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Critical assessment of soil fertility characteristics of long-term chemical fertilized coconut palm fields in India: a sustainability perspective

Sreejamol T. Nadesan[1*], Joseph George Ray[1**]

[1] School of Biosciences, Mahatma Gandhi University, Priyadarshini Hills P.O., Kottayam, Kerala, India – 686560

* Corresponding author: Ph.D. Research Scholar, Laboratory of Ecology and Plant Science, sreejanadesan@mgu.ac.in

**Professor Joseph George Ray Research Guide, School of Biosciences; jgray@mgu.ac.in, ORCID iD: . https://orcid.org/0000-0001-5045-050X

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Abstract

Monitoring soil fertility in chemicalized perennial tree crop fields worldwide is crucial, in line with the UN Sustainable Development Goals (SDG 2). We conducted a random assessment of soil fertility status across the entire six-decade-old chemicalized traditional Coconut fields in Kerala state, South India, across palm varieties, soil types, palm health conditions, and agroclimatic zones in two seasons to critically analyse factors affecting the sustainability of soil fertility in such palm fields. The average physicochemical soil parameters, including soil pH, field water content (FWC), total organic carbon (TOC), soil available nitrogen (SAN), soil available phosphorus (SAP), and soil available potassium (SAK), were determined for each palm grove category and compared. The results revealed that soil pH, FWC, TOC, SAN, SAP, and SAK varied significantly across different Coconut fields, soil types, and seasons. Moreover, a tendency toward soil acidification (pH < 7) was observed in most Coconut fields, reflecting the general impact of long-term chemicalized farming in the region. Most fields were found deficient in SAN and SAK, whereas TOC and SAP were high or moderate. The findings also indicated that nutrient deficiency, particularly in SAK, is common in RWD fields. Overall, the findings suggest the importance of continuous monitoring of NPK nutrient regimes, soil pH, TOC, and above all, soil health parameters in palm fields to ensure the sustainability of Coconut productivity. This study serves as a model for general soil fertility assessments in long-term, chemicalized perennial tree crop fields worldwide.

1. Introduction

The Coconut palm (*Cocos nucifera* L.), the most widely cultivated tree (Daa-Kpode et al., 2021) and the most valuable palm in the world (Owoyemi et al., 2022), is a significant oil crop grown worldwide. It is a tree crop that yields a range of versatile products, including food, drink, sugar, animal feed, fuel, and wood for shelter (Pathirana et al., 2021). Its primary production area is the Asia-Pacific region (Rethinam, 2018), and approximately 80% of its intensive cultivation is concentrated in a few tropical countries. However, it is a globally significant crop cultivated worldwide in 97 nations across three continents: Asia, Africa, and the Americas (Sreeja and Ray, 2024). In many countries, Coconut has a significant economic, social, and cultural role (Rethinam, 2018; Alouw and Wulandari, 2020). Apart from providing valuable edible oil with a multitude of industrial uses, the Coconut palm is a sustainable source of wood material (Sodangi and Kazmi, 2020), agro-industrial raw material (Ramirez et al., 2023), and sugar (Saravia et al., 2023), and is necessary for a sustainable future world. The global demand for various Coconut products is increasing yearly (Abeysekara and Waidyarathne, 2020), and Coconut farming supports the subsistence of millions worldwide (Malhotra et al., 2017; Rethinam, 2018). It is also inevitable for rural agroforestry development in the tropics (Ruba and Talucder, 2023). Therefore, the sustainable cultivation of this plantation oil crop is crucial in achieving the UN Sustainable Development Goals (SDGs) by 2030 (Nuwarapaksha et al., 2022). However, a comprehensive analysis of soil fertility parameters in long-term chemically managed crop fields, especially Coconut fields, from a global sustainability perspective, has not yet been conducted anywhere in the world. The current attempt was to overcome this vacuum.

Supplementary materials for this article are available at: https://www.soilsa.com/SuppFile/221709/1/

India is the third-largest Coconut producer, accounting for 10.61 million metric tons annually (FAOSTAT, 2022). In India, Coconut is grown under varying soil conditions (Subramanian et al., 2018), and soil fertility plays a significant role in the growth, health, and productivity of Coconut palms (Issaka et al., 2012; Chandrakala et al., 2018; Nair et al., 2018b). Soil fertility management and nutrient replenishment through the application of chemical fertilizers or manure in fields is a common practice for improving Coconut yield (Nirukshan et al., 2016). However, the excessive application of chemical fertilizers, pesticides, and insecticides for over six decades of the green revolution has been causing harmful impacts on soil health and fertility of Coconut field soils in India (Chandrakala et al., 2018) and other Coconut-cultivating nations (Nirukshan et al., 2016; Dissanayaka et al., 2022). The excessive application of chemical fertilizers in crop fields, including Coconut fields, has been shown to cause damage to crop and soil health worldwide (Bhattacharyya et al., 2015; Tripathi et al., 2020; Puspaningrum et al., 2023). Notably, the continuous application of diverse chemical fertilizers in fields has a significantly adverse impact on crops and soil (Sahodaran and Ray, 2018; Lins et al., 2021; Varghese and Ray, 2025; Sreejamol and Ray, 2025). Due to the prolonged use of inorganic fertilizers, the soils of Coconut fields in Asian countries, such as Sri Lanka, have begun to show a decline in fertility and productivity (Nirukshan et al., 2016; Dissanayaka et al., 2022). Soil fertility loss has been reported from Coconut fields in South India (Vasundhara et al., 2021).

Coconut is a fast-growing, high-yielding perennial tree crop that can lead to excessive nutrient removal from the soil. Nutrient depletion can be speedy in Coconut palm groves (Somasiri et al., 2003). Accordingly, lack of soil fertility and inadequate nutrition are causing a reduction in the yield of Coconut palms, and their cultivation is becoming unsustainable (Subramanian et al., 2005; Kalidas et al., 2014; Nair et al., 2018a; Sudhalakshmi, 2021) in many parts of the world, including South India. Continuous cultivation of a single crop in an agricultural region over a prolonged period can lead to soil fertility loss and degradation (Lu et al., 2023). Therefore, experts recommend transitioning from monocultures to mixed cropping systems to sustain Coconut farms worldwide (Coconut agroforestry) (Dissanayaka et al., 2023). Although comprehensive nutrient availability evaluations concerning diverse variables exist for many crops (Ray and Nidheesh, 2019; Varghese and Ray, 2023; Joseph and Ray, 2025; George and Ray, 2025), a similar assessment is lacking for perennial Coconut-cultivated fields. Therefore, comprehensively evaluating soil fertility in this long-term chemicalized Coconut cultivation zone, considering agroclimatic zones, crop varieties, crop health, soil types, and seasons, is crucial for generating information to sustain both soil health and global coconut production.

