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SOIL QUALITY IN PADDY FIELDS OF COASTAL KARNATAKA, INDIA

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Abstract

Coastal soils are typically nutrient-dense, acidic and extremely saline. Synthetic N:P:K supplementation and biofertilizers are essential for paddy cultivation. Global warming causes the ozone depletion, creating a harsh agro-environment for crop plants and beneficial soil organisms. Physico-chemical analysis was carried out for the twenty-five soil samples collected from the paddy fields of Coastal Karnataka in the present study. The results of the soil experiment indicated that TMR$_3$ (S$_2$) was more acidic (4.06), and the pH was essentially supported by the extremely low amount of organic carbon material in the HK (S$_2$) region (0.63%). With the exception of sulphur (S), which is less available and negatively correlated with other soil properties, it also exhibits a positive correlation with micronutrients (Ca, Mg, Zn, Cu, Fe, Mn and B). The highest content of macronutrients is nitrogen 502.00 kg/ac in the GSUK region, phosphate 27.30 kg/ac in the SK (S$_1$), and potassium 402.66 kg/ac in the HUK region. The results indicate that the more acidic-saline soil is harmful to rice crops, and less beneficial to agriculture.

Key words: *paddy soil, algal bloom, cyanobacteria, global warming, synthetic and biofertilizers.*

INTRODUCTION

Soil is a region found directly on the surface of the Earth that serves as a natural growing medium for plants. They differ from their parent materials in a number of physico-chemical and bio-morphological ways. The Earth's surface contains loose mineral and organic matter that reflects the effects of genetic and environmental factors, such as climate, temperature, and water variations, as well as macro and microorganisms that function throughout time on parent material and are regulated by solution. The quantity of different sized inorganic particles in soil is a significant determinant of its texture. Understanding soil texture is necessary, which produces awareness of soil behaviour, including sensation, colour, sound and cohesion. Sand, silt and clay particle proportions determine the physical properties of soil, including its texture. Given that many plants require soil that drains properly, soil drainage is an important factor to consider. Plants that have poorly drained soil may experience stunting or even death as a result of inadequate oxygen reaching their roots. The soil system is composed of clay particles and the pores that link them. Soils with a structure that promotes plant development contain stable aggregates. Clays are very chemically active and retain nutrients on their surface better than other inorganic components. As soon as these nutrients are released into soil water, plants can start using them. Like nutrients, water also clings to the soil's top, although it is difficult for plants to consume. Iron, silicon, and aluminium make up the majority of the chemical components of soil's inorganic minerals, but they don't do much to satisfy the nutritional needs of plants. The organic matter component of soil comes from biodegradable components. Organic matter in the soil contributes to stable soil aggregation by binding soil particles together. Organic elements are regularly added by soil-dwelling plants through their roots and excrement. This organic waste is broken down by microbes, which releases nutrients for other plants to thrive on. Certain proteins, starches and sugars can all be easily broken down by microorganisms. The presence of significant organic content and less easily degradable materials like lignin and tannin gives the soil its black colour. An essential subgroup of semi-wetland, paddy soils are characterized by water saturation, which controls soil development as well as the kinds of plant and animal populations. The pedogenic characteristics and shape of paddy soil differ from those of dry land because it floods for several months of the year (Kawaguchi & Kyuma, 1977). Iron and manganese may form in paddy soil as a result of the repeated puddling and drying (redox cycle) of dissolved iron and manganese that build up in the B horizon (Kurniati et al., 2016). Field crops may face challenges due to the pedogenic characteristics and shape of paddy soil, even if a crop rotation plan is in place prior to planting. Top-layered paddy soil is less conducive to farming. Plow pan layers will negatively impact root development and crop nutrient availability. Paddy soil morphology varied generally according to the intensity of rice farming (i.e., the length of time the soil was immersed) during a year. The distinct features of paddy soil, which are made up of minerals, water, air, and soil organic materials (SOMs), include the soil's texture, structure, and porosity. The numerous minerals, organic matter, and nutrients that are present, determine the soil's chemical composition. The pH of the soil regulates the amount of organic matter, soil organism activity, and mineral concentration. The coastal parts of Karnataka are classified according to their soil geography as red, black, lateritic, alluvial-colluvial, forest, and coastal soils (laterite or coastal alluvium). Most coastal soils are clay and loamy in texture, with small amounts of silt and sand, saline to very saline, low to well-drained conditions, low to high organic matter content, and deficiencies or toxicity in certain minerals (Velayutham et al., 1999; Shamsudheen & Dasog, 2005; Paul & Rashid, 2017). They are also less productive because of their low organic content (Patil & Anil Kumar, 2014), which is usually a primary indicator of the poor physical quality of coastal soils. A negligible quantity of nitrogen, ranging from 1 to 1.5% is also present (SRDI, 2001). Similarly, most coastal soil shortages in copper and zinc are associated with low phosphorus concentrations (Karim et al., 1990). High salinity negatively affects agriculture claim (Mahajan et al., 2015), because the inherent functional characteristics of soil fertility are changed by both natural and man-made influences. Moreover, a range of abiotic stresses affect coastal soils. The coastal agricultural area is mostly marshy, moist, saline, alkaline and acid sulphate. The majority of coastal soils have an acidic pH with the top soil surface being primarily acidic and the lower areas being slightly alkaline to neutral. This ecosystem's low land and water productivity is therefore mostly caused by unfavourable weather, deteriorating soil health and poor water quality. Thus, it is necessary to create appropriate agro-strategies for higher agricultural yields. By using natural resources and a population of people and livestock, coastal Karnataka's economy depends on tourism and agriculture to give both rural and urban dwellers a steady level of living and food security. There is also a vast variety of plants from tropical rainforest and mangrove ecosystems. Thus, the present work aims to give detailed note on soil properties of paddy field in Coastal Karnataka which supports the agriculture.

This study aims to analyse the impact of saline environments and soil properties on the water logged paddy fields ecosystem in Coastal Karnataka. By investigating the region's unique soil characteristics and their influence on paddy cultivation, the research seeks to provide insights into sustainable agricultural practices and soil management strategies tailored to saline environments.

MATERIALS AND METHODS

Study Area

A remarkable natural ecosystem, the Coastal Karnataka, which includes portions of the Sahyadri Mountains and Western Ghats, lies between the lithospheric and hydrospheric sections of the Arabian Sea's Western Peninsula, and is home to Konkan region. The state of Karnataka covers roughly 320 km^2 of the Arabian Sea. The distribution of the region stretches to the plains of Kerala to the south, at latitudes of 15° 19' 2.1972" N and longitude of 75° 42' 50.0040" E. Over 1000 km^2 on the southwest coast of India, from Karwar, the capital of Uttara Kannada, to Mangalore, the principal city of Dakshina Kannada, lies Coastal Karnataka also known as the Kanara and Karavali region and it is a historically significant area.

Method of soil sampling

A total of 1000 grams of soil samples were taken from each sampling site using (particular spot utilizing) the Z and V-shaped sampling methods. The soil samples were dug up to a depth of 30 cm using a digger, and the samples were subsequently sealed in the sterile zip bags. From the Coastal Karnataka taluks, a total of 25 paddy field soil samples were collected during the period of February 2023 to May 2024 as shown in Table 1. The soil samples were subsequently air-dried under shaded laboratory conditions to maintain their physical and chemical properties for analysis.

Macro and micro nutrient evaluation

The colour, texture, type, moisture, density, pH, electrical conductivity, organic carbon, nitrogen, phosphate, potassium, magnesium, sulphur, manganese, iron, copper, and zinc of soil in agricultural ecosystems were estimated by the standard laboratory methods for physico-chemical examination listed in Table 2.

