Journal of Geography, Environment and Earth Science International

Volume 28, Issue 9, Page 33-43, 2024; Article no.JGEESI.122785
ISSN: 2454-7352

Assessment of Land Use Systems on for Soil Quality in the Semi-A Arid Region, of Bengaluru, India

Karan Sathish [a*], A. S. Devakumar [b], A. Kokila [b], C. Vairavan [c], Thrilekha D. [d], Chethan Kumar K. B. [e], Shankar M. [e], Narayanaswamy Jeevan [f], Saleemali Kannihalli [g], Moorthy A. V. [h], V. Kousalya [b], Shruthi G. S. [i] and Shweta Saraswat [a]

[a] Department of Environmental Sciences, College of Basic Science & Humanities, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand-263 145, India.
[b] Department of Forestry and Environment Science, University of Agricultural Sciences, Bangalore, Karnataka-560 065, India.
[c] Department of Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharastra-413 722, India.
[d] Department of Sericulture, University of Agricultural Sciences, Bangalore, Karnataka-560 065, India.
[e] Department of Plant Genetic Resources, ICAR-IARI, New Delhi, 110012, India.
[f] Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore-641003, India.
[g] Department of Entomology, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka-560 005, India.
[h] Department of Entomology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand-263 145, India.
[i] Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Bangalore, Karnataka-560 065, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jgeesi/2024/v28i9810

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/122785

**Corresponding author: E-mail: karansathish555@gmail.com;*

Cite as: *Sathish, Karan, A. S. Devakumar, A. Kokila, C. Vairavan, Thrilekha D., Chethan Kumar K. B., Shankar M., Narayanaswamy Jeevan, Saleemali Kannihalli, Moorthy A. V., V. Kousalya, Shruthi G. S., and Shweta Saraswat. 2024. "Assessment of Land Use Systems on for Soil Quality in the Semi-A Arid Region, of Bengaluru, India". Journal of Geography, Environment and Earth Science International 28 (9):33-43. https://doi.org/10.9734/jgeesi/2024/v28i9810.*

Original Research Article

Received: 02/07/2024
Accepted: 05/09/2024
Published: 05/09/2024

ABSTRACT

Understanding the impact of diverse land-use systems (LUS) on soil quality is crucial for sustainable land management practices. This study was conducted in Bengaluru, India, to estimate the soil quality index (SQI) under different LUSs. Twenty-four sampling sites were identified in four different LUSs across the Bangaluru, and soil samples were collected monthly over five months during the Rabi cropping season of 2020-2021. The soil quality assessment involved selecting the minimum data set (MDS) via principal component analysis (PCA) and correlation, scoring soil indicators, and combining these scores to create the soil quality index (SQI). PCA was used to identify key soil properties, which included soil organic carbon (SOC), pH, dehydrogenase, nitrogen (N), and urease, for different LUSs derived from the MDS. The SQI was highest in the horticulture cropping system (0.58), followed by the agro + horticulture cropping system (0.53) and the vegetable cropping system (0.49), and lowest in the pulse cropping system (0.44). These findings emphasize the importance of sustainable land management practices to preserve and boost soil quality across cropping systems.

Keywords: Soil quality index; land-use systems; principal component analysis; horticulture cropping system; pulse cropping system.

1. INTRODUCTION

Throughout human history, soil health has been a crucial determinant of the success or failure of human civilizations. Over the years, extensive deforestation has occurred to meet the increasing demands for food, fodder, and timber driven by population growth and urbanization. The process of deforestation has transformed natural forests into various land uses, such as agroforestry, horticulture, tree plantations, and agriculture [1]. Sadly however, the development processes brought about by human being seem to neglect the crucial issues of soil health and sustainability. Unscientific agricultural intensification, driven by the pursuit of self-sufficiency, has inflicted damage on soils and hastened degradation [2]. In semiarid regions, inadequate soil management practices contribute primarily to physical deterioration and soil nutrient depletion [2]. Various types of vegetation can profoundly influence the physical, chemical, and biological attributes of the soil [3].

The soil quality index (SQI) is a critical tool used to assess and monitor the health and functionality of soils, particularly in agricultural and ecological contexts. Various soil properties are integrated to provide a comprehensive evaluation of soil quality, which is essential for sustainable land management and agricultural practices [4]. According to Karlen et al. [5], it is important to quantify all the aspects of soil properties to assess soil quality because of their significant impact on the ability of soils to accomplish specific functions. Although various techniques are used to determine the quality of SQIs, however technique developed with a minimum data set (MDS) of characteristics have been shown to reflect soil performance due to changes in management practices, such as alterations in land use patterns [6,1]. However, the impact of diverse LUSs on soil quality has yet to be determined. Hence, to determine the significance of soil quality, this study was undertaken with the following objectives: (1) To evaluate the physicochemical and biological attributes of soil across various LUSs in Bengaluru, India. (2) To establish a MDS of soil parameters for soil quality indexing to evaluate soil quality under distinct LUSs.