In India, 90 percent of the total Coconut production comes from the four southern states: Andhra Pradesh, Tamil Nadu, Karnataka, and Kerala (CDB, 2021–22). Approximately 75% of cultivation occurs in coastal regions (Devi and Ghatani, 2022). Kerala, the southwestern coastal state of India, is one of the leading Coconut-producing states (Manjula et al., 2014), and Coconut farming plays a crucial role in the state's agro-economy (Thamban et al., 2016). The annual Coconut production in Kerala is 6,942.60 million nuts from an area of 768.81 hectares, with an average productivity of 9,030 nuts/ha (CDB, 2021–22). However, Coconut is currently becoming unsustainable in the state, primarily due to soil fertility depletion, inadequate nutrition, pests, and diseases (Somasiri et al., 2003; Malhotra et al., 2017; Subramanian et al., 2018; Maruthi and Peter, 2019; George and Kuruvila, 2022; Athira and Guledagudda, 2024). Therefore, Kerala has become a global benchmark for assessing soil quality in Coconut farms, particularly in terms of sustainability and productivity.

Since several studies detailing soil fertility status of Coconut farms are already available from different parts of South India (Kavitha and Sujatha, 2015; Chandrakala et al., 2018; Mini and Mathew, 2018; Nair et al., 2018a, 2018b; Vasundhara et al., 2021), a comprehensive comparative assessment of soil fertility parameters of Coconut growing soils over broad areas concerning diverse variables has now become essential. Moreover, specific studies assessing soil fertility for different Coconut varieties are also unavailable in the literature.

Additionally, Coconuts are affected globally by numerous diseases. Among the various diseases of Coconuts, root-wilt disease (RWD) is a severe threat to the Coconut palm globally, especially in South India (Kerala and Tamil Nadu). It is causing heavy economic loss to Coconut farmers (Thamban et al., 2016; Rajendran et al., 2019; KSCSTE, 2021). RWD remains uncontrolled in the state and prevails in the eight southern districts of Kerala at varying intensities (Krishnakumar et al., 2011). Although soil fertility issues and soil health problems are attributed to RWD in Coconut palm-growing areas in Kerala (Verghese, 1966), no comprehensive assessment of the interrelationships among RWD, soil fertility parameters, and soil types in this region has yet been conducted. In the above contexts, a thorough evaluation of soil fertility parameters for the two different agroclimatic zones of Coconut cultivation in the state, including seasons, Coconut varieties, and plant health, has been carried out in the Kerala region of South India.

In the above-mentioned contexts, the primary working goals of the current investigation were: (1) to identify diversity of soil types of Coconut fields (soil orders and soil series) per the USDA system (per existing general soil data based on 'Benchmark Soils of Kerala') in the region, (2) a random assessment of the percentage-wise cultivation of different Coconut varieties in Kerala (3) to determine the current status of soil fertility parameters concerning Coconut growing soil types in the state, (4) to understand variations in soil fertility of fields concerning Coconut varieties such as West Coast Tall (WCT), Chowghat Orange Dwarf (COD), Chowghat Green Dwarf (CGD) cultivated in the state, (5) to examine soil quality over the two major agroclimatic regions (low lands and midlands) of Coconut cultivations in the state, (6) to examine the nutrient status of soils under both healthy and Root-wilt-diseased Coconut palms (7) to know seasonal variations in soil quality parameters in the palm groves of Kerala. Overall, the objectives were to identify soil fertility issues in palm groves related to soil types, agroclimatic zones, palm varieties, palm health conditions, and seasons, and to generate valid data for comparisons worldwide.

2. Materials and methods

2.1. Period of study and study area

A three-year systematic study was conducted from March 2018 to March 2021, accompanied by a detailed investigation of the mycorrhizal community in these fields. However, the details of the mycorrhizal association of Coconut in the region (Sreejamol and Ray, 2024) and the extent of heavy metal contamination in these chemicalized fields (Sreejamol and Ray, 2025) have already been published. The area of study was mainly long-term cheimicalized (since India's green revolution from 1960s) Coconut fields (monocrop plantations) of five representative districts (Kannur, Thrissur, Kottayam, Alappuzha, and Thiruvananthapuram) of Kerala (08°34'40'' to 12°06'52'' N latitudes and 75°16'41'' to 77°05'43'' E longitude) belonging to the two agroclimatic zones of the state, namely the lowlands (elevation below 30m) and midlands (30–300 m) (Fig. 1). Soil samples were taken from the field in the summer (January to May) and monsoon (June to December) seasons. The varieties of Coconut palms cultivated in Kerala's palm groves were identified at random based on their morphological characteristics and included WCT, COD, and CGD (Supplementary Table 1). Based on the health status of the palms, soils selected for the study included those from Healthy and Root-wilt diseased fields. Details of the symptoms affecting both healthy and diseased plants are provided in Supplementary Table 2.

2.2. Soil sampling

The samples were collected from 61 randomly selected Coconut fields located in five representative districts of Kerala: Kannur (20 samples from 10 fields), Thrissur (24 samples from 4 fields), Kottayam (88 samples from 21 fields), Alappuzha (92 samples from 21 fields), and Thiruvananthapuram (24 samples from 5 fields) in two seasons. Only monoculture Coconut fields were selected. Each of the 61 fields sampled was approximately one acre (0.4 ha) in size, and the fields were selected to represent the diverse agroclimatic regions of Coconut cultivation in the state, comprising 43 fields from the lowlands and 18 fields from the midlands. The samples for Coconut varieties, as well as for healthy and diseased Coconut palms, from the 61 fields investigated, often overlapped. Accordingly, the plant variety-wise sites included 52 for WCT and 15 each for COD and CGD (a total of 82). Diseased plants were available only for the WCT variety. Since many of the 61 fields studied included both diseased and healthy WCT palms, the total number of healthy sites was 52, and the number of diseased sites was 42 (total 92). Different sites were randomly sampled from each field for the various categories (specific Coconut varieties and healthy or diseased plants for WCT varieties), per availability. In many cases, different palm varieties and healthy or diseased types (for WCT) were available in the same field. Therefore, the total number of fields for palm varieties and healthy and diseased palms exceeds the total of 61 fields sampled for the study.

The soil sample was collected from 0–20 cm at each palm location. Each sampling site in a field was always located at the base of a Coconut tree (within a 1.5 m area around the trunk). About three small pits of 20 cm depth were made around a tree. A soil sample was collected at 5 cm intervals from a hole, then mixed to form a composite soil sample (approximately 1 kg) from a single site.