Table 1. Soil samples collected from the paddy fields of Coastal Karnataka

Collection site code	Village or place	Taluk	District	Geographical coordinates (D˚M′ S″)	
				Latitude (N)	Longitude (E)
HK (S_2)	Halga	Karwar	Uttara Kannada	14˚52′ 24.9″	74˚13′ 17.5″
KK (S_1)	Kinnar	Karwar		14˚52′ 00.2″	74˚12′ 23.8″
SK (S_1)	Sawantwada	Karwar		14˚53′ 14.6″	74˚09′ 48.6″
$AKUHR_1$ (S_1)	Hosur	Ankola		14˚35′ 44.1″	74˚22′ 58.0″
$AKSR_2$ (S_2)	Shiroor	Ankola		14˚36′ 03.1″	74˚21′ 51.4″
GKR_2 (S_1)	Gokarna	Kumta		14˚32′ 52.7″	74˚20′ 05.3″
$GKTR_3$ (S_2)	Torke (Gokarna)	Kumta		14˚33′ 27.3″	74˚21′ 02.7″
DJUK	Durgi	Joida		15˚20′ 15.8″	74˚32′ 07.1″
BSUK	Bisalkoppa	Sirsi		14˚32′ 37.1″	74˚49′ 32.7″
GSUK	Ghattikai	Siddapur		14˚31′ 02.4″	74˚50′ 32.8″
YUK	Yallapur	Yallapur		14˚59′ 08.7″	74˚43′ 12.6″
HUK	Halyal	Halyal		15˚19′ 53.1″	74˚44′ 38.7″
KGMUK	Kop Gotgudi	Mundagod		14˚45′ 40.0″	75˚01′ 28.1″
DUK	Dandeli	Dandeli		15˚14′ 39.3″	74˚37′ 37.4″
UDR_3	Doddanagudde	Udupi	Udupi	13˚21′ 46.2″	74˚49′ 42.9″
UDR_4 (S_2)	Devinagar	Udupi		13˚20′ 52.7″	74˚49′ 01.0″
$BKUS_1$	Brahmavar	Brahmavar		13˚25′ 52.3″	74˚45′ 39.1″
BKU	Kundapura	Kundapura		13˚37′ 07.5″	74˚41′ 48.6″
KKU	Karkala	Udupi		13˚13′ 55.3″	74˚53′ 34.0″
TMR_3 (S_2)	Thiruvali	Mangaluru	Dakshina Kannada	12˚55′ 12.1″	74˚55′ 00.2″
TUB	Thannirapantha	Beltangady		12˚52′ 59.3″	75˚14′ 46.0″
BSDK	Bellare	Sulya		12˚39′ 43.3″	75˚22′ 21.6″
KPDK	Kemminje	Puttur		12˚44′ 56.4″	75˚13′ 36.1″
KKDK	Kadaba	Kadaba		12˚44′ 49.6″	75˚27′ 59.6″
KBDK	Kula	Bantwala		12˚46′ 40.3″	75˚08′ 35.1″

Table 2. Physico-chemical properties of soil and standard analytical methods

Depth (cm)	Parameters	Analytical method	References
0 to 30	Texture	Hydrometric	Das et al. (2020)
	Moisture (%)	Gravimetric	Das et al. (2020)
	Density (g/cm^3)	Core	Jabro et al. (2020)
	pH (1:2.5)	Potentiometry	Jackson (1973)
	EC (ds/m)	Conductometry	Jackson (1973)
	OC (%)	Wet oxidation	Walkley & Black (1934)
	N (kg/ac)	Alkaline permanganate	Subbiah & Asija (1956)
	P (kg/ac)	Olsen's P	Olsen et al. (1954)
	K (kg/ac)	Flame photometry	Richards (1954)
	Ca (meq/100g)	Versenate titration	Jackson (1973)
	Mg (meq/100g)		
	S (ppm)	Turbidometry	Black (1965)
	Zn (ppm)	DTPA extraction AAS	Lindsay & Norvell (1978)
	Cu (ppm)		
	Fe (ppm)		
	Mn (ppm)		
	B (ppm)	Hot water soluble extraction	Devi & Sumathy (2017)

Statistical analysis

The IBM SPSS statistics, version 20 software and XLSTAT applications were used to analyse the soil properties using principal component analysis, Pearson correlations, and cluster analysis for qualitative cluster characteristics of locations based on geography.

RESULTS AND DISCUSSIONS

The results show significant variations in the physicochemical properties of coastal paddy field soils.

The coastal soil is laterite to medium black in colour, with a loamy texture that also contains sand and silt. BKU had the highest moisture content in this analysis, measuring 48.00±0.57, whereas HUK, GSUK, AKSR$_2$ (S$_2$), and KK (S$_1$) had intermediate moisture contents, measuring 25.00±0.57 to 26.00±0.57. Lastly, very low moisture content was found in GKR$_2$ (S$_1$) that is 18.00±0.57. The density in TMR$_3$ (S$_2$) is high at 49.99±48.50, whereas GKTR$_3$ (S$_2$) displays a medium range of 6.18±4.61 and TUB had a significantly lower value of 1.28±0.0, as shown in Table 3.

Table 3. Physical properties of collected soil samples from the different paddy fields of Coastal Karnataka

Site (code)	Moisture	Density	Colour	Type	Texture
HK (S$_2$)	23.50 ± 0.28^{i,j,k}	1.54 ± 0.08^{b}	Laterite yellow	Laterite	Sandy loam
KK (S$_1$)	25.00 ± 0.57^{h,i}	1.72 ± 0.15^{b}	Laterite yellow	Laterite	Sandy loam
SK (S$_1$)	22.00 ± 0.57^{k}	1.45 ± 0.0057^{b}	Laterite yellow	Laterite	Sandy loam
AKUHR$_1$ (S$_1$)	23.00 ± 0.57^{j,k}	1.52 ± 0.057^{b}	Laterite yellow	Laterite	Sandy loam
AKSR$_2$ (S$_2$)	26.00 ± 0.57^{h}	1.61 ± 0.057^{b}	Laterite yellow	Laterite	Sandy loam
GKR$_2$ (S$_1$)	**18.00 ± 0.57^{l}**	1.44 ± 0.011^{b}	Laterite yellow	Laterite	Sandy loam
GKTR$_3$ (S$_2$)	22.00 ± 0.57^{k}	6.18 ± 4.61^{b}	Laterite yellow	Laterite	Sandy loam
UDR$_3$	23.00 ± 0.57^{j,k}	1.52 ± 0.0088^{b}	Laterite yellow	Laterite	Sandy loam
UDR$_4$ (S$_2$)	23.00 ± 0.57^{j,k}	1.54 ± 0.0057^{b}	Laterite yellow	Laterite	Sandy loam
TMR$_3$ (S$_2$)	24.00 ± 0.57^{i,j}	**49.99 ± 48.50^{a}**	Laterite yellow	Laterite	Sandy loam
DJUK	30.00 ± 0.57^{f}	1.45 ± 0.011^{b}	Laterite yellow	Laterite gravel	Sandy loam
BKUS	41.00 ± 0.57^{b}	1.48 ± 0.0057^{b}	Laterite yellow	Laterite gravel	Sandy loam
KBDK	35.00 ± 0.57^{d}	1.42 ± 0.0082^{b}	Laterite yellow	Laterite gravel	Sandy loam
BSUK	38.00 ± 0.57^{c}	1.43 ± 0.0057^{b}	Laterite yellow	Laterite	Silt loam
GSUK	26.00 ± 0.57^{h}	1.42 ± 0.0088^{b}	Laterite yellow	Laterite	Silt loam
YUK	41.00 ± 0.57^{b}	1.35 ± 0.0057^{b}	Laterite yellow	Laterite	Silt loam
KGMUK	42.00 ± 0.57^{b}	1.36 ± 0.0057^{b}	Laterite yellow	Laterite	Silt loam
DUK	36.00 ± 0.57^{d}	1.40 ± 0.057^{b}	Laterite yellow	Laterite	Silt loam
KKU	28.00 ± 0.57^{g}	1.37 ± 0.0088^{b}	Laterite yellow	Laterite	Silt loam
TUB	28.00 ± 0.57^{g}	**1.28 ± 0.0057^{b}**	Laterite yellow	Laterite	Silt loam
BSDK	41.00 ± 0.57^{b}	1.36 ± 0.0057^{b}	Laterite yellow	Laterite	Silt loam
KPDK	38.00 ± 0.57^{c}	1.34 ± 0.0057^{b}	Laterite yellow	Laterite	Silt loam
KKDK	32.33 ± 0.88^{e}	1.37 ± 0.0057^{b}	Laterite yellow	Laterite	Silt loam
HUK	26.00 ± 0.57^{h}	1.37 ± 0.0088^{b}	Laterite yellow	Medium laterite	Silt loam
BKU	**48.00 ± 0.57^{a}**	1.38 ± 0.0057^{b}	Medium black	Medium black	Silt loam