2. MATERIALS AND METHODS

2.1 Site Description, Experimental Details and Soil Sampling

The detailed site descriptions, experimental procedures, and soil sampling methods have been comprehensively outlined in Table 1 [7].

2.2 Soil Analysis

The soil pH was determined using a combination glass electrode immersed in a 1:2.5 soil–water slurry [8]. The electrical conductivity (EC) was measured in a 1:2.5 soil–water suspension using

an EC meter [8]. The soil organic carbon (SOC) content was determined using the modified $K_2Cr_2O_7$-H_2SO_4 oxidation method [9]. The alkaline potassium permanganate method was employed to estimate the available nitrogen (N) content [10]. Available phosphorus (P) was determined using the Bray 1 method [11]. The soil available potassium (K) concentration was measured using a normal neutral 1 N ammonium acetate extractant. Inductively coupled plasma–optical emission spectrometry (ICP–OES) was used to estimate the concentrations of iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn). The bulk density (BD), particle density (PD), and porosity of the soil were determined using the Keen–Raczkowski cup method [12]. The soil moisture content was determined using the gravimetric method by drying the soil to a constant weight at 105°C [13]. Microbial biomass carbon (MBC) [14] and nitrogen (MBN) [15] were measured using the chloroform fumigation extraction technique. Soil dehydrogenase activity was assessed by the reduction of 2,3,5-triphenyl tetrazolium chloride (TTC) [16]. Soil urease activity was analyzed through the incubation method outlined by Kandeler and Gerber [17].

2.3 Assessment of the Soil Quality Index (SQI)

Soil quality assessment entails three primary steps: selecting the MDS through principal component analysis (PCA) and determining the significance difference in correlation ($p<0.05$), scoring soil indicators, and amalgamating scores to formulate the SQI [18,1]. PCA, employing the varimax rotation technique, was also conducted to explore the relationships among these indicators. Principal components (PCs) explaining a minimum of 5% of the variance and possessing eigenvalues >1 was considered for indicator selection. Within each PC, indicators with weighted loading values within 10% of the highest loading were selected for the MDS, irrespective of their sign. Multivariate correlation was used to detect and eliminate redundant data when multiple factors were retained within a single PC. In instances of high correlation (r >0.60) among variables, only the variable with the highest correlation was retained for the MDS and considered a "key indicator" used for computing the SQI. [1].

A linear scoring method was used to convert the data of each identified critical MDS indicator into scores. The indicators were ranked in to determine whether a higher or lower value corresponded to better soil function. For indicators where higher values indicated better function, each observation was divided by the highest observed value and vice versa [19]. This process was performed using the following formula [20]: Linear normalization (S_L) was carried out using the maximum (X_{max}) and minimum (X_{min}) values for each soil indicator (X), as shown in Equations 1 and 2.

$$S_L = \frac{X}{X_{max}} \quad (1)$$

$$S_L = \frac{X_{min}}{X} \quad (2)$$

MDS indicators for each observation were weighted following conversion into linear scores. Each PC in the data set represented a certain percentage of variance, and the weighted factor for each MDS indicator was determined by dividing the percentage variance by the cumulative variance for all PCs with eigenvalues >1. Equation 3 was used to calculate the SQI by the weighted scores of the MDS indicators for each observation.

$$SQI = \sum_{i=1}^{n}(Wi \times Si) \quad (3)$$

The subscripted variable's score is denoted as (Si), with its weighting factor from PCA represented as (Wi). The SQI values were standardized to a range of 0 to 1 by dividing all the SQI values by the maximum SQI value. Subsequently, the SQI was calculated as a percentage of the average score for each element in the MDS. According to the classification of Li et al. [21], soils are grouped into five grades based on their SQI values (Table 2).

2.4 Statistical Analysis

A randomized block design (RBD) analysis and Tukey HSD procedure were applied to compare the means of various soil parameters across different LUSs; these analyses were conducted using Origin (Pro) software, 2024, produced by Origin Lab Corporation, Northampton, MA, USA. Pearson's correlation coefficient was used to assess the relationships among the soil quality properties. PCA was carried out using SPSS 20.0 software, and these results were subsequently used to create the MDS for SQI development. Radar plots depicting the % contribution of each indicator to the SQI were generated using Origin (Pro) software, 2024, by Origin Lab Corporation, Northampton, MA, USA.