The details of soil samples collected from the 61 different fields are given in Supplementary Table 3. Altogether,

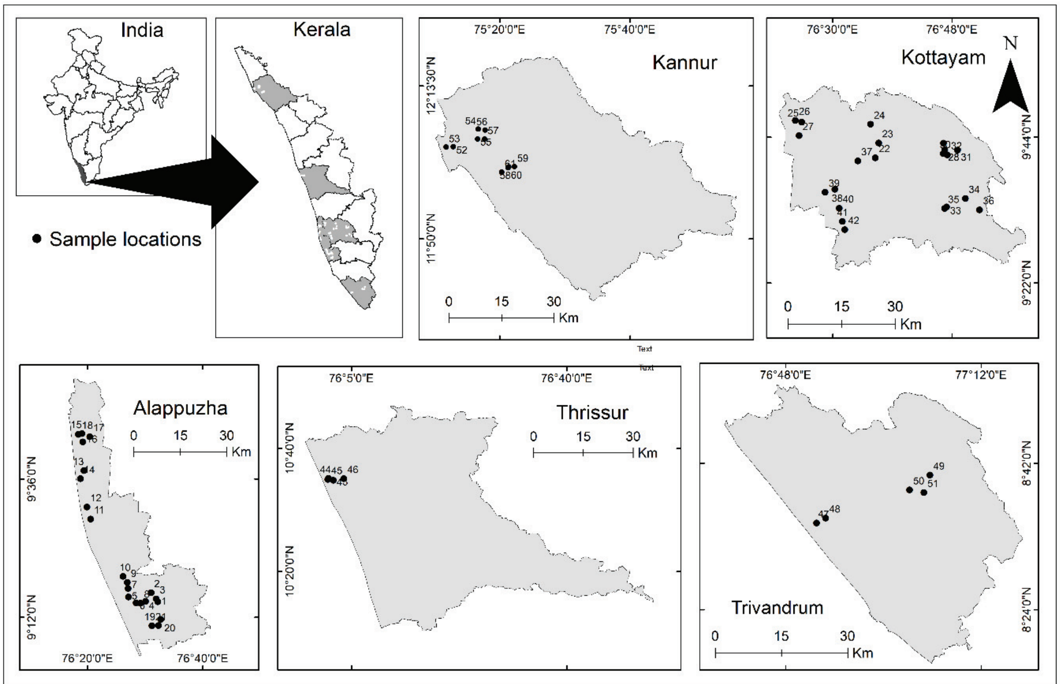

Fig. 1. Location map of the study area

248 composite soil samples (124 samples of monsoon and 124 samples of summer seasons) representing the two agroclimatic zones (180 composite samples representing 43 fields and 68 composite samples representing 18 fields of two seasons), three different Coconut varieties (188 composite samples for WCT from 52 fields; 30 composite samples for COD from 15 fields; 30 composite samples for CGD from 15 fields of two seasons), and healthy (104 composite samples from 52 fields of two seasons) and diseased plants (84 composite samples from 42 fields of two seasons) were collected for the study.

Each composite soil sample from a sampling site was collected into a labelled polythene bag for laboratory studies. The online geographic mapping system was used to ensure the reproducibility of the collection sites. The collected soil samples were air-dried, sieved, and kept under laboratory conditions for various soil chemical analyses.

2.3. Determination of soil types

The soil order and soil series of Coconut cultivated fields per the USDA systems were determined from the Benchmark Soils of Kerala (Soil Survey Organization, 2007) using the GPS coordinates system (Supplementary Table 3).

2.4. Soil Chemical analysis

Chemical analysis of soil samples was carried out using standard methods. Soil pH was measured from a soil suspension of 1:2.5 (soil/water) ratio using a pH meter (HANNA, HI 5522, Hong Kong), and the Field water content (FWC) of the soil was measured gravimetrically (Anderson and Ingram, 1993). The total organic carbon (TOC) was estimated by wet digestion with chromic acid (Walkley and Black, 1934). The soil's available nitrogen (SAN) was measured using the microdiffusion method (Sparks, 1996). The soil-available phosphorus (SAP) was measured using a spectrophotometer (Shimadzu UV-2600, Japan) after extraction with No. 1 Bray and Kurtz solution (Bray and Kurtz, 1945). The soil available potassium (SAK) was measured using a flame photometer (Systronics Flame Photometer 130, India) after extraction with one Normal ammonium acetate solution (Jackson, 1973).

2.5. Statistical analysis

Statistical analysis was conducted using IBM SPSS Statistics version 20 (SPSS Inc., Chicago, IL). The seasonal variations in soil fertility parameters, such as pH, FWC, TOC, SAN, SAP, and SAK, of the studied Coconut fields, considering varieties, palm health conditions, agroclimatic zones, soil order, and soil series, were analyzed using a paired sample t-test. An independent-samples t-test was used to analyze variation in soil fertility parameters across palm health conditions and agroclimatic zones. One-way ANOVA was used to investigate the variation in soil fertility parameters among various Coconut varieties, soil orders, and soil series. Pearson's correlation analysis was used to examine the interrelationships among soil fertility parameters.

3. Results

3.1. Coconut Varieties Identified in Kerala Fields

Among the total 248 Coconut palms randomly sampled from 61 fields, 188 palms were WCT (76%), 30 palms were COD (12%), and 30 were CGD (12%).

3.2. Soil types of the Coconut-cultivated fields of Kerala

The soils of Coconut-cultivated fields randomly sampled from five districts of Kerala belonged to 14 different soil series of four soil orders: Ultisols, Entisols, Inceptisols, and Spodosols (Supplementary Table 4). Entisols is the most commonly observed soil order in Coconut-cultivated soils in Kerala, according to the current survey, with eight soil series identified. The Coconut varieties, such as WCT and CGD, were found growing in all soil orders, including Ultisols, Entisols, Inceptisols, and Spodosols, whereas the Coconut variety COD was not found in Spodosols. Among the three varieties identified in the study, the tall cultivar WCT was found in all 14 soil series, whereas the dwarf cultivars CGD and COD were found in specific 11 and 8 soil series, respectively. The diseased and healthy plants were found in almost all soil orders. However, diseased and healthy plants were found across all soil series in the districts of Thiruvananthapuram, Alappuzha, Kottayam, and Thrissur. In contrast, diseased plants were absent in the two soil series, *Arathil* and *Narikkot*, of the Kannur district.

3.3. Agroclimatic zones of Coconut-cultivated fields of Kerala

The Coconut-cultivated fields selected for the present study are located in the agroclimatic zones of lowland (elevation below 30 m) and midland regions (30–300 m) in Kerala. Among the 61 Coconut-cultivated fields investigated in the current study, 43 (70.4%) were located in the lowland region, and 18 (29.6%) were located in the midland region. In some fields in both the lowlands and midlands, the three different varieties were found cultivated together. Of the 43 lowland fields, WCT was found in 39 fields (90%), whereas COD and CGD were found in only 10 fields (23% each). However, among the 18 midland fields, WCT was detected in 13 (72%), whereas COD and CGD were detected in only 5 (27%). Regarding diseases, RWD-affected Coconut palms were found in 42 fields (69%), 31 lowland fields (51%), and 11 midland fields (18%).