The mean of the replicates ± standard error (SE) is represented for each value. A significant difference (Duncan's multiple range test, $P < 0.01$) was demonstrated by a one-way ANOVA with distinct letters in a column representing probability values.

According to recent research findings, soil characteristics have an impact on plant crops, the environment, and beneficial soil organisms. But the best soil texture material preserves pore space, which implies that air and water may support life. Paddy field soil contains complex chemical properties that are more crucial for plant development and the beneficial biological life of the soil shown in Table 4. The pH of the soil varied significantly across the samples. KGMUK had the highest pH at 6.44±0.01, while HUK and HK (S$_2$) exhibited medium pH levels of 5.33±0.14 to 5.34±0.08, and finally lowest pH was observed in TMR$_3$ (S$_2$) at 4.06±0.01. Both beneficial microbial populations and plants are influenced by pH (Zhang et al., 2017; Li et al., 2020). Although it naturally varies based on the surroundings, the acidity level is increased by the use of specific fertilizers (Song et al., 2022). However, due to the acidifying nature of coastal soils, a high algal biomass content leads to breakdown and CO_2 enters the soil through coastal waters; an extensive fertilizer application, on the other hand, produces the biological content. In the interaction of soil health with ecosystems and the environment, pH plays a critical role in ensuring the development of high-quality agricultural products and food security. But according to Gentili et al. (2018), pH controls both major and minor nutrient absorption. Rice, groundnuts, cucumbers, tuber crops, and other agro-crops along the coastline are under stress due to the low to moderate pH range (4.06±0.01 to 6.44±0.01), which is almost acidic.

Table 4. Chemical evaluation of soil samples collected from paddy fields of Coastal Karnataka

Sample I D	**Chemicals Parameters**		
	pH (1:2.5)	**EC (ds/m)**	**OC (%)**
HK (S_2)	$5.34 \pm 0.08819^{g,h}$	1.41 ± 0.057^{b}	**0.63 ± 0.057^{j}**
KK (S_1)	$5.44 \pm 0.13868^{f,g}$	**3.61 ± 0.11^{a}**	0.71 ± 0.086^{j}
SK (S_1)	4.25 ± 0.00577^{m}	$0.05 \pm 0.0057^{i,j}$	$1.08 \pm 0.0057^{d,e}$
$AKUHR_1$ (S_1)	$4.16 \pm 0.00577^{m,n}$	$0.07 \pm 0.0057^{h,j}$	$1.14 \pm 0.0033^{c,d}$
$AKSR_2$ (S_2)	5.88 ± 0.03512^{b}	0.94 ± 0.020^{c}	$0.94 \pm 0.0082^{f,g,h,i}$
GKR_2 (S_1)	4.44 ± 0.02028^{l}	0.04 ± 0.0057^{j}	$1.07 \pm 0.011^{d,e,f}$
$GKTR_3$ (S_2)	$4.53 \pm 0.01155^{k,l}$	**0.04 ± 0.0057^{j}**	$0.97 \pm 0.011^{e,f,g,h}$
UDR_3	4.23 ± 0.00577^{m}	$0.06 \pm 0.0057^{h,i,j}$	$0.95 \pm 0.0082^{e,f,g,h,i}$
UDR_4 (S_2)	4.56 ± 0.00882^{k}	$0.06 \pm 0.0057^{h,i,j}$	$0.92 \pm 0.0082^{g,h,i}$
TMR_3 (S_2)	**4.06 ± 0.01202^{n}**	$0.07 \pm 0.0082^{h,i,j}$	$0.96 \pm 0.0082^{e,f,g,h}$
DJUK	4.95 ± 0.01764^{j}	$0.34 \pm 0.014^{d,e}$	**1.70 ± 0.11^{a}**
TUB	$5.23 \pm 0.00577^{h,i}$	$0.22 \pm 0.0057^{f,g}$	$0.96 \pm 0.0082^{e,f,g,h}$
BSUK	5.64 ± 0.01155^{d}	0.43 ± 0.088^{d}	$1.25 \pm 0.014^{b,c}$
BSDK	$5.84 \pm 0.01453^{b,c}$	$0.15 \pm 0.0082^{g,h,i,j}$	$1.26 \pm 0.0082^{b,c}$
KPDK	$5.47 \pm 0.00882^{e,f}$	$0.30 \pm 0.057^{e,f}$	1.36 ± 0.0057^{b}
BKUS	5.76 ± 0.00577^{c}	$0.18 \pm 0.0057^{g,h}$	1.30 ± 0.057^{b}
GSUK	$5.25 \pm 0.00882^{h,i}$	$0.35 \pm 0.0082^{d,e}$	$0.96 \pm 0.0082^{e,f,g,h}$
KKDK	5.15 ± 0.00882^{i}	$0.24 \pm 0.012^{e,f,g}$	$1.03 \pm 0.0082^{d,e,f,g}$
YUK	4.95 ± 0.00577^{j}	$0.26 \pm 0.0057^{e,f,g}$	$0.95 \pm 0.011^{e,f,g,h,i}$
KBDK	5.20 ± 0.05774^{i}	$0.16 \pm 0.0082^{g,h,i}$	1.34 ± 0.0082^{b}
HUK	$5.33 \pm 0.01453^{g,h}$	$0.30 \pm 0.057^{e,f}$	$1.26 \pm 0.088^{b,c}$
KGMUK	**6.44 ± 0.01453^{a}**	$0.17 \pm 0.0082^{g,h}$	$1.14 \pm 0.012^{c,d}$
DUK	$5.55 \pm 0.01202^{d,e}$	$0.32 \pm 0.0057^{e,f}$	1.35 ± 0.0082^{b}
BKU	$5.82 \pm 0.00577^{b,c}$	$0.18 \pm 0.0057^{g,h}$	0.84 ± 0.011^{i}
KKU	$5.25 \pm 0.00882^{h,i}$	$0.17 \pm 0.0082^{g,h}$	$0.87 \pm 0.011^{h,i}$

The mean of the replicates ± standard error (SE) is represented for each value. A significant difference (Duncan's multiple range test, $P < 0.01$) was demonstrated by a one-way ANOVA with distinct letters in a column representing probability values.

