Effect of different factors on the soil quality of *typic ustipsamments* of state Kerala, in India

ABSTRACT

Aims: Assessment of soil quality of selected panchayaths of sandy plains (*Typic Ustipsamments*) of Kerala based on various soil attributes and to work out soil quality index (SQI).

Study design: A study was conducted in the selected panchayaths of sandy plains of Kerala (AEU 3) and 100 representative georeferenced surface soil samples were collected from various land uses. These soil samples were characterized for important physical, chemical, and biological properties.

Place and Duration of Study: Onattukara Regional Agricultural Research Station, Kayamkulam between April 2021 and May 2022.

Methodology: Hundred geo-referenced surface soil samples were collected from various land uses of selected panchayaths of sandy plains of Kerala and characterized for various physical (texture, bulk density, particle density, porosity, aggregate analysis, soil moisture, and WHC), chemical (pH, EC, organic carbon and available macro and micronutrients and biological attributes (acid phosphatase and dehydrogenase activity). Principal component analysis was used to set up the minimum data set of the indicators to compute the soil quality index. Seven principal components were extracted from which nine indicators that highly influenced the soil quality were identified. Scores and weights were assigned to each indicator, and they were aggregated to compute the soil quality index. The relative soil quality index of the soils was also found.

Results: Increased soil acidity and low levels of nutrients like nitrogen, potassium, magnesium, sulfur, and boron were noticed in these soils. The available P content of the soil was high. Mg, S, and B were deficient in 100 percent of the samples, whereas, Fe and Mn remained sufficient. Ca, Zn, and Cu exhibited 72.9, 24.3, and 21.7 percent deficiency, respectively. The majority of the soils belonged to medium soil quality (78.6 percent), followed by poor (12.8 percent) and good (8.6 percent) quality.

Conclusion: The majority of soils of selected panchayaths of sandy plains of Kerala fell into the medium soil quality class. However, there are several soil fertility issues in these soils. Hence site-specific and crop-specific management strategies have to be followed for the profitable cultivation of the crops and soil test-based fertilizer application has to be followed. It is mandatory to maintain the fertility of the soil for the sustainability of the environment.

Keywords: [Sandy plain, soil quality, PCA, SQI, RSQI, Typic Ustipsamments]

1. INTRODUCTION

Soil quality is an assessment of the present functioning capacity of the soil and how well it will be preserved for future use. As soil quality cannot be measured directly, it must be inferred from measuring changes in attributes of the ecosystem, referred to as indicators. Measurable soil attributes that influence the capacity of soil to perform crop production or environmental functions are referred as the soil quality indicators [1]. Identifying key soil attributes that are sensitive to soil functions allows the establishment of minimum data sets (MDS). Such data sets are composed of a minimum number of soil properties that will provide a practical assessment of one or several soil processes of importance for a specific soil function [2]. Use of MDS reduces the need for determining a large number of indicators to assess soil quality [3].

Key attributes of soil quality include different physical, chemical and biological properties which interact in complex ways to determine its potential fitness or capacity to produce healthy and nutritious crops [4].Decline of soil quality is crucial in land degradation [5]. Soil quality indicators based on a combination of soil properties could better reflect the status of soil quality degradation as compared to individual parameters. Soil quality index (SQI) can reflect the extend of degradation and suggest appropriate remedial measures such as optimal fertilizer rate and suitable land management practices considering potentials and constraints of different fields at large scale. In a state like Kerala with high population density, land is definitely a scarce resource. Moreover, higher than 67 per cent of the total geographic area of the state is subjected to soil degradation due to various factors like erosion, landslides, water logging, acidification, pollution *etc.* This resulted in a higher rate of soil loss, compared to the national average. Soil quality index combine various information effectively and hence is an effective tool for multi-objective decision-making [6]. The sandy plain region of Kerala comprises a unique agro-ecological unit designated as Onattukara sandy plain (AEU 3). The soils of this region exhibit wide spatial variability in their properties. These soils are generally coarse textured with immature profiles and low nutrient and water retention capacity. The ultimate purpose of assessing soil quality is to protect and improve long term agriculture productivity, water quality and habitats of all organisms including human. So the present study was undertaken to assess the soil quality of selected panchayaths of sandy plains of Kerala based on various soil attributes and to work out soil quality index (SQI) which will help to evaluate soil quality, and in turn, help to enhance the environmental sustainability. Soil health test reports developed will allow for an overall assessment, as well as the identification of specific soil constraints and soil quality build up will help in the resilience of degraded soils.