Table 1. Details of the experimental sites

Transects	Areas	Cropping systems	Latitude (N)	Longitude (E)
North Bengaluru	Urban	A+HCS	13°08'03.0"	77°34'48.2"
		PCS	13°06'41.64"	77°36'05.94"
		VCS	13°04'56.85"	77°36'32.33"
		HCS	13°07'29.5"	77°33'27.86"
	Peri urban	A+HCS	13°08'00.77"	77°34'40.77"
		PCS	13°09'39.16"	77°36'31.24"
		HCS	13°09'52.7"	77°36'53.48"
		VCS	13°12'43.55"	77°35'14.95"
	Rural	VCS	13°22'26.76"	77°34'50.12"
		PCS	13°20'10.12"	77°35'39.24"
		HCS	13°15'12.22"	77°35'53.91"
		A+HCS	13°14'28.53"	77°36'39.09"
South Bengaluru	Urban	VCS	12°50'50.7"	77°35'50.51"
		PCS	12°50'50.7"	77°35'50.51"
		HCS	12°51'25.23"	77°35'50.23"
		A+HCS	12°50'50.3"	77°30'42.18"
	Peri urban	HCS	12°48'27.41"	77°30'44.91"
		PCS	12°48'46.67"	77°31'28.14"
		VCS	12°48'46.67"	77°31'28.14"
		A+HCS	12°48'27.38"	77°32'33.21"
	Rural	PCS	12°43'41.59"	77°29'29.03"
		A+HCS	12°43'26.26"	77°28'53.7"
		HCS	12°44'40.52"	77°26'27.12"
		VCS	12°45'20.6"	77°26'17.68"

Note: PCS- Pulse cropping system (red gram), VCS-Vegetable cropping system (tomato and ridge gourd), HCS-Horticulture cropping system (grapes and chikoo), A+HCS-Agriculture + horticulture cropping system (coconut + fodder plantation)

Table 2. Soil quality grade classification

Indicator	Soil Quality Grade				
	Very High	High	Moderate	Low	Very Low
	Grade-I	Grade-II	Grade-III	Grade-IV	Grade-V
SQI	>0.60	0.55–0.60	0.45–0.54	0.38–0.44	<0.38

3. RESULTS

Univariate ANOVA is used to determine the relationship between soil parameters and different LUSs. The univariate ANOVA results for 18 soil physicochemical and biological properties across diverse LUSs are shown in Table 3.

3.1 Soil Physical Properties

The soil bulk density (BD), particle density (PD), and moisture content did not significantly differ across the different LUSs ($p>0.05$). Among the LUSs, high soil BD was observed in the PCS, VCS, and HCS (1.35 Mg m-3), while the lowest BD was found in the A+HCS (1.34 Mg m-3). The soil PD was greater in the VCS, HCS, and A+HCS treatments (2.22 Mg m-3), with the PCS showing a slightly lower PD (2.21 Mg m-3). The soil porosity varied significantly across the four LUSs. A+HCSs exhibited the highest soil porosity (39.41%), followed by VCSs (39.34%) and HCSs (39.03%), while PCSs had the had the lowest porosity (38.88%). The HCSs had the highest soil moisture content (9.00%), whereas the PCS had the lowest (7.72%).

3.2 Soil Chemical Properties

The soil pH and soil organic carbon (SOC) content differed significantly among the four LUSs ($p<0.05$). In all the systems, the soil pH was acidic. The highest soil pH was observed in the VHCS (6.95), followed by that in the A+HCS (6.87) and that in the PCS (6.73), with the lowest (more acidic) pH recorded in the HCS (6.71). The electrical conductivity (EC) of PCS was greater (0.14 dS m^{-1}) than that of the other three systems