The electrical conductivity is then examined and found to be higher in KK (S_1) at 3.61±0.11, and medium in HUK, KPDK, and DJUK at 0.30±0.05 to 0.34±0.01. Finally, in TMR_3 (S_2), UDR_4 (S_2) and UDR_3, it is extremely low at 0.04±0.00. The combined effect of pH and electrical conductivity (EC) on pH variations brought on by both natural and man-made farming procedures (fertilizer application) indicates that salinity increases electrical conductivity. Although higher nitrogen concentrations caused plant stress, which affects rice production grade, they did not increase the pH range with EC. According to Huang et al. (2017), nitrogen fertilization frequently increases the pH and electrical conductivity of soil. Most plants usually relate to the range of 0.8 to 2.5 mS/m, although salt-sensitive plants require 1 to 2.6 mS/m. In this case, coastal agriculture is generally supported by the total EC (0.04±0.0 to 3.61±0.11). Additionally, the proportion of soil organic carbon is very low in HK (S_2) (0.63±0.05), medium in GKR_2 (S_1) and KKDK (1.03±0.0082 to 1.07±0.011), and high in DJUK (1.70±0.11).

Naturally, coastal soils with lower fertility levels support less organic matter; exposure to organic carbon has a positive correlation with these soil microbial activities (Nisha et al., 2018), and pH has a positive correlation with the inter-root bacterial population in maize (Wang et al., 2018). Jin et al. (2020) claim that treating the soil with rice straw successfully preserved soil organic carbon.

However, with the help of soil microorganisms the plant waste progressively dissolves down after harvesting, raising the amount of organic carbon elements. The results showed that the amount of organic matter in coastal paddy soils ranged from 0.63±0.05 to 1.70±0.11, which is low to moderate. The composition of organic matter in soil is more popular for microbial diversity than the composition of sand, despite the fact that organic matter both directly and indirectly serves as a primary source of food and energy for the microbial community (Rashid et al., 2016; Naylor et al., 2022).
Biological processes that enrich soil organic matter with carbonates are driven by the photosynthetic contribution of primary producers and photosynthetic microorganisms such as cyanobacteria (Singh et al., 2016). According to Plante & McGill (2002), soil contains cyanobacterial discharges. The development of stable macro-aggregates and a reduction in the soil's C:N ratio brought on by the breakdown of organic waste are important aspects of remediation. Prior to the discovery of macro and micronutrients in this parametric investigation, soil matter was more than just a physico-chemical property, as indicated in Table 5. Here, nitrogen (N), phosphate (P), and potassium (K) are macronutrients; calcium (Ca), magnesium (Mg), sulphur (S), zinc (Zn), copper (Cu), iron (Fe), manganese (Mn) and boron (B) are micronutrients. Furthermore, during this experiment a significant nitrogen concentration (502.00±0.57) was found in GSUK. In DUK, DJUK and YUK a modest range of nitrogen levels (351.00±0.57 to 337.00±0.57) was found. Lastly, UDR_3 showed a relatively low nitrogen concentration (221.00±0.57). More importantly, plants use inorganic conditions like ammonium nitrate to absorb nitrogen-limited organic resources. Ammonia volatilization and the use of chemical fertilizers are two natural processes that increase the pH of soil. The nitrogen needs of rice crops were satisfied by chemical fertilizers (Lin et al., 2013). The primary element controlling rice crop is nitrogen; fertilizers can damage rice crops and increase global temperatures, which further increases the likelihood of global warming as a result of CO_2 produced from paddy fields (Park et al., 2023).
Growth of paddy fields, therefore elevated levels of nitrogen-based fertilizers might negatively affect rice crops and increase global temperatures, which would increase the likelihood of global warming as a result of CO_2 emissions from paddy fields (Park et al., 2023). Coastal paddy soil has moderate to high levels of accessible soil nitrogen, ranging from 221.00±0.57 to 502.00±0.57, according to this analysis. Manure is being substituted by microbial-based biofertilizers (Tirol et al., 1982), which is a very efficient source of nitrogen and increases the production of rice (Roger & Kulasooriva, 1980). Therefore, using biofertilizers like cyanobacteria, *Azotobacter*, *Azospirillum*, *Rhizobium*, and so on can improve agricultural land both economically and environmentally. In sandy soils, nitrate from core soil seeps around the root zone, and in flooded soils, nitrogen fixation by bacteria converts gaseous nitrogen into a form that plants can use. However, nitrate from core soil is not immediately available to plants. Additionally, by raising the soil's N and P content and promoting development through the secreting of phytohormones, nitrogen-fixing bacteria have a major effect on plant growth (Hameeda et al., 2008). Phosphate content is another important macronutrient that is moderately available in KKU, BKU, DUK, HUK, BSDK, BSUK and HK (S_2) at 14.26±0.08 to 16.80±0.05, while it is high in SK (S_1) at 27.30±0.65. However, the phosphate concentration in TMR_3 (S_2) and UDR_4 (S_2) is extremely low at 8.00±0.57. Phosphate is critical for rice production and influences crop productivity. Its excessive use, along with the presence of heavy metals like Pb, Hg, and As in rice, increases the risk of food insecurity (Cao et al., 2009; Dang et al., 2016). The overuse of phosphate fertilizers affects paddy crops and can reduce yields. The easy and natural availability of nitrate and the rise in phosphate content have a virtuous effect on the domination of soil microbes (Zancan et al., 2006; Yandigeri et al., 2011). These parameters are also effective indicators of anthropogenic compression to the agro-environment (Zutshi et al., 1984), and field soil benefits from this as well (Roger & Kulasooriya, 1980).

Table 5. Micro and macro nutrient concentration of soil samples collected from paddy fields of Coastal Karnataka