2. MATERIALS AND METHODS

A study was conducted in seven selected panchayaths representing the sandy plains of Kerala *viz.*, Thazhakkara, Cheruthana, Bharanikkavu, Alappad, Palamel, Muthukulam and Thekkekkara panchayths. The major land uses in these panchayaths were rice, coconut, banana and vegetables. Hundred geo-referenced surface soil samples were collected from these panchayaths and characterized for various physical (texture, bulk density, particle density, porosity, aggregate analysis, soil moisture, and WHC), chemical (pH, EC, organic carbon, available macro and micronutrients) and biological attributes (acid phosphatase and dehydrogenase activity) using standard analytical procedures (Table 1).

Principal component analysis was used to set up the minimum data set of the indicators to compute the soil quality index. Among the well-correlated variables in the PC, the variables with highest sum of correlation coefficients were chosen for the MDS [7]. Seven principal components were extracted from which nine indicators that highly influenced the soil quality were identified, *viz.* sand percent, available P, available Ca, available Mg, bulk density, percent of water stable aggregates, organic carbon, available Zn and available B. Scores and weights were assigned to each indicator, and they were aggregated to compute the soil quality index. The relative soil quality index of the soils was also found. GIS techniques were used to prepare thematic maps of various soil attributes and relative soil quality indices of these panchayaths.

Table 1. Analytical methods followed in physical, chemical and biological analysis of the soil.

Sl. No.	Parameter	Method	Reference
1.	Bulk density	Undisturbed core samples	Blake and Hartge (1986) [8]
2.	Particle density	Pycnometer method	Vadyunina and Korchagina (1986) [9]
3.	Porosity	Calculation using bulk density and particle density	Danielson and Sutherland (1986)[10]
4.	Soil texture	Bouyoucos hydrometer method	Bouyoucos (1936) [11]
5.	Aggregate analysis	Yoder's wet sieving method	Bavel (1949) [12]
6.	Soil moisture	Gravimetric method	Gupta and Dakshinamurthy (1980) [13]
7.	Water holding capacity	Core method	Gupta and Dakshinamurthy(1980)
8.	Soil pH	pH meter (1:2.5 soil water ratio)	Jackson (1973) [14]
9.	Electrical conductivity	Conductivity meter (1:2.5 soil water ratio)	Jackson (1973)
10.	Organic carbon	Walkley and Black method	Walkley and Black (1934) [15]

11.	Available N	Alkaline permanganate method	Subbiah and Asija (1956) [16]
12.	Available P	Bray No.1 extraction and estimation using spectrophotometer	Watanabe and Olsen (1965) [17]
13.	Available K	Neutral normal ammonium acetate extraction and estimation using flame photometry	Jackson (1973)
14.	Available Ca and Mg	Neutral normal ammonium acetate extraction and estimation using atomic absorption spectrophotometer	Hesse (1971) [18]
15.	Available S	$CaCl_2$ extraction and estimation using spectrophotometer	Massoumi and Cornfield (1963) [19]
16.	Available Fe, Mn, Cu and Zn	0.1 N HCl extraction and estimation using atomic absorption spectrophotometer	Sims and Johnson (1991) [20]
17.	Available B	Hot water extraction and estimation using spectrophotometer (Azomethane H method)	Gupta (1972) [21]
19.	Acid phosphatase activity	Colorimetric estimation of PNP released g^{-1} of soil h^{-1}	Eivazi and Tabatabai (1977) [22]