3.4. Physicochemical soil parameters of Coconut fields of Kerala

The edaphic factors significant to Coconut palms in the fields assessed include soil pH, field water content (FWC), total organic carbon (TOC), soil available nitrogen (SAN), soil available phosphorus (SAP), and soil available potassium (SAK). The range and average value of different soil parameters for the entire set of soil samples studied are presented in Supplementary Table 5. However, the ecological amplitude of soil parameters for each palm variety, agroclimatic zone, healthy and root-wilt-diseased palm fields, soil order, and soil series, along with their statistical details, is presented in Table 1.

Table 1
Ecological amplitude and statistical details of soil parameters of fields concerning different palm varieties, agroclimatic zones, healthy and root wilt-diseased coconut palm fields, soil orders, and soil series of Kerala

Categories		pH	FWC (%)	TOC (%)	SAN (kg ha^{-1})	SAP (kg ha^{-1})	SAK (kg ha^{-1})
Coconut varieties	WCT	4.11–8.29	1.02–36.75	0.1–4.3	51.33–457.33	6.5–184.85	22.40–632.80
	COD	5.36–7.53	1.08–25.93	0.06–3.11	46.66–466.68	4.05–106.35	29.68–275.54
	CGD	4.6–6.96	1.41–23.17	0.16–2.88	51.34–434	6.59–115.62	22.40–232.01
	Statistical significance (ANOVA) (*P*>0.05)	sig = 0.055	sig = 0.627	sig = 0.177	sig = 0.365	sig = 0.344	sig = 0.001
Agroclimatic zones	Lowlands	4.26–8.29	1.02–36.75	0.06–4.3	46.66–457.33	10.02–184.85	22.40–632.80
	Midlands	4.11–8.08	2.5–26.86	0.1–3.2	65.33–466.68	4.05–128.52	33.60–627.2
	Statistical significance (Independent t-test) (*P*>0.05)	sig = 0.670	sig = 0.000	sig = 0.228	sig = 0.000	sig = 0.102	sig = 0.145
Palm health	Healthy palms	4.11–8.12	1.02–36.75	0.1–3.22	56–340.67	7.47–184.85	22.40–632.80
	RWD affected palms	4.34–8.29	1.02–27.85	0.18–4.3	51.33–457.33	6.5–170.5	28.56–378.04
	Statistical significance (Independent t-test) (*P*>0.05)	sig = 0.311	sig = 0.044	sig = 0.316	sig = 0.362	sig = 0.011	sig = 0.115
Soil orders	Ultisols	4.26–8.08	2.5–25.32	0.1–3.2	51.33–238	4.05–179.11	39.2–632.8
	Entisols	4.34–8.29	1.02–36.75	0.06–4.3	46.66–457.33	11.34–184.85	22.4–610.92
	Inceptisols	4.11–6.9	8.6–26.86	0.58–3.11	74.66–466.67	11.11–87.33	78.21–627.20
	Spodosols	5.93–7.26	2.2–14.88	0.18–1.71	70–177.33	10.02–41.06	22.40–305.09
	Statistical significance (ANOVA) (*P*>0.05)	sig = 0.025	sig = 0.000	sig = 0.000	sig = 0.000	sig = 0.000	sig = 0.001
Soil series	Arathil	4.26–8.08	2.5–15.27	0.1–3.2	51.33–224	33.25–179.11	67.2–632.8
	Narikkot	5.13–8.12	16.28–36.75	1.72–3.22	158.67–336	163.94–184.85	296.8–604.8
	Manathala	5.09–6.93	1.02–25.93	0.15–1.82	51.34–275.33	16.37–111.93	22.4–136.27
	Kottapuram	4.42–6.92	5.84–19.82	0.64–2.12	70–228.67	7.47–121.72	47.60–386.40
	Manjoor	5.05–6.92	2.92–23.45	0.34–4.3	60.67–457.33	11.34–146.83	95.20–610.92
	Paippara	4.11–6.84	9.24–26.86	0.58–3.11	98–466.67	11.11–87.83	78.40–627.20
	Parampuzha	4.6–6.9	8.6–21.4	0.9–2.99	74.66–331.33	12.22–51.74	78.21–218.40
	Mannar	4.34–8.07	1.02–27.85	0.34–3.08	51.33–242.67	12.41–170.5	35.84–560.13
	Champakulam	4.83–6.98	4.7–18.28	0.06–2.13	46.66–200.67	13.05–41.1	45.73–250.34
	Alappuzha	5.93–7.26	2.2–14.88	0.18–1.71	70–177.33	10.02–41.06	22.40–305.09
	Punnapra	5.14–8.29	1.92–20.78	0.12–1.7	56–144.67	14.86–37.87	29.68–327.17
	Kazhakootam	5.75–6.93	7.43–17.43	0.22–1.24	102.67–135.33	15.63–34.49	50.4–75.41
	Amaravila	5.14–6.88	9.40–26.72	0.16–1.22	135.33–289.33	22.10–90.98	33.6–79.15
	Nedumangad	4.86–6.82	5.62–25.32	0.22–2.12	65.33–238	4.05–105.76	39.2–240.8
	Statistical significance (ANOVA) (*P*>0.05)	sig = 0.302	sig = 0.000	sig = 0.000	sig = 0.000	sig = 0.000	sig = 0.001

Explanations
Coconut varieties:WCT – west coast tall, COD – Chowghat orange dwarf, CGD – Chowghat green dwarf.
Soil fertility parameters: FWC – field water content, TOC – total organic carbon, SAN – soil available nitrogen, SAP – soil available phosphorus, SAK – soil available potassium.

3.4.1. Soil pH, FWC, and TOC

Out of the 248 composite soil samples collected from 61 fields, 85% showed a pH range of 5.5 to 7.5, 12% below 5.5, and 3% above 7.5. The ANOVA revealed a significant difference in soil pH among 248 samples from Coconut-growing sites ($P < 0.05$, sig = 0.000). The soil samples generally showed a significant seasonal variation in soil pH during the summer and monsoon seasons ($P < 0.05$, sig = 0.043). However, no significant difference in soil pH was observed between soil samples of different Coconut variety growing sites ($P>0.05$, sig = 0.055), lowland and midland sites ($P > 0.05$, sig = 0.670), healthy and diseased sites ($P > 0.05$, sig = 0.311), and different soil series (Table 1). ANOVA showed a significant difference in pH between different palm fields belonging to soil orders ($P<0.05$, sig = 0.025). In general, WCT showed the broadest amplitude in soil pH (4.11 to 8.29), followed by COD (5.36 to 7.53), and CGD had the narrowest amplitude (4.6 to 6.96).