Sample I D	Macronutrients			Micronutrients							
	N (kg/ac)	P (kg/ac)	K (kg/ac)	Ca (meq/100 g)	Mg (meq/100 g)	S (ppm)	Zn (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	B (ppm)
HK (S_2)	324.00 ± 0.57^{k}	16.30 ± 0.057^{e}	92.23 ± 0.62^{i,j}	5.43 ± 0.29^{i}	2.76 ± 0.18^{j,k}	14.50 ± 0.30^{c}	0.62 ± 0.12^{e,f}	0.41 ± 0.057^{g,h}	11.50 ± 0.31^{b}	9.17 ± 0.54^{h}	0.27 ± 0.03^{i,j}
KK (S_1)	265.16 ± 0.60^{q}	10.70 ± 0.057^{k}	116.00 ± 0.57^{h,i}	10.20 ± 0.05^{a}	5.40 ± 0.057^{g}	10.55 ± 0.0088^{g}	**0.22 ± 0.0057^{h}**	0.56 ± 0.0057^{e,f,g,h}	14.56 ± 0.0057^{b}	11.22 ± 0.0057^{f}	0.62 ± 0.0057^{f}
SK (S_1)	229.16 ± 0.60^{r}	**27.30 ± 0.65^{a}**	56.18 ± 0.60^{k,l}	2.20 ± 0.05^{k}	2.00 ± 0.57^{l,m}	11.70 ± 0.24^{f}	**0.22 ± 0.0057^{h}**	0.50 ± 0.057^{f,g,h}	17.16 ± 0.60^{b}	9.23 ± 0.033^{h}	0.45 ± 0.0088^{h}
AKUHR$_1$ (S_1)	364.16 ± 0.60^{h}	11.70 ± 0.11^{j}	51.43 ± 0.18^{k,l,m}	5.56 ± 0.17^{i}	2.50 ± 0.057^{k,l}	10.51 ± 0.057^{g}	0.42 ± 0.0088^{g}	0.33 ± 0.011^{h}	19.55 ± 0.020^{b}	11.24 ± 0.020^{f}	0.26 ± 0.011^{j}
AKSR$_2$ (S_2)	283.80 ± 0.15^{p}	12.60 ± 0.11^{h,i}	227.53 ± 0.23^{d,e}	6.46 ± 0.17^{h}	3.23 ± 0.088^{i,j}	11.73 ± 0.12^{f}	0.25 ± 0.0088^{h}	0.42 ± 0.0088^{g,h}	19.63 ± 0.011^{b}	12.54 ± 0.011^{d,e}	0.32 ± 0.0088^{i}
GKR$_2$ (S_1)	400.50 ± 0.11^{d}	11.70 ± 0.11^{j}	35.00 ± 0.57^{l,m}	2.40 ± 0.11^{k}	1.33 ± 0.088^{n}	11.53 ± 0.14^{f}	0.32 ± 0.0088^{g,h}	0.55 ± 0.0057^{e,f,g,h}	**392.37 ± 380.81^{a}**	8.93 ± 0.014^{h}	0.52 ± 0.0088^{g}
GKTR$_3$ (S_2)	265.70 ± 0.11^{q}	18.60 ± 0.15^{d}	**22.26 ± 0.0088^{m}**	**1.70 ± 0.11^{l}**	0.66 ± 0.088^{o}	16.26 ± 0.088^{b}	0.53 ± 0.017^{f}	0.33 ± 0.014^{h}	17.50 ± 0.11^{b}	9.25 ± 0.014^{h}	0.25 ± 0.0088^{j}
UDR$_3$	**221.00 ± 0.57^{s}**	13.53 ± 0.088^{g}	81.33 ± 0.088^{j,k}	2.70 ± 0.057^{j}	1.20 ± 0.057^{n}	9.53 ± 0.011^{h}	0.43 ± 0.011^{g}	**0.26 ± 0.011^{h}**	**4.55 ± 0.012^{b}**	**3.12 ± 0.0088^{k}**	0.45 ± 0.014^{h}
UDR$_4$ (S_2)	368.00 ± 0.57^{g}	**8.00 ± 0.57^{l}**	57.22 ± 0.012^{k,l}	2.33 ± 0.088^{k}	1.56 ± 0.088^{m,n}	11.54 ± 0.0088^{f}	0.28 ± 0.0057^{h}	0.72 ± 0.0088^{d,e,f,g}	14.53 ± 0.011^{b}	13.00 ± 0.57^{c,d}	0.45 ± 0.0057^{h}
TMR$_3$ (S_2)	368.00 ± 0.57^{g}	**8.00 ± 0.57^{l}**	45.34 ± 0.012^{l,m}	8.64 ± 0.011^{e}	**0.60 ± 0.057^{o}**	10.52 ± 0.0088^{g}	0.32 ± 0.0057^{g,h}	0.96 ± 0.0057^{c,d}	17.40 ± 0.057^{b}	9.020 ± 0.0057^{h}	**0.23 ± 0.088^{j}**
DJUK	351.00 ± 0.57^{i}	10.30 ± 0.11^{k}	126.00 ± 0.57^{g,h}	7.05 ± 0.0088^{g}	5.73 ± 0.088^{f,g}	8.18 ± 0.017^{j,k}	0.75 ± 0.014^{d}	0.73 ± 0.011^{d,e,f,g}	7.56 ± 0.12^{b}	10.66 ± 0.088^{g}	**1.36 ± 0.0057^{a}**
TUB	391.00 ± 0.57^{e}	20.20 ± 0.057^{c}	395.00 ± 0.57^{a}	8.64 ± 0.011^{e}	4.80 ± 0.057^{h}	7.63 ± 0.088^{l}	**1.20 ± 0.057^{a}**	1.05 ± 0.0057^{b,c,d}	6.00 ± 0.57^{b}	5.70 ± 0.11^{j}	0.75 ± 0.011^{e}
BSUK	403.33 ± 0.88^{c}	15.40 ± 0.11^{f}	301.00 ± 0.57^{c}	6.57 ± 0.011^{h}	3.66 ± 0.088^{i}	12.93 ± 0.012^{d}	0.94 ± 0.0088^{b}	0.86 ± 0.0088^{c,d,e,f}	5.95 ± 0.011^{b}	14.63 ± 0.14^{b}	0.84 ± 0.011^{d}
BSDK	431.00 ± 0.57^{b}	15.40 ± 0.11^{f}	402.00 ± 0.57^{a}	8.95 ± 0.008^{d}	4.73 ± 0.088^{h}	16.46 ± 0.12^{b}	0.66 ± 0.088^{d,e}	**2.00 ± 0.57^{a}**	7.70 ± 0.11^{b}	7.70 ± 0.11^{i}	1.02 ± 0.0057^{b}
KPDK	297.00 ± 0.57^{o}	10.30 ± 0.11^{k}	241.33 ± 0.88^{d}	9.60 ± 0.057^{b,c}	6.20 ± 0.057^{e,f}	9.03 ± 0.011^{i}	0.95 ± 0.011^{b}	0.85 ± 0.011^{c,d,e,f}	12.00 ± 0.57^{b}	**15.83 ± 0.011^{a}**	0.85 ± 0.011^{d}
BKUS	302.00 ± 0.57^{m,n}	13.00 ± 0.57^{g,h}	283.33 ± 1.20^{c}	9.50 ± 0.11^{b,c}	9.76 ± 0.088^{b}	**20.36 ± 0.088^{a}**	0.87 ± 0.0057^{b,c}	1.06 ± 0.0088^{b,c,d}	12.40 ± 0.11^{b}	10.36 ± 0.088^{g}	1.03 ± 0.011^{b}
GSUK	**502.00 ± 0.57^{a}**	19.66 ± 0.088^{c}	342.00 ± 0.57^{b}	9.32 ± 0.0088^{c}	8.60 ± 0.057^{c}	**6.94 ± 0.0088^{m}**	0.94 ± 0.0088^{b}	1.02 ± 0.0057^{b,c,d}	12.20 ± 0.057^{b}	10.36 ± 0.088^{g}	0.95 ± 0.0057^{c}
KKDK	315.00 ± 0.57^{l}	10.20 ± 0.057^{k}	217.00 ± 0.57^{d,e}	8.60 ± 0.057^{e}	5.60 ± 0.057^{g}	7.95 ± 0.014^{k}	0.75 ± 0.012^{d}	0.77 ± 0.011^{d,e,f,g}	12.36 ± 0.14^{b}	10.36 ± 0.088^{g}	0.84 ± 0.0088^{d}
YUK	351.00 ± 0.57^{i}	10.20 ± 0.057^{k}	151.00 ± 0.57^{g}	9.63 ± 0.0057^{b}	6.36 ± 0.088^{e}	8.11 ± 0.095^{j,k}	0.95 ± 0.011^{b}	0.84 ± 0.014^{c,d,e,f}	12.00 ± 0.57^{b}	10.50 ± 0.11^{g}	1.03 ± 0.0088^{b}
KBDK	303.66 ± 0.88^{m}	21.20 ± 0.057^{b}	130.40 ± 0.11^{g,h}	7.82 ± 0.0088^{f}	8.70 ± 0.057^{c}	8.36 ± 0.088^{j}	0.77 ± 0.0088^{c,d}	1.20 ± 0.057^{b,c}	10.43 ± 0.011^{b}	13.23 ± 0.066^{c}	1.05 ± 0.0088^{b}
HUK	297.66 ± 0.88^{o}	14.26 ± 0.088^{g}	**402.66 ± 0.88^{a}**	6.94 ± 0.014^{g}	8.00 ± 0.57^{d}	8.30 ± 0.11^{j}	0.75 ± 0.014^{d}	1.03 ± 0.0057^{b,c,d}	11.53 ± 0.014^{b}	10.42 ± 0.0088^{g}	0.96 ± 0.0057^{c}
KGMUK	301.00 ± 0.57^{n}	12.23 ± 0.088^{i,j}	202.00 ± 0.57^{e,f}	**10.46 ± 0.0088^{a}**	**22.50 ± 0.057^{a}**	10.40 ± 0.057^{g}	0.77 ± 0.011^{c,d}	1.05 ± 0.011^{b,c,d}	12.23 ± 0.088^{b}	12.26 ± 0.12^{e}	0.94 ± 0.0057^{c}
DUK	337.00 ± 0.57^{j}	16.30 ± 0.11^{e}	64.50 ± 48.25^{j,k,l}	8.56 ± 0.0088^{e}	4.50 ± 0.11^{h}	9.83 ± 0.0011^{h}	0.70 ± 0.057^{d,e}	0.93 ± 0.012^{c,d,e}	10.73 ± 0.0088^{b}	10.23 ± 0.088^{g}	1.03 ± 0.0088^{b}
BKU	302.33 ± 0.88^{m,n}	14.70 ± 0.11^{f,g}	293.33 ± 1.45^{c}	9.63 ± 0.011^{b}	5.70 ± 0.057^{f,g}	8.36 ± 0.14^{j}	0.87 ± 0.0088^{b,c}	1.40 ± 0.057^{b}	12.26 ± 0.088^{b}	10.73 ± 0.011^{f,g}	1.03 ± 0.011^{b}
KKU	381.00 ± 0.57^{f}	16.80 ± 0.057^{e}	180.40 ± 0.11^{f}	7.66 ± 0.01^{f}	8.66 ± 0.088^{c}	12.23 ± 0.088^{e}	0.96 ± 0.0088^{b}	1.02 ± 0.0057^{b,c,d}	18.30 ± 0.057^{b}	10.60 ± 0.057^{g}	0.83 ± 0.0088^{d}