20.	Dehydrogenase activity	Colorimetric estimation of TPF hydrolysed g^{-1} of soil 24^{-1} hrs	Casida (1977) [23]

3. RESULTS AND DISCUSSION

3.1 SOIL QUALITY ANALYSIS

The soil samples collected were characterized for important physical, chemical, and biological properties to assess the soil quality. **S**oil samples were subjected to analysis of various physical properties like bulk density, particle density, porosity, texture, aggregate analysis, soil moisture content, and water holding capacity. Geo-referenced soil samples were analyzed for fertility parameters like pH, electrical conductivity, organic carbon, and available primary nutrients *viz*. N, P, and K, secondary nutrients *viz*. Ca, Mg, and S and micronutrients *viz*. Fe, Mn, Cu, Zn, and B and categorized into various categories based on soil fertility ratings [24] (Table 2). Acid phosphatase and dehydrogenase activity were also assessed as part of assessing the biological properties of the soil. Depletion of nutrients like nitrogen, potassium, magnesium, sulfur, and boron was also noticed in these soils. Mg, S, and B were deficient in 100 percent of the samples, whereas, Fe and Mn remained sufficient. Ca, Zn, and Cu exhibited 72.9, 24.3, and 21.7 percent deficiency, respectively.

Table 2. STATUS OF SOIL REACTION AND NUTRIENTS

Parameter	Fertility class	Ratings	Percent samples
pH	Extremely acidic	3.5-4.5	37.2
	Very strongly acidic	4.5-5.0	57.1
	Strongly acidic	5.0-5.5	5.7
Organic carbon (%)	Low	< 0.3	20
	Medium	0.3-0.9	50
	High	> 0.9	30
Available N (kg ha^{-1})	Low	<280kg ha^{-1}	71.4

	Medium	280-560 kg ha^{-1}	28.6
	High	>560 kg ha^{-1}	0
Available P (kg ha^{-1})	Low	< 10 kg ha^{-1}	0
	Medium	10-24 kg ha^{-1}	28.6
	High	> 24 kg ha^{-1}	71.4
Available K (kg ha^{-1})	Low	< 120 kg ha^{-1}	62.9
	Medium	120-280 kg ha^{-1}	37.1
Available Ca (mg kg^{-1})	Deficient	< 300 mg kg^{-1}	72.9
	Sufficient	> 300 mg kg $^{-1}$	27.1
Available Mg (mg kg^{-1})	Deficient	<120 mg kg $^{-1}$	100
	Sufficient	> 120 mg kg $^{-1}$	0
Available S (mg kg^{-1})	Deficient	<5 mg kg -1	100
	Sufficient	5-10 mg kg -1	0
Available Zn (mg kg^{-1})	Deficient	<1 mg kg -1	24.3
	Sufficient	> 1 mg kg -1	75.7
Available Cu (mg kg^{-1})	Deficient	<1 mg kg -1	21.7
	Sufficient	> 1 mg kg -1	78.3
Available B (mg kg^{-1})	Deficient	<0.5 mg kg -1	100
	Sufficient	> 0.5mg kg -1	0

3.2. FORMULATION OF MINIMUM DATA SET (MDS)

Principal component analysis (PCA) was used for setting up the minimum data set (MDS). The PCA resulted in seven principal components (PCs), which had an eigenvalue of more than 1, which was selected for the MDS (Table 3). Only the highly weighted variables (within 10 percent of the factor loading) within each PC were retained. When more than one variable was retained in a PC, the correlation between them was worked out and if they were significantly correlated (r > 0.6), the one with the highest loading factor was retained for the MDS, and the rest were excluded.