The field water content (FWC) of Coconut palm cultivated soils of the entire study field, irrespective of seasons, ranged from 1.02 to 36.75%. The ANOVA revealed a significant difference in FWC among 248 samples from different coconut-growing sites ($P < 0.05$, sig = 0.000). The soil samples generally showed a significant seasonal variation in FWC between the summer and monsoon seasons ($P < 0.05$, sig = 0.000). The diseased plant sites generally showed a significantly higher FWC ($P < 0.05$, sig = 0.044) than the healthy ones. However, a season-wise analysis revealed that the difference in FWC is significant ($P < 0.05$, sig = 0.046) only during the monsoon season. Statistical analysis revealed significant differences in FWC among agroclimatic zones ($P < 0.05$, sig = 0.000), soil orders ($P < 0.05$, sig = 0.000), and soil series ($P < 0.05$, sig = 0.000). However, the difference in FWC of different Coconut variety growing sites was insignificant. In general, the WCT showed the broadest amplitude in FWC (1.02 to 36.75%), followed by COD (1.08 to 25.93%), and CGD had the narrowest amplitude (1.41 to 23.17%).

Among the 248 composite soil samples collected from 61 fields, 66% had TOC above 0.75% (high), 19% between 0.5% and 0.75% (medium), and 15% below 0.5% (low). The ANOVA revealed a significant difference in TOC between 248 samples from Coconut-growing sites ($P < 0.05$, sig = 0.000). Generally, soil samples showed significant variation in TOC across the summer and monsoon seasons ($P < 0.05$, sig = 0.000). However, there was no significant difference in TOC across different Coconut variety growing sites ($P > 0.05$, sig = 0.177), healthy and diseased sites ($P > 0.05$, sig = 0.316), and lowland and midland sites ($P > 0.05$, sig = 0.228). ANOVA revealed significant variations in TOC between soil samples of different soil orders ($P < 0.05$, sig = 0.000) and between the various soil series ($P < 0.05$, sig = 0.000). A comparison of the TOC amplitude of the three varieties reveals that WCT has the broadest amplitude (0.1% to 4.3%), followed by COD (0.06% to 3.11%), and CGD has the narrowest amplitude (0.16% to 2.88%).

3.4.2. Soil Nutrients (SAN, SAP, and SAK)

A critical analysis of SAN over 248 composite soil samples collected from 61 fields revealed that 94% of the samples contained SAN levels below 280 kg ha^{-1} (low), and 6% had levels between 280 and 560 kg ha^{-1} (medium). The ANOVA revealed a significant difference in SAN between 248 samples from Coconut–growing sites ($P < 0.05$, sig = 0.000). The soil samples generally showed a significant seasonal variation in SAN between the summer and monsoon seasons ($P < 0.05$, sig = 0.000). However, ANOVA showed no significant difference in SAN between soil samples from different Coconut variety growing sites ($P > 0.05$, sig = 0.365). Independent sample t–test revealed a significant difference in SAN between soil samples of lowland and midland sites ($P < 0.05$, sig = 0.000) but no significant difference in SAN between soil samples of healthy and diseased sites ($P > 0.05$, sig = 0.362). However, ANOVA revealed significant differences in SAN between soil orders ($P < 0.05$, sig = 0.000) and soil series ($P < 0.05$, sig = 0.000). A comparison of the SAN amplitude of the three varieties revealed that COD has the broadest amplitude (46.66 to 468.68 kg ha^{-1}), followed by WCT (51.33 to 457.33 kg ha^{-1}), and CGD has the narrowest amplitude (51.34 to 434 kg ha^{-1}).

In general, 58% of the samples showed SAP above 25 kg ha^{-1} (high), 40% between 10 and 25 kg ha^{-1} (medium), and 2% below 10 kg ha^{-1} (low). The ANOVA revealed a significant difference in SAP between 248 samples of Coconut-growing sites ($P < 0.05$, sig = 0.000). The soil samples generally showed a significant seasonal variation in SAP over the summer and monsoon seasons ($P < 0.05$, sig = 0.002). In general, SAP of healthy Coconut growing sites showed a significantly higher SAP ($P < 0.05$, sig = 0.011) than the diseased sites, but no significant difference was observed in SAP between soil samples of lowland and midland sites ($P > 0.05$, sig = 0.102) and different Coconut variety growing sites ($P > 0.05$, sig = 0.344). However, ANOVA revealed significant variation in SAP between various soil orders ($P < 0.05$, sig = 0.000) and soil series ($P < 0.05$, sig = 0.000). A comparison of the SAP amplitude of the three varieties reveals that WCT has the broadest amplitude (6.5 to 184.85 kg ha^{-1}), followed by CGD (6.59 to 115.62 kg ha^{-1}), and COD has the narrowest amplitude (4.05 to 106.35 kg ha^{-1}).

An examination of Coconut fields regarding SAK revealed that 51.2% of the samples showed a SAK below 120 kg ha^{-1} (low), 37.09% between 120 and 280 kg ha^{-1} (medium), and 11.69% above 280 kg ha^{-1} (high). The ANOVA revealed a significant difference in SAK between 248 samples from Coconut-growing sites ($P < 0.05$, sig = 0.000). Generally, soil samples showed significant seasonal variation in SAK during the summer and monsoon seasons ($P < 0.05$, sig = 0.000). However, there was no significant difference in SAK between soil samples of healthy and diseased sites ($P > 0.05$, sig = 0.115) and between lowland and midland sites ($P > 0.05$, sig = 0.145). ANOVA showed a significant variation in SAK between soil samples of different Coconut variety growing sites ($P < 0.05$, sig = 0.001), soil orders ($P < 0.05$, sig = 0.001), and soil series ($P < 0.05$, sig = 0.000). A comparison of the SAK amplitude of the three varieties reveals that WCT has the broadest amplitude (22.40 to 632.80 kg ha^{-1}), followed by COD (29.68 to 275.54 kg ha^{-1}), and CGD has the narrowest amplitude (22.40 to 232.01 kg ha^{-1}).

Pearson's correlation analysis examined the interrelationships among soil fertility parameters and different palm varieties, as well as healthy and root-wilt-diseased palms, across diverse agroclimatic zones in the traditional Coconut groves of Kerala.

4. Discussion

In general, Coconuts stand out as a unique horticultural crop and are among the most significant palm species in the humid tropics. Diverse varieties of Coconuts, including tall, dwarf, and hybrids, are cultivated in various regions worldwide (Niral and Jerard, 2018; Subramanian et al., 2018; Niral et al., 2019; CDB, 2022). However, in the current investigation, only three varieties, namely WCT, COD, and CGD, were visibly identified in the studied Coconut fields in Kerala. However, the most commonly grown Coconut variety in Kerala, as noted in the fields currently, was WCT, which agrees with previous observations in the state (Manjula et al. 2014; Subramanian et al. 2018). The dwarf cultivars observed in the fields, such as COD and CGD, were also the most commonly grown dwarf varieties reported in earlier studies from India (Niral and Jerard, 2018; Subramanian et al., 2018; CDB, 2022). Although several Coconut cultivars and hybrids are suitable for growing across all areas of Kerala (Subramanian et al., 2018), the limited visibility of only these three varieties is a significant limitation of Coconut farming in the state. Some rare varieties cultivated may have been missed in this random survey, which is a limitation of this study. Similarly, a selection of Coconut fields for soil sample collections might not have encompassed all the different types of Coconut-growing soil in the state. However, a sufficient number of samples (248) from randomly selected fields allowed for a reasonable interpretation of the facts regarding Coconut-growing soil types in the region.