The mean of the replicates ± standard error (SE) is represented for each value. A significant difference (Duncan's multiple range test, $P < 0.01$) was demonstrated by a one-way ANOVA with distinct letters in a column representing probability values.

Since cyanobacteria are thought to be significant P sinks, they are constantly causing P-transformations. The quantity of phosphate available to rice plants is increased by the absorption of phosphate during cell growth and its excretion in soluble organic form during decomposition, which results in mineral orthophosphates and phosphate containing compounds (Manal et al., 1999). In addition, soil microbial interactions can use heterocyclic chemicals, produce organic acids, or mobilize different insoluble forms of inorganic phosphate. When cyanobacteria are employed as biofertilizers, Nisha et al. (2014) reported phosphomonoesterase activity facilitates the binding of organic phosphorus in soil. Concurrently, the medium low and high phosphate levels in paddy field soil were found to vary from 8.00±0.57 to 27.30±0.65. As a result of that, potassium availability, the last significant macronutrient, is higher in HUK at 402.66±0.88 and varies from 130.40±0.11 to 202.00±0.57 in KKU, KGMUK, KBDK and YUK at medium doses decreasing to 22.26±0.00 in $GKTR_3$ (S_2). For healthy plant growth and the presence of beneficial soil organisms, potassium (K^+) is one of the most sought-after macronutrients in soil. However, it has a direct effect on the growth, productivity, and dispersion of living organisms in soil media that contain carbonates and organic carbon (El-Gamal et al., 2016) and is intimately linked to cationic salts like Na^+, Ca^{+2} and Mg^{+2} (Shi & Wang, 2005). The potassium values in the paddy field soil parametric research ranged from 22.26±0.0088 to 402.66±0.88. Rashid et al. (2016) state that N:P:K based fertilizers are frequently used to maintain potassium levels in rice crop paddy fields. When excessive N fertilizer is applied, the soil's N content increases but the P and K concentrations remain unchanged (Clark, 1982; Stiling & Moon, 2005; Sarwar, 2012; Rashid et al., 2016). Excessive potassium fertilizer application reduces plant soluble proteins, nitrogen concentration, and carbohydrate content (Salim, 2002b). Similarly, since cyanobacteria initially developed cyanobacterial biofilms on the soil's surface, high pH and potassium rich topsoil have been used as biomarkers of cyanobacteria in agricultural settings (Alghanmi & Jawad, 2019). Now, focusing on micronutrients, calcium is mostly available in KGMUK (10.46±0.0088), moderately available in DUK, KBDK, KKDK, TUB, and TMR_3 (S_2) (7.82±0.0088 to 8.64±0.011), and finally available in $GKTR_3$ (S_2) at a lesser concentration of 1.70±0.11. Calcium (Ca) is by far the most prevalent cationic micronutrient in soil. According to Zutshi et al. (1980), cationic calcium is abundant in areas such as the Himalayas and coastal regions that include exposed limestone-rich rocks. White & Bradley (2003) claim that hydration bonding increases the pH range of soil; as a result, calcium affects plant physiological processes and rice crop growth (Gentili et al., 2018).

According to this analysis, the calcium concentration of the soil in the coastal paddy field varied from 1.70±0.11 to 10.46±0.0088. Macro and micronutrients including N, P, Mg, OC, Na, K and calcium build up as reserve traces after microbial biomass breaks down, leading to soil enrichment (Yanni & Abd-El-Rahman, 1993; Mandal et al., 1999; Kaushik, 2014). The microbial community is altered by more calcium and carbonate, which also alters the soil's chemistry. The combination of calcium and nitrogen changes the active reaction of photosynthetic bacteria, according to study by Piccioni & Mauzerall (1978). In the end, this impact on photosynthesis causes an excess of oxygen to accumulate in the atmosphere. Additionally, to stabilize carbonic calcium ions in a soluble form and reduce the amount of sodium ions in the soil, cyanobacteria and other soil microbes generate oxalic, organic, succinic, and lactic acids (Bhatnagar & Roychoudhury, 1992). Applying soil calcium topically can reduce nickel toxicity in soil (Aziz et al., 2014). The current available magnesium content is very low in TMR_3 (S_2) at 0.60±0.057, moderate (4.73±0.088 to 9.76±0.088) in BSDK, DJUK, BKU, KKDK, BKUS, TUB, and KK (S_1), and high in KGMUK at 22.50±0.05. Magnesium, an essential structural component of chlorophyll pigments, facilitates photosynthetic processes in autotrophs such as plants, algae and cyanobacteria. According to this investigation, the soil's total magnesium availability varied between 0.60±0.05 and 22.50±0.05. Magnesium is one of the most important cationic salts that supports the growth and spread of plants as well as the health of the soil microbial community. Magnesium levels in the soil promote leaf girth and stability. However, insufficient supply causes rice leaves to lose their chlorophyll, which decreases the rate of photosynthesis and resulting in stunted and dry shoots (Shaul, 2002; Shabala & Hariadi, 2005). A sufficient amount of magnesium promotes photosynthesis and other physiological functions in plants (Ding et al., 2006). Sulphur concentrations in $AKUHR_1$ (S_1), SK (S_1), KK (S_1), $AKSR_2$ (S_2), GKR_2 (S_1), UDR_4 (S_2), TMR_3 (S_2), and KGMUK are in the medium range (10.40±0.05 to 11.73±0.12), while GSUK has the lowest concentration (6.94±0.0088). BKUS has the highest concentration (20.36±0.08). Sulphur content in this study was low to moderate, ranging from 6.94±0.00 to 20.36±0.08. Positive interactions with other soil factors were not seen. The amount of sulphur in the soil has a major effect on plant growth and affects the girth and elongation rate of rice grains and straw (Ram et al., 2014). According to Tripathi et al. (1992), a formulation of soil organic matter with a high sulphur content was found to be sufficient in enhancing the potential for soil organism and plant physiological activities. Furthermore, the zinc concentration was the lowest (0.22±0.0057) in SK (S_1) and KK (S_1), moderate in DJUK, BSDK, KKDK, and DUK (0.66±0.088 to 0.75±0.014), and much higher in TUB (1.20±0.05). Zinc levels in soil decrease when nitrogen is added (Salim, 2002a). As per Westerman (1990) and Horneck et al. (2011), the available zinc concentration in the soil ranged from medium to high (0.22±0.00 to 1.20±0.05) in this analysis. Low yield circumstances, especially in onion crops, are caused by inadequate zinc concentration. In contrast, the use of biofertilizers neutralizes the zinc concentration (Khokhar, 2019) and increases crop yields (Dake et al., 2011; Manna & Maity, 2015; Babaleshwar et al., 2017). Copper concentrations currently range from moderate (0.72±0.00 to 0.93±0.01) in UDR_4 (S_2), DJUK, KPDK, KKDK, YUK, and DUK, to very low (0.26±0.01) in UDR_3 and exceeding 2.00±0.57 in BSDK. Plants primarily use copper (Cu) conductivity in soil to move cationic elements; in extremely saline soil conditions, copper and electrical conductivity are positively correlated. Copper concentrations in the studied coastal paddy soils ranged from 0.26±0.01 to 2.00±0.57, which are regarded as partially low and high, according to the data. A rice plant that has taken up the right amount of copper from the soil is considered healthy. However, Cu toxicity can sometimes negatively affect rice plant growth, including root and shoot development, as well as grain quality when elevated copper levels are present (Thounaojam et al., 2012; Htwe et al., 2020).

