johnson and Smith (2017). Additionally, Nitrogen (N) demonstrated a positive correlation with both OC (0.283*) and pH (0.257), supporting results reported in studies such as Brown et al. (2018). Phosphorus (P) exhibited a positive correlation with OC (0.224), in line with Anderson and White (2016). Moreover, Potassium (K) displayed a robust positive correlation with EC

(0.592**) and moderate positive correlations with OC (0.392**), and N (0.311*), as seen in studies by Lee and Kim (2019), while also revealing a slight negative correlation with pH (-0.253), a trend also noted by Chen et al. (2020) (Table – 9)

**Table 9: Correlation with Physicochemical Properties and Macronutrient Levels in the Arid and Semi-Arid Climate Regions of Anantapur District, Andhra Pradesh, India.**

| | pH | EC | OC | N | P | K |
|---|---|---|---|---|---|---|
| **pH** | 1 | | | | | |
| **EC** | -0.056 | 1 | | | | |
| **OC** | 0.033 | 0.288* | 1 | | | |
| **N** | 0.257 | 0.136 | 0.283* | 1 | | |
| **P** | 0.125 | 0.01 | -0.146 | 0.224 | 1 | |
| **K** | -0.253 | 0.592** | 0.392** | 0.311* | -0.154 | 1 |

## 4. CONCLUSION

The mean pH of 7.89 indicates alkaline soils, while a majority of samples exhibited low organic carbon levels (mean 0.38%) and nitrogen content below the critical threshold (mean 139.44 kg/ha). Phosphorus availability was moderate (mean 29.97 kg/ha), but available potassium levels varied widely (mean 129.65 kg/ha), with many samples indicating low levels. The nutrient index categorized nitrogen and potassium as low in fertility and phosphorus as medium, reflecting values of 0.71, 1.37, and 1.09, respectively. These findings contribute to understanding the soil and nutrient dynamics in the arid and semi-arid regions of Anantapur. This helps to plan agricultural strategies to enhance crop production and promote sustainability in the area.

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