Table 3. Minimum Data Set

PC1	PC2	PC3	PC4	PC5	PC6	PC7
Sand per cent	Available P	Available Mg	Bulk density	Per cent of water stable aggregates	Organic carbon	Available B
	Available Ca				Available Zn	

3.3.FORMULATION OF SOIL QUALITY INDEX

3.3.1. SCORING OF THE PARAMETERS

To formulate the soil quality index of the analyzed soil samples, the parameters in the minimum data set were assigned with appropriate weights based on existing soil conditions, cropping patterns, and agro-climatic conditions and each class with a proper score according to the procedure by [25,26,27] with slight modifications based on the soil fertility ratings for secondary and micronutrients for Kerala soils (table4).

TABLE 4. SCORING OF THE PARAMETERS

SOIL QUALITY INDICATORS	WEIGHTS	CLASS I WITH SCORE 4	CLASS II WITH SCORE 3	CLASS III WITH SCORE 2	CLASS IV WITH SCORE 1
WSA%	15	>90	70 – 90	50 – 70	< 50
B D (Mg m^{-3})	10	1.3 – 1.4	1.2 – 1.3 OR 1.4 – 1.5	1.1 – 1.2 OR 1.5 – 1.6	< 1.1/ > 1.6
TEXTURE (SAND %)	10	LOAM	CLAY LOAM/ SANDY LOAM	SAND/CLAY	GRIT
OC (%)	15	>1	1 – 0.75	0.75 – 0.5	< 0.5
AVAILABLE P (kg ha^{-1})	10	>24	15 – 24	15 – 10	<10

AVAILABLE Ca (kg ha^{-1})	10	>300	300 – 250	250 – 150	<150
AVAILABLE Mg (kg ha^{-1})	10	>120	120 – 90	90 – 60	<60
AVAILABLE Zn (kg ha^{-1})	10	>1.0	1.0 – 0.5	0.5 – 0.25	< 0.25
AVAILABLE B (kg ha^{-1})	10	>0.5	0.5 – 0.25	0.25 – 0.1	<0.1

3.3.2. COMPUTATION OF SOIL QUALITY INDEX AND RELATIVE SOIL QUALITY INDEX.

The soil quality index (SQI) of the soil samples was calculated using the weighted additive method using the equation ,

SQI = $\sum W_i \times M_{i,}$ Where W_i is weight of the indicators and M_i is the marks of the indicator classes. The relative soil quality index (RSQI) of the samples was calculated to study the change in soil quality of the samples (table 5). The soil quality index of the samples varied between 176 and 294, with a mean value of 239. The mean value of sqi was found to be a maximum (259) in the palamel panchayath and a minimum (218) in the alappad panchayath. The relative soil quality index of the samples ranged from 43.6 percent to 78.7 percent. The palamel panchayath was observed to have the highest mean rsqi (64.6 percent) and alapapd was observed to have the lowest value (50.1 percent).

The soils were categorized into poor, medium, and good based on the relative soil quality index. The majority of the samples (78.6 percent) fell in the medium class and 12.8 percent into the low class of soil quality. Only 8.6 percent of the samples were regarded as good-quality soil (fig. 1).

TABLE 5. SQI AND RSQI OF VARIOUS PANCHAYATHS

PARAMETERS→ PANCHAYATH↓	SOIL QUALITY INDEX (SQI)		RELATIVE SOIL QUALITY INDEX (%) (RSQI)	
	MEAN ± SD	RANGE	MEAN ± SD	RANGE
THAZHAKKARA	250 ± 29.1	205 – 295	62.5 ± 7.26	52.5 - 73.8
CHERUTHANA	240 ± 18.6	215 – 275	60.0 ± 4.64	53.8 - 68.8
BHARANIKKAVU	241 ± 23.1	200 - 270	60.3 ± 5.77	50.0 - 67.5
ALAPPAD	218 ± 39.9	170 - 295	50.1 ± 9.98	42.5 - 73.8
PALAMEL	259 ± 34.4	195 - 305	64.6 ± 8.59	48.8 - 76.3
MUTHUKULAM	256 ± 25.5	230 - 320	63.9 ± 6.39	57.5 - 80.0
THEKKEKKARA	220 ± 24.2	190 - 255	55.0 ± 6.04	47.5 - 63.8
AEU 3	239 ± 31.5	176 - 294	59.7 ± 7.87	43.6 - 78.7