(0.12 dS m^{-1}). SOC was significantly greater in A+HCSs (0.38%), followed by HCSs (0.37%) and VCSs (0.36%), with the lowest SOC found in PCSs (0.34%). The macronutrients (N, P, and K) exhibited significant differences ($p<0.05$) between the various LUSs. The available N in these systems was generally low (<280 kg/ha). A+HCSs had the highest available N (157.33 kg/ha), while PCS had the lowest (133.56 kg/ha), despite pulses being leguminous. Available P was significantly highest in the PCS (31.69 kg/ha) and VCS on par with A+HCS and was significantly lowest in the HCS (25.11 kg/ha). Among the diverse LUSs, PCS had the highest available K (181.37 kg/ha), while A+HCS had the lowest (164.57 kg/ha). Among the four LUSs, the available Fe and Zn contents exhibited significant differences, while the available Cu and Mn contents exhibited nonsignificant differences. The highest available Fe concentration was found in PCS (4.64 ppm), followed by VCS (3.90 ppm), HCS (3.75 ppm), and A+HCS (2.54 ppm). For Mn, PCS had the highest content (2.46 ppm), followed by HCS (2.11 ppm), VCS (1.75 ppm), and A+HCS (1.06 ppm). Available Zn was significantly highest in A+HCSs (0.32 ppm), followed by PCSs (0.31 ppm), VCSs (0.31 ppm), and HCSs (0.29 ppm). Available Cu was highest in A+HCSs (0.24 ppm) and lowest in PCSs (0.19 ppm).

3.3 Soil Biological Properties

The soil MBC is an indicator of the soil microbial load and significantly differed among the LUS. The MBC concentration was highest in VCS (118.63 µg g^{-1}), followed by A+HCS (118.27 µg g^{-1}) and HCS (116.51 µg g^{-1}), and lowest in PCS (116.29 µg g^{-1}). In the VCS treatment, the turnover rate of organic carbon (OC) was also high, followed by that in the A+HCS treatment, compared to that in the other cropping systems. The same trend was observed for MBN across the four LUSs, although the differences were not statistically significant. High soil MBN was found in VCS (13.82 µg g^{-1}), followed by A+HCS (13.77 µg g^{-1}), HCS (13.59 µg g^{-1}), and PCS (13.57 µg g^{-1}). Soil dehydrogenase activity was highest in A+HCSs (98.34 µg TPF g^{-1} soil 24 h^{-1}), followed by HCSs (87.62 µg TPF g^{-1} soil 24 h^{-1}) and VCSs (82.72 µg TPF g^{-1} soil 24 h^{-1}), with the lowest activity occurring in PCSs (75.27 µg TPF g^{-1} soil 24 h^{-1}). Among the four LUSs, A+HCSs had the highest soil urease activity (19.03 µg NH4-N g^{-1} soil h^{-1}), while PCS had the lowest (13.94 µg NH4-N g^{-1} soil h^{-1}).

Table 3. Soil physical, chemical and biological properties of the different LUSs

	PCS	VCS	HCS	A+HCS
pH	6.73±0.20^{b}	6.95±0.18^{a}	6.71±0.26^{b}	6.87±0.20^{ab}
EC (dSm^{-1})	0.14±0.01^{a}	0.12±0.01^{a}	0.12±0.01^{a}	0.12±0.01^{a}
SOC (%)	0.34±0.01^{b}	0.36±0.01^{ab}	0.37±0.01^{a}	0.38±0.01^{a}
Moisture content (%)	7.72±0.36^{a}	8.62±0.30^{a}	9.00±0.41^{a}	8.71±0.42^{a}
Bulk density (Mgm^{-3})	1.35±0.01^{a}	1.35±0.01^{a}	1.35±0.01^{a}	1.34±0.01^{a}
Particle density (Mgm^{-3})	2.21±0.01^{a}	2.22^{a}	2.22±0.01^{a}	2.22^{a}
Porosity (%)	38.88±0.24^{b}	39.34±0.37^{a}	39.03±0.37^{ab}	39.41±022^{a}
N (kg/ha)	133.56±6.11^{c}	142.41±4.44^{b}	151.28±8.19^{ab}	157.33±7.72^{a}
P (kg/ha)	31.69±1.91^{a}	27.20±0.96^{ab}	25.11±1.46^{b}	26.68±1.06 ^{ab}
K (kg/ha)	181.37±6.96^{a}	170.30±6.21^{ab}	167.25±8.66^{b}	164.57±7.87^{b}
Zn (ppm)	0.31±0.01^{b}	0.31±0.01^{b}	0.29 ^{c}	0.32±0.01^{a}
Fe (ppm)	4.64±0.24^{a}	3.90±0.28^{ab}	3.75±0.16^{b}	2.54±0.18^{c}
Mn (ppm)	2.46±0.13^{a}	1.75±0.27 ^{a}	2.11±0.15^{a}	1.06±0.11^{a}
Cu (ppm)	0.19±0.02^{a}	0.19±0.02^{a}	0.21±0.02^{a}	0.24±0.01^{a}
Dehydrogenase (µg TPF g^{-1} soil 24 h^{-1})	75.27±3.81^{b}	82.72±5.60^{ab}	87.62±4.85^{ab}	98.34±3.12^{a}
Urease (µg NH_4- N g^{-1} soil h^{-1})	13.94±1.10^{b}	15.41±1^{ab}	17.31±1.18^{ab}	19.03±0.98^{a}
MBC (µg g^{-1})	116.29±3.91^{b}	118.63±3.77^{a}	116.51±3.66^{b}	118.27±4.08^{a}
MBN (µg g^{-1})	13.57±0.49^{a}	13.82±0.43^{a}	13.59±0.42^{a}	13.77±0.49^{a}