Coconut cultivation in Kerala occurs across diverse agroclimatic zones and soil conditions (Issaka et al., 2012; Manjula et al., 2014). This study identified 14 Coconut-cultivated soil series across four soil orders: Ultisols, Entisols, Inceptisols, and Spodosols. While Ultisols, Alfisols, and Entisols are generally considered suitable for Coconut growth in Kerala (Nair et al., 2018a; Surendran et al., 2019), this survey found that Entisols are the most prevalent soil type. It aligns with findings from the South Eastern Ghats of Tamil Nadu region, where Entisols are the primary soil type used for Coconut cultivation, while others, such as Inceptisols, Alfisols, and Vertisols, are also used for the same purpose (Srinivasan et al., 2021). In southern Karnataka, Inceptisols, Alfisols, and Ultisols are the primary soils for Coconut cultivation (Avinash et al., 2019). Furthermore, Ultisols, Entisols, Alfisols, and Oxisols are reported in Sri Lanka (Loganathan et al., 1984). Therefore, while this survey highlighted Entisols as the most common soil type for Coconut in Kerala, further research is needed worldwide to determine Coconut's preferred soil type.

The survey indicated that RWD incidence is limited to WCT Coconut varieties and is more common in the coastal lowlands than in the midlands of Kerala, supporting Nayar's (1980) observation that waterlogged conditions increase disease susceptibility. However, the absence of RWD in the *Arathil* and *Narikkot* soil series of the Kannur district, which belong to lowland zones, contradicts this belief. These regions exhibited higher TOC, SAP, and SAK levels than others, suggesting that nutrient sufficiency, rather than waterlogging, may be a key factor in disease resistance. It aligns with observations of Cecil and Amma (1998), who linked potassium deficiencies to RWD. Conversely, Verghese (1966) associated high nitrogen levels with increased disease incidence, potentially explaining the absence of RWD in *Arathil* and *Narikkot* soils of Kannur, which had low nitrogen levels. Therefore, further research is warranted to fully elucidate the role of soil nutrients in the incidence of RWD in Kerala Coconut fields.

Coconut palms thrive in soils with a pH of 5 to 7, according to previous studies (Chan & Elevitch, 2006; Malhotra et al., 2017). In this survey, however, soil pH varied widely (4.34–8.29), consistent with previous findings in Coconut fields of Kerala (Ambili et al., 2012; Rajeshkumar et al., 2015; Chandrakala et al., 2018; Mini & Mathew, 2018; Nair et al., 2018a, 2018b) and Karnataka (Vasundhara et al., 2021). Other regions within and outside India also exhibit similar variability: Tamil Nadu (6.84–9.90; Sudhalakshmi, 2021), Mexico (7.5–7.6; Lara-Perez et al., 2020), and Lakshadweep (6.6–7.5; Gopal et al., 2022). Notably, most soil samples (90.72%) in the current study fell within the ideal pH range, while only 4.83% were strongly acidic (pH < 5) and 4.43% were alkaline (pH > 7). Similar wide fluctuations in pH levels in Coconut fields have rarely been documented earlier, with values ranging from below 5 (Chandrakala et al., 2018; Ambili et al., 2012) to above 7 (Vasundhara et al., 2021; Rajeshkumar et al., 2015). Thus, the current study endorsed a pH range of 5 to 7 as ideal for Coconut cultivation in soils.

Coconut palm soils (Ultisols, Entisols, and Inceptisols) are generally acidic with low fertility (Malhotra et al., 2017). This survey found that most soil samples from Ultisols (96%), Entisols (94.02%), and Inceptisols (100%) had a pH below 7. Diseased palm sites also showed a predominantly acidic pH (96.42% below 7), consistent with previous findings (Verghese, 1966; Cecil and Amma, 1998). Since it is well-known that prolonged chemicalized cultivation and base leaching in wet tropical climates may contribute to pH remaining below seven even in good soils (Salim et al., 2015; Chandrakala et al., 2018; Khadka et al., 2019), the role of chemicalized farming, acidification of soils, and especially, prevalence of RWD in acidic soils needs further investigation.

Analysis of 248 soil samples from Kerala's Coconut-growing regions revealed a significant negative correlation between soil pH and field water content (FWC), consistent with existing literature (Za'rate-Valdez et al., 2006; Gazali et al., 2020). This negative correlation was more pronounced in soils supporting WCT and CGD Coconut varieties, particularly in lowland fields. While WCT sites exhibited the widest range of pH and FWC values, CGD sites showed the narrowest. Given the interdependence of soil pH and plant nutrient availability, as well as the soil- and plant-dependent nature of nutrient acquisition (Barrow and Hartemink, 2023), this study emphasizes the need for further detailed research to understand the implications of the stronger negative correlation between pH and FWC in WCT and CGD growing sites.

Maintaining optimal soil moisture is essential for Coconut yield (Kumar et al., 2006). However, FWC varies significantly across Coconut fields in Kerala, indicating a lack of ideal conditions and effective water conservation practices. This moisture stress negatively affects coconut growth, fertilizer requirements, and water use (Verghese, 1966). The observed wide FWC range (1.02 to 36.75% annually) highlights increased water stress on Coconut trees. FWC variation likely stems from differences in soil management, water-holding capacity, irrigation, and fertilization (Subramanian et al., 2005). While an ideal FWC depends on factors such as soil and climate, excessive moisture can harm palms by promoting root pathogens (Williamson-Benavides and Dhingra, 2021) and limiting oxygen availability for root activity. A higher FWC at diseased palm sites than at healthy sites supports the link between high moisture and RWD in Coconut fields of Kerala (Verghese, 1966).

Correlation analysis showed a positive relationship between FWC and TOC, SAN, and SAK, consistent with previous research highlighting strong interrelationships between soil moisture and organic carbon (Kerr and Ochsner, 2020), soil nitrogen (Zhang and Wienhold, 2002; Lu et al., 2025), and soil potassium (Sardi and Fulop, 1994). However, category-wise analysis revealed a positive correlation between FWC and TOC in WCT-growing soils, COD-growing soils, lowlands, and both healthy and diseased palm-growing soils. It suggests that increased soil moisture may enhance biological activity on dead organic matter, such as Coconut leaf litter, leading to increased soil organic carbon (Fang et al., 2022), regardless of other variables. However, since soil moisture affects nutrient availability, further research is needed to explore the interrelationship between soil moisture content and optimum nutrient availability to palms, especially in Coconut fields.

In general, soil organic carbon plays a significant role in soil fertility and productivity (Meena, 2023; Kimaro et al., 2024). Since more than 50% of Earth's land is used for agriculture, monitoring and finding ways to enhance carbon content in these fields is crucial, as field soils are essential for both food security and carbon conservation, both of which are crucial for a stable climate (Zomer et al., 2017). Additionally, organic carbon is a crucial source of nutrients essential for crop growth, and it also contributes to various other aspects of soil fertility (Karthika et al., 2019), such as enhancing soil structure and increasing porosity.