At 392.37±380.81, GKR_2 (S_1) has the highest available iron concentration, whilst UDR_3 has the lowest at 4.55±0.01. Additionally, India's forest and coastal soils are "Congo red" due to the high concentration of iron ores in them. An iron level of 4.55±0.012 to 392.37±380.81, as determined by soil analysis, is sufficient for plants and agricultural produce. Furthermore, soil microorganism biomass rises with soil iron (Fe) levels (Alghanmi & Jawad, 2019). In general, N:P:K in combination with Cu, Zn, and Fe increases plant crop yield via influencing stem strength and girth (Fouda, 2016). Samaranayake et al. (2012) state that low iron weakens stems and roots, while high iron is harmful to stem and root cells. In this experiment, manganese availability is highest in KPDK (15.83±0.01), moderate in $AKSR_2$ (S_2) (12.54±0.011), and lowest in UDR_3 (3.12 ± 0.0088). The amount of accessible manganese (Mn) in the soil increased from 3.12±0.008 to 15.83±0.01 in the analysis. Appearances of iron and zinc reduce the amount of Mn accessible in soils (Chaudhry & Wallace, 1976; Alam, 1982). Although manganese is essential for plant growth, an increasing amount of it may be harmful to plants (Rajput et al., 2021). Similarly, plants slow down photosynthesis when exposed to high Mn concentrations, especially in rice fields (Lidon & Teixeira, 2000a; 2000b).

Accordingly, the accessible boron concentration in TUB and KK (S_1) is generally available (0.62±0.00 to 0.75±0.01), with DJUK having the highest concentration (1.36±0.0057) and TMR_3 (S_2) having the lowest value (0.23±0.08). In summary, the micronutrient boron (B) concentrations in the soil samples of medium low to high in rice fields ranged from

0.23±0.088 to 1.36±0.0057. With an emphasis on the onion crop, Khokhar (2019) researched on boron concentrations to increase plant yield coinciding with other works (Smriti et al., 2002; Dake et al., 2011; Manna & Maity, 2015; Babaleshwar et al., 2017). This leads to a lack of mineral boron because the soils of the majority of countries have low levels of organic saturation and granular structure (Takkar et al., 1989; Razzaq & Rafiq, 1996; Borkakati & Takkar, 2000).

Principal component analysis, one of several statistical methods employed in this study, yielded six rotated components, PC1, PC2, PC3, PC4, PC5, and PC6, listed in Table 6. Thus, according to this parametric statistic, PC1 has the largest percentage of variance and cumulative percentage of all six components; in contrast to PC6, which has the highest eigenvalue, PC1's eigenvalue is lower than the other components'. With a variance percentage of 5.752, a cumulative percentage of 35.951, moisture content of 0.8, pH of 0.817, potassium as a macronutrient of 0.828, and micronutrients of calcium (0.866), magnesium (0.648), zinc (0.773), copper (0.812) and boron (0.756), PC1 is ideally balanced. Comparing these parameters to other parameters, they are the highest-grade parameters in this analysis. With an organic carbon content of 0.816 and a density of 0.087, the PC2 component is significantly higher than the other components.

Table 6. Principal component analysis of soil properties

Parameters	Rotated component matrix					
	PC1	PC2	PC3	PC4	PC5	PC6
% of variance	**5.752**	1.953	1.502	1.241	1.178	1.102
Cumulative %	**35.952**	12.209	9.391	7.756	7.361	6.886
Eigen values	35.952	48.161	57.551	65.307	72.668	**79.554**
Moisture	**.811**	.222	.245	.007	-.194	.109
Density	-.242	**.087**	.049	-.886	-.009	.023
pH	**.817**	-.205	.258	.256	-.089	.218
EC (ds/m)	-.001	-.825	**.281**	.092	-.150	-.010
OC %	.180	**.816**	.297	.000	-.038	-.031
N (kg/ac)	.339	.072	-.084	-.238	**.782**	-.112
P (kg/ac)	.073	.117	-.719	**.405**	-.167	.082
K (kg/ac)	**.828**	-.049	-.213	.012	.142	-.018
Ca (ppm)	**.866**	-.191	.245	.199	-.072	-.183
Mg (ppm)	**.648**	.060	.277	.252	-.145	-.059
S (ppm)	-.047	-.015	-.042	-.007	-.013	**.962**
Zn (ppm)	**.773**	.227	-.178	.107	.072	-.247
Cu (ppm)	**.812**	.229	-.076	-.237	.195	.135
Fe (ppm)	-.398	.072	.144	.270	**.743**	.105
Mn (ppm)	.199	.080	**.721**	.146	-.071	.011
B (ppm)	**.756**	.366	.169	.230	.032	-.231

The cumulative percentage is 12.209, the variance percentage of 1.953, and the Eigen value as 48.161.

The PC3 data set shows that manganese (0.721) and electrical conductivity (0.281) are the most readily obtainable elements.

The eigen value is 57.551, the cumulative percentage as 9.391, and the variance percentage represents 1.502. With an eigen value of 65.307, a cumulative percentage of 7.756, and a percentage of variance of 1.241, PC4 has a higher phosphate content (0.405) than the other six components. The PC5 component's Eigen value has 72.668, its cumulative percentage is 7.361, and its variance percentage as 1.178. The remaining six components have modest levels, with the two highest being 0.782 nitrogen and 0.743 iron.

Finally, among the six components' soil parameters, PC6 has the highest content, explaining 1.102 percent of variance, 6.886 cumulative percentage, and 79.554 eigen value interaction with sulphur (0.962).

Figure 1 displays the results of principal component analysis, which shows both positive and negative correlation between the parameters in a biplot spanning four quadrants.

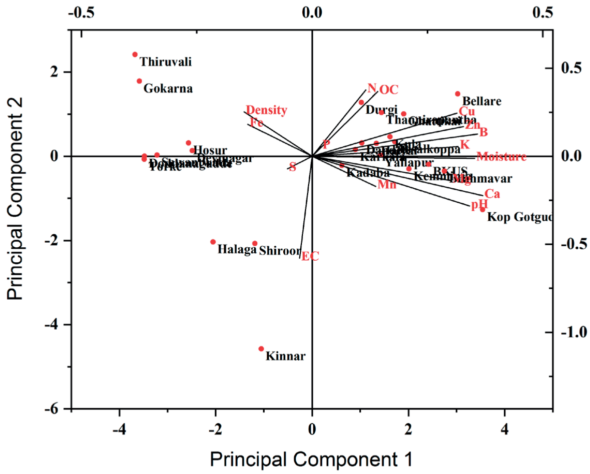

Figure 1. Principal component biplot analysis of 25 paddy field locations: correlations among physicochemical properties (moisture, density, pH, EC, OC, N, P, K, Cu, Fe, Mn, Mg, S, Zn, Ca and B)

It should be noted that the density is positively correlated with nitrogen (N), sulphur (S), and iron (Fe), but negatively correlated with organic carbon (OC), copper (Cu), zinc (Zn), boron (B), potassium (K), moisture, phosphate (P), magnesium (Mg), manganese (Mn), electrical conductivity (EC), and pH in two components. In contrast to nitrogen, organic carbon, copper, zinc, boron, phosphate, potassium, magnesium, manganese, calcium, pH, and EC, only density and sulphur (S) show a positive link with iron.