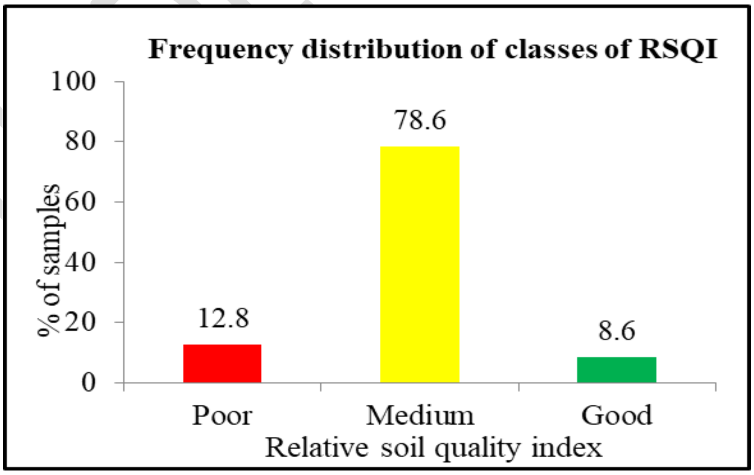

Fig.1. Frequency distribution of classes of RSQI in the sandy plain

4. CONCLUSION

The majority of the soils of selected panchayaths of sandy plains of Kerala fell into the medium soil quality class. However, there are several soil fertility issues in these soils. Soil acidity is a major problem in this region which demands the application of adequate liming materials. The addition of more organic inputs can minimize the physical constraints of sandy soils [28]. Split application of N and K fertilizers can reduce the leaching losses [29]. The dose of P fertilizer has to be modified in the light of high P status in the AEU. Monitoring of secondary and micronutrients regularly is also required. Site-specific nutrient management is required to restore the soil health in these soils. Hence site-specific and crop-specific nutrient management strategies have to be followed for the profitable cultivation of the crops and soil test-based fertilizer application has to be followed. It is mandatory to maintain the fertility of the soil for the sustainability of the environment.

REFERENCES

1. Arshad, M. A. and Martin, S. Identifying critical limits for soil quality indicators in agro-ecosystems. *Agric. Ecosyst. Environ.* 2002; 88(2): 153-160.
2. Seybold, C. A., Mausbach, M. J., Karlen, D. L., and Rogers, H. H. *Soil processes and the carbon cycle*. CRC Press, Boca Raton, 1997; 387-404.
3. Rezaei, S. A., Gilkes, R. J., and Andrews, S. S. A minimum data set for assessing soil quality in rangelands. *Geoderma*. 2006;136: 229-234
4. Parr, J. F., Papendick, R. I., Hornick, S. B., and Meyer, R. E. Soil quality: attributes and relationship to alternative and sustainable agriculture. *Am. J. Altern. Agric.* 1992; 7(1): 5-11.
5. Drechsel, P., Giordano, M., and Gyiele, L. 2004. *Valuing nutrients in soil and water: Concepts and techniques with examples from IWMI studies in the developing world*. Research report 82. International Water Management Institute, Colombo, Sri Lanka, 33p.
6. Karlen, D. L. and Stott, D. E. A framework for evaluating physical and chemical indicators of soil quality. *Defining Soil Qual. Sustain. Environ.* 1994;35: 53-72.
7. Andrews, S. S., Karlen, D. L., and Mitchell, J.P. A comparison of soil quality indexing methods for vegetable production systems in Northern California. *Agric. Ecosyst. Environ*. 2002; 90: 25-45.
8. Blake, G. R. and Hartge, K. H. Methods of soil analysis: Part 1 Physical and mineralogical methods, Vol 5, 1986; pp.363-375.