Coconut plantations show a high potential for carbon storage among agricultural fields (Chanlabut and Nahok, 2023). The range of TOC (0.06 to 4.3%) observed in the studied Coconut fields is similar to previous reports from Kerala and other parts of India (Ambili et al., 2012; Kavitha and Sujatha, 2015; Rajeshkumar et al., 2015; Chandrakala et al., 2018; Mini and Mathew, 2018; Sudhalakshmi, 2021; Gopal et al., 2022) and other countries (Lara-Perez et al., 2020). Although the TOC of the majority (65.72%) of the Coconut fields exceeded 0.75%, the current range of carbon in the Coconut fields (0.06–4.3%) indicates that further carbon conservation is possible in the region. It can be achieved through agroforestry (Hombegowda et al., 2016; Dissanayaka et al., 2023) and the integration of suitable intercrops in Coconut fields (Huang et al., 2023), as well as the implementation of integrated nutrient management practices (Shinde et al., 2020), to enhance carbon sequestration in Coconut fields. The comparatively high TOC observed in some fields of Kerala may be attributed to a continuous natural or purposeful addition of organic matter, such as Coconut waste biomass, including fallen leaves and Coconut husks (Kumar, 2004; Subramanian et al., 2009; Thankamani et al., 2022), and organic manuring in such fields (Subramanian et al., 2005; Chandrakala et al., 2018; Vasundhara et al., 2021). Correlation analysis between TOC and other variables revealed that, among the 248 soil samples analyzed, TOC showed a positive correlation with SAN, SAP, and SAK. It is in agreement with several previous reports, which highlight the positive correlation of soil organic carbon with soil nitrogen (Wibowo and Kasno, 2021; Zhou et al., 2023), soil phosphorus (Hou et al., 2014; Azene et al., 2022; Yan et al., 2023; Rahman et al., 2024), and soil potassium (Swamanna et al., 2015; Kaur, 2019; Vanitha and Subbarayappa, 2022) in crop fields. Moreover, strong interrelationships exist between TOC, N, P, and K (Wibowo and Kasno, 2021; Zhang et al., 2021), which are well known in soils. Although soil organic carbon and soil nitrogen are closely linked components of soil organic matter (SOM) (Farzadfar et al., 2021), this positive relationship indicates a strong stoichiometric connection between carbon and nitrogen in SOM pools (Wibowo and Kasno, 2021). Similarly, the interaction between carbon and phosphorus controls microbial reactions that mineralize organic P compounds, leading to increased soil-reactive phosphorus and higher soil organic carbon (Rahman et al., 2024). In addition, the positive relationship between carbon and potassium may indicate that SOC influences K in rhizospheric soil (Kai-lou et al., 2022). However, positive interrelationships were found between carbon and nitrogen, as well as between potassium, only in WCT, COD, and CGD growing soils, including those in lowlands, midlands, and healthy and diseased palm-growing soils. A positive interrelationship of carbon with phosphorus was visible only in WCT-growing soils, lowlands, and healthy and diseased palm-growing soils. Such interrelationships in soils may be influenced by vegetation, climate, and specific soil properties (Swamanna et al., 2015; Li et al., 2017; Santana et al., 2019; Chen et al., 2022; Zhou et al., 2023).

Soil nitrogen is an essential plant nutrient vital to crop production and varies with soil type (Selvamani et al., 2017). Among the significant Coconut-growing soils in India, sandy soils are known to have a low amount of soil nitrogen (Khan and Krishnakumar, 2018) because of high nitrate loss through leaching from such soils (Malhotra et al., 2017), whereas clay content enhances N fixation in soils (Thabit et al., 2023). In general, Coconut-growing soils in Kerala encompass a range of soil types, including clayey, loamy, and sandy soils (Nair et al., 2018a). In the current study, approximately 72% of the samples were from coastal sandy soil regions, and the remaining samples were from midland loams. As expected, a significant difference in N content ($P < 0.05$) was observed between the two soils in the current study. Soil nitrogen (N) is one of the most significant nutrients in field soils, influencing crop sustainability. Since it is a costly nutrient and more than 50% of it is lost from fields through leaching or denitrification, measures to improve nitrogen use efficiency (NUE) of crops in fields (Govindaswamy et al., 2023) and conservation of N in fields are significant in achieving the sustainability of agricultural productivity of all crops. Generally, soil N at 280 kg ha^{-1} in a field is considered low (Byju, 2001). In the current study, most soil samples of the palm fields (94%) showed low nitrogen levels. Similar low nitrogen levels have been reported in Coconut fields of Tamil Nadu (Sudhalakshmi, 2021) and Karnataka (Vasundhara et al., 2021). A low level of N in the fields is part of good farm conservation management (Valenzuela, 2023).

On the contrary, only 4% of the soil samples showed a medium range (280–560 kg ha ą) of N in the soils, similar to a previous report from Coconut fields of Kerala (Kavitha and Sujatha, 2015).

Therefore, N management in most Coconut palm fields in Kerala may be considered safe. However, factors contributing to low SAN in Coconut fields may include diverse variables, including negative impacts from leaching, volatilization, immobilization, and denitrification. The present findings emphasize the need for further investigation through intensive study. However, the range of SAN observed in the current study (46.66 to 466.68 kg ha^{-1}) indicated that the NUE of Coconut fields in the state has not yet been standardized. Previously, similar instability, characterized by a wide variation in N content, has been observed in Coconut fields of Kerala (Ambili et al., 2012; Kavitha and Sujatha, 2015; Rajeshkumar et al., 2015) and Karnataka (Vasundhara et al., 2021). Excessive removal of N and crop harvest without proper compensation for N added to the soil (Hofman and Cleemput, 2004) can also lead to low N levels in the field. Therefore, monitoring N management in Coconut fields in Kerala has become significant to sustaining soil health and Coconut productivity in the region. Regarding the interrelationship between soil N and palm health, no significant differences in N content were observed in the rhizospheres of diseased palms compared to those of healthy palms in the current study, as was previously observed (Verghese, 1966).

Correlation analysis in Coconut fields showed a positive relationship between soil available nitrogen and FWC, TOC, SAP, and SAK, consistent with existing literature on soil moisture (Zhang and Wienhold, 2002; Lu et al., 2025), organic carbon (Sainju et al., 2021; Wibowo and Kasno, 2021), phosphorus (Yang and Luo, 2021), and potassium (Zhang et al., 2010) in soils. However, these relationships were primarily observed in lowland Coconut farms and were only partial in other conditions (WCT-growing soils, COD-growing soils, CGD-growing soils, midlands, and healthy versus diseased plant sites). While the spatial variability of soil nutrients is well documented (Xue-song et al., 2019), the interrelationships among them, as observed in the current study, warrant further intensive investigation.