Note: PCS- Pulse cropping system, VCS-Vegetable cropping system, HCS-Horticulture cropping system, A+HCS-Agriculture + horticulture cropping system, EC- Electrical Conductivity, SOC- Soil Organic Carbon, N-Nitrogen, P- Phosphorus, K- Potassium, Zn- Zinc, Fe- Iron, Mn-, Manganese, Cu- Copper, MBC- Microbial Biomass Carbon and MBN- Microbial Biomass Nitrogen

^{z} in a row value followed by similar letter specifies no significance

3.4 Principal Component Analysis (PCA) and Selection of Minimum Data Set (MDS)

3.4.1 PCA and MDS for soil property determination for different LUSs

Table 4 shows PCA results for soil quality indicators for several LUSs, Of the 18 soil properties assessed, 11 exhibited significant variation among the LUSs and were selected for PCA. Two principal components (PCs) with eigenvalues > 1 were chosen; these PCs collectively explained 92.03% of the cumulative variance. Varimax rotation was employed to optimize the distribution of variance across the selected PCs. PC1, with an eigenvalue of 7.60, accounted for approximately 69.11% of the variance. SOC had the highest positive factor loading (0.97), followed by dehydrogenase (0.96), N (0.94), and urease (0.93). On the other hand, PC2 explained 22.92% of the variation, with an eigenvalue of 2.52. For this component, the soil pH exhibited the highest factor loading at 0.82.

In the case of various LUSs, two PCs with eigenvalues > 1 were chosen for MDS. In the first PC, the SOC, dehydrogenase, N, and urease parameters were within 10% of the highest factor loading (Table 4). All four parameters from PC1 correlated positively with a correlation coefficient (r) greater than 0.60. Since they represent two different aspects of soil, i.e., chemical properties (organic and inorganic nutrients) and biological properties (soil enzymatic activity), they were selected for analysis (Fig. 1). In PC2, pH was highly weighted and hence retained for MDS. SOC, pH, dehydrogenase, N, and urease are crucial soil quality indicators for different LUSs derived from the MDS.

3.5 Soil Quality Index (SQI)

Fig. 2 displays the values of the soil quality indices for the various LUSs. Radar plot diagrams depict the contributions of soil indicators to the SQI under different land-use systems across various rural–urban transition zones (Fig. 3).

3.5.1 SQIs under different LUSs

The linear scoring method used to calculate the SQI was highest under HCSs (0.58), followed by A+HCSs (0.53) and VCSs (0.49), with the lowest SQI recorded in the PCS (0.44). The HCSs exhibited a high SQI (0.58), which fell within the range of 0.55–0.60 (Grade II; Table 1), indicating good soil quality maintenance. In the HCSs, the contributions of the indicators to soil quality, in terms of percentage, were ranked as follows: pH (24.1%) > urease (20.3%) > dehydrogenase (20%) > N (18%) > SOC (17.7%) (Fig. 3). The soil in A+HCS (0.53) and VCS (0.49) exhibited

Table 4. PCA results for soil quality indicators of various LUSs

Factors	Land Use Systems	
	PC1	PC2
Porosity	0.86	0.49
pH	0.51	**0.82**
SOC	**0.97**	-0.24
N	**0.94**	-0.32
P	-0.79	0.44
K	-0.96	0.22
Zn	0.24	0.72
Fe	-0.96	-0.01
Dehydrogenase	**0.96**	-0.14
Urease	**0.93**	-0.29
MBC	0.68	0.68
highest	0.97	0.82
10% of highest	0.87	0.74
Eigenvalue	7.60	2.52
Variance (%)	69.11	22.92
Cumulative variance (%)	69.11	92.03

Note- PC- Principal Component, EC- Electrical Conductivity, SOC- Soil Organic Carbon, N- Nitrogen, P- Phosphorus, K- Potassium, Zn- Zinc, Fe- Iron, Mn-, Manganese, MBC- Microbial Biomass Carbon and MBN- Microbial Biomass Nitrogen