9. Vadyunina, A. F. and Korchagina, Z. A. Methods of Studying the Physical Properties of Soils. Agropromizdat, Moscow, 1986;416p.
10. Danielson, R. E. and Sutherland, P. L. Methods of Soil Analysis: Part 1 Physical and Mineralogical Methods, Vol 5, 1986; pp.443-461.
11. Bouyoucos, G. J. Directions for Making Mechanical Analysis of Soils by the Hydrometer Method. Soil Sci. 1936; 225-228.
12. Bavel, V. C. H. M. Mean weight diameter of soil aggregates as a statistical index of aggregation. Soil. Sci. Soc. Am. Proc. 1949;14: 20-21.
13. Gupta, R. P. and Dakshinamoorthy, C. Procedures for Physical Analysis of Soil and Collection of Agrometeorological Data. India Agricultural Research Institute, New Delhi, 1980; 293p.
14. Jackson, M. L. 1973. Soil chemical Analysis (2nd Ed.). Prentice Hall of India Pvt. Ltd., New Delhi, India, 498p.
15. Walkley, A. and Black, I. A. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci. 1934;37: 29-38.
16. Subbiah, B. V. and Asija, G. L. A rapid method for the estimation of nitrogen in soil. Curr. Sci. 1956;26: 259-260.
17. Watanabe, F. S. and Olsen, S. R. Test of an ascorbic acid method for determining phosphorus in water and NaHCO3 extracts from soil. Soil Sci. Soc. Am. J. 1965; 29: 677-678.
18. Hesse, P. R. 1971. A Textbook of Soil Chemical Analysis. William Clowes and Sons, London, 153p.
19. Massoumi, A. and Cornfield, A. H. A rapid method for determining sulphate in water extracts of soils. Analyst. 1963;88: 321-322.
20. Sims, J. T. and Johnson, G. V. Micronutrient soil tests. Micronutrients in Agriculture. 1991; 4: 427-476.
21. Gupta, U. C. Interaction effects of boron and lime on barley. Soil Sci. Soc. Am. Proc. 1972; 36: 332-4.
22. Eivazi, F. and Tabatabai, M. A. Phosphatases in soils. Soil. Biol. Biochem. 1977; 9:167-172.
23. Casida, L. E. Microbial metabolic activity in soil as measured by dehydrogenase determinations. Appl. Environ. Microbiol. 1977;34: 630-636.

24. KAU [Kerala Agricultural University] 2014. Package of Practices Recommendations: Crops (15th Ed.), Kerala Agricultural University, Thrissur, 360p.

25. Singh, A. K., Mazumdar, S. P., Saha, A. R., and Kundu, D. K. Soil quality changes resulting from long-term fertilizer application under intensive cropping system in Alluvial soils. *Commun. Soil Sci. Plant Anal*. 2017; 48(13): 1503-1510.

26. Kundu, S., Coumar, M. V., Saha, J. K., Rajendiran, S., Hati, K. M., Biswas, A. K., Reddy, K. S., and Rao, A.S. Assessing soil health of Vertisol of AESR 10.1 using selected physical, chemical and biological attributes of soils. *J. Indian Soc. Soil Sci.* 2012;60(4): 281-287.

27. Mukherjee, A. and Lal, R. Comparison of soil quality index using three methods. *PloS one*. 2014; 9(8): 1-15.

28. Athulya B.M., Gowri Priya, Rani,B., Aparna, B. and Nishan,M.A. *Assessment of Soil Quality Index in the Southern Coastal Sandy Soils of Kerala, India* Int. J. Environ. Clim. Change,2023; 13(8); 526-536

29. Mini, V. Assessment and management of micronutrient deficiencies in Onattukara. Ph.D. thesis, Kerala Agricultural University, Thrissur, 2015; 246p.