While phosphorus (P) is generally sufficient in Coconut fields of Kerala (Khan and Krishnakumar, 2018), low P levels have been reported in various other Coconut-growing regions of India (Selvamani et al., 2017; Vasundhara et al., 2021; Gopal et al., 2022). It is also deficient in Coconut cultivation zones in many other countries (Issaka et al., 2012; Nirukshan et al., 2016; Khan and Krishnakumar, 2018). However, consistent with earlier findings (Kavitha and Sujatha, 2015; Mini and Mathew, 2018; Nair et al., 2018b), this study observed high soil available P (SAP) in most (58%) Coconut fields, particularly in Ultisols (77.77%) and Entisols (57.46%) fields. Despite the known P deficiency in Entisols in Sri Lanka (Loganathan et al., 1984), the high P content in Kerala's Coconut fields is likely due to the regular application of chemical fertilizers. Moreover, the wide variation in soil available phosphorus (SAP) (4.05 to 184.85 kg ha^{-1}) observed in this study, consistent with findings from Kerala, (Kavitha and Sujatha, 2015; Mini and Mathew, 2018), Tamil Nadu (Sudhalakshmi, 2021), Karnataka (Vasundhara et al., 2021) and Lakshadweep (Gopal et al., 2022) indicated a lack of standardized phosphorus fertilizer management in South Indian Coconut fields. The high P content in Kerala Coconut fields is likely due to the indiscriminate application of manure and phosphatic fertilizers. (Kavitha and Sujatha, 2015).

SAP in the studied Coconut fields showed a positive correlation with TOC, SAN, and SAK, consistent with prior studies that have demonstrated a positive relationship between soil phosphorus (Hou et al., 2014; Azene et al., 2022; Yan et al., 2023; Rahman et al., 2024) and organic carbon and nitrogen. (Yang and Luo, 2021). This interrelationship likely stems from the influence of SOC and total nitrogen, key factors governing soil P fractions (Azene et al., 2022). The same author also demonstrates that soil organic matter makes a significant contribution to maintaining soil phosphorus reserves. However, these strong interrelationships between SAP and other soil parameters are primarily observed in lowland fields. In WCT, COD, CGD, and soils of both healthy and diseased palms, the observed relationships were only partial. While no direct studies correlate SAP with other soil nutrients across crop varieties, agroclimatic zones, and palm health, our findings suggest influences from vegetation, soil type, topography, and fertilization (Qaswar et al., 2019; Xue-song et al., 2019). Therefore, the findings suggest the scope for further intensive research to clarify such interrelationships between SAP and other soil parameters observed in Coconut fields.

While potassium (K) is abundant in soils (Weil and Brady, 2017), its availability to potassium-demanding monocots, such as Coconut, depends on the parent material composition (Graham and Fox, 1971). Humid tropical Coconut fields typically have low to medium K content, unlike alluvial and black soils (Malhotra et al., 2017). Coconut removes 3–4 times more K than nitrogen and phosphorus (Malhotra et al., 2017). Kerala's weathered laterite and sandy soils are deficient in K-bearing minerals due to leaching and poor cation exchange capacity (Nair et al., 2018b; Rajasekharan et al., 2014). Accordingly, coconut-cultivated fields in Kerala are generally K-deficient (Khan and Krishnakumar, 2018). This study found low K levels in most (51.2%) Coconut fields, consistent with prior research in Kerala (Rajeshkumar et al., 2015; Mini and Mathew, 2018; Nair et al., 2018b) and Karnataka (Vasundhara et al., 2021). The K deficiency observed in diseased palm-growing sites (47.61%) aligns with earlier findings (Cecil and Amma, 1998). Similar to nitrogen and phosphorus, a wide range of available K (22.40 to 632.80 kg ha^{-1}) indicated a lack of standardized K content in the region's Coconut fields, echoing previous observations in Kerala (Mini and Mathew, 2018), Tamil Nadu (Sudhalakshmi, 2021), Karnataka (Vasundhara et al., 2021), and Lakshadweep (Gopal et al., 2022). However, the range reported by Kavitha and Sujatha (2015) in Kerala (4 to 1790 kg ha^{-1}) was even broader. This low K content in Kerala Coconut fields may result from leaching in the heavily rain-fed region or imbalanced fertilizer application (Kavitha and Sujatha, 2015). The current observations, therefore, emphasize that continuous K monitoring is crucial for sustainable Coconut production in the region. Furthermore, the potential for excessive K to induce magnesium deficiency (Lins et al., 2021) warrants further intensive study.

Correlation analysis revealed a positive interrelationship among SAK, FWC, TOC, SAN, and SAP in the Coconut fields of

Kerala, corroborating previously established relationships. This positive correlation was particularly evident in WCT and soils supporting healthy palms, but less pronounced in soils associated with COD, CGD, lowlands, midlands, and diseased palms. While direct studies linking SAK with soil nutrients relative to crop varieties, agroclimatic zone, and palm health are lacking, the observed correlation may stem from similar chemical fertilizer applications in the fields (Liu et al., 2024), parent material chemistry (Osayande et al., 2022), or other factors like vegetation, soil type, and topography (Qaswar et al., 2019; Xue-song et al, 2019). However, observations of such interrelationships also warrant intensive research to explore the underlying reasons in crop fields, especially in the Coconut fields of Kerala.

5. Conclusions

The study correlating soil properties with soil type, crop variety, agroclimatic zone, and plant health in Kerala's Coconut fields revealed that optimal soil conditions for sustainable production depend on soil type and season, with Entisols being the most common soil order. The study identified relationships between specific crop varieties and health conditions (RWD) with soil types and fertility parameters. The West Coast Tall (WCT) variety showed the broadest tolerance to soil variations. While nutrient variations (except in SAP) were generally insignificant between healthy and RWD-affected soils, moisture levels (FWC) varied significantly between the two. Correlations between soil parameters and soil types, particularly in the *Arathil* soil series, suggested that nutrient deficiencies, rather than FWC variations, contributed to RWD susceptibility in Coconut. Six decades of chemicalized cultivation have decreased soil pH across the region. Low levels of SAN and SAK, coupled with high SAP and TOC, indicated a need for improved NPK nutrient management to address low Coconut yields in the region. This comparative assessment, which correlates soil, environmental, and crop variables, can facilitate continuous monitoring of nutrient deficiencies and promote sustainable crop productivity globally, contributing to UN SDG 2. It serves as a model for assessing soil fertility under long-term chemicalized cultivation.

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Data Availability Statement

All the associated data are given in the supplementary tables.

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Conflict of interest

The authors declare no conflict of interest. The authors also declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. This research did not involve human or animal subjects.

Author Contributions

Sreejamol T. Nadesan – Investigation, Methodology, Validation, Writing – original draft.

Joseph George Ray – Conceptualization, Methodology, Supervision, Visualization, Writing – review & editing. All authors read and approved the final manuscript.

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