Sulphur is positively correlated with density, iron, and EC, but negatively correlated with N, OC, Cu, Zn, B, K, P, moisture, Mg, Mn, Ca and pH. Nitrogen, organic carbon, copper, zinc, boron, phosphate, potassium, magnesium, manganese, calcium, moisture and pH are all positively connected, according to this association.

On the other hand, there is a negative correlation between density, iron, sulphur, and EC. Magnesium, Mn, Ca and pH, on the other hand, correlate favourably with N, OC, Cu, Zn, B, P, K, moisture and EC and negatively with S, Fe, and density. However, EC and pH are positively correlated, as are all macro and micro variables except density, Fe and S.

A higher pH concentration is invariably the result of a higher moisture content, as indicated by the basic expression of the Pearson correlation on the physico-chemical characteristics of soil in Table 7.

Organic carbon and current electrical conductivity are negatively correlated. Potassium and moisture are positively correlated. There is also a positive correlation between calcium and moisture, pH, and potassium. There is a positive correlation between magnesium and moisture, pH, and calcium. Zinc also has a positive relationship with moisture, pH, calcium, magnesium, and potassium. Copper is positively correlated with moisture, pH, nitrogen, potassium, calcium, magnesium, and zinc. Finally, boron is positively correlated with organic carbon, pH, calcium, magnesium, zinc, copper, and moisture. Therefore, whereas negativity should either be constant or result from holdings that are equal to or less than one, positive always influences growing parameters.

Figure 2 illustrates the experimental cluster analysis of soil characteristics under four groups in a graph, with sites assigned based on virtually identical qualitative features with geography. The seven locations that comprise cluster one are Shiroor, Kop Gotgudi, Kemminje, Kadaba, Halyal, Brahmavar, and BKUS. The only location that comprises the second cluster is Gokarna. The third cluster has thirteen locations, including Yallapur, Torke, Thiruvail, Sawantwada, Kula, Kinnar, Karkala, Hosur, Halaga, Durgi, Doddanagudde, Devinagar, and Dandeli. Finally, the fourth cluster consists of four locations: Bellare, Bisalkoppa, Ghattikai, and Thannirapantha.

Table 7. Pearson correlations among physical and chemical properties of soil

Soil properties	Moisture	Density	pH	EC	OC	N	P	K	Ca	Mg	S	Zn	Cu	Fe	Mn	B
Moisture	1															
Density	-.188	1														
pH	**.708****	-.386	1													
EC	-.142	-.099	.244	1												
OC	.297	.044	.063	**-.420***	1											
N	.049	.085	.069	-.205	.093	1										
P	-.089	-.274	.004	-.146	-.070	-.059	1									
K	**.499***	-.257	**.641****	-.051	.121	.345	.135	1								
Ca	**.734****	-.388	**.794****	.283	.112	.172	-.064	**.628****	1							
Mg	**.549****	-.247	**.679****	-.014	.182	.027	-.001	.391	**.676****	1						
S	.026	.009	.117	.017	-.039	-.086	.058	-.067	-.201	-.108	1					
Zn	**.611****	-.266	**.482***	-.276	.219	.368	.170	**.648****	**.649****	**.471***	-.195	1				
Cu	**.686****	.036	**.536****	-.218	.291	**.438***	.085	**.666****	**.548****	**.412***	.025	**.515****	1			
Fe	-.335	-.031	-.250	-.099	-.030	.206	-.124	-.267	-.323	-.194	.048	-.276	-.171	1		
Mn	.324	-.120	.370	.121	.254	.064	-.222	.044	.302	.294	-.050	.103	.072	-.102	1	
B	**.712****	-.359	**.555****	-.124	**.544****	.234	.022	**.535****	**.725****	**.570****	-.247	**.679****	**.656****	-.166	.206	1

*At the 0.05 level (2-tailed), the correlation is significant.
**At the 0.01 level (2-tailed), the correlation is significant.

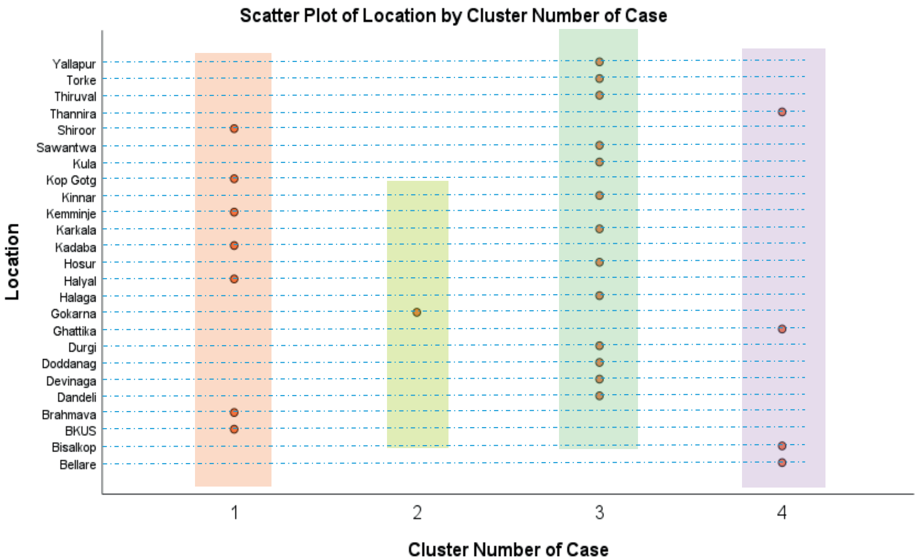

Figure 2. Using the k-means clustering method, a cluster diagram was created, and cluster number case scores were used to distribute locations

CONCLUSIONS

Coastal Karnataka's soil type advantageous because of a sufficient scope of agro-climatic influence, which boosts coastal crop yields. A tolerable pH and a supportive EC with micro and macronutrients are essential for rice growing, which is the agricultural technique that makes Coastal Karnataka popular for its heritage and culture. This is the case for Coastal Karnataka, where large-scale distributed algal biomass in marine habitats supports pH and OC parameters in extremely saline soil environments linked to electrical conductivity, and where synthetic fertilization has allowed soils to become acidic. Furthermore, the high nitrogen concentration is a crucial macronutrient for rice crops. For this subject, comfortable concentrations of nitrogen availability may be supplemented by N fertilization (inorganic form); rising global temperatures generate global warming processes, which in turn cause ozone depletion. The nutrients needed by the plant are supplied by N:P:K fertilization in this parametric analysis. However, excessive application of organic and manure fertilizers in combination with synthetic fertilizers is toxic to plants; as a result, agricultural crops that contain beneficial soil microorganisms are stressed and by these physiological and mechanical activities in the agricultural environment. Due to synthetic fertilization or biofertilization (microorganisms), soil phosphate and potassium in this examination also seem to be in good condition. This is because cyanobacteria are naturally occurring P-sinkers in agricultural soils. Lastly, all other micronutrients were available in good concentrations and had positive correlations with pH, EC, OC, and macronutrients, with the exception of sulphur, which had a negative correlation and was present in delicate levels. The interactions between beneficial soil microbes and plants in the soil profile, and soil and agricultural economics are the only focus of this study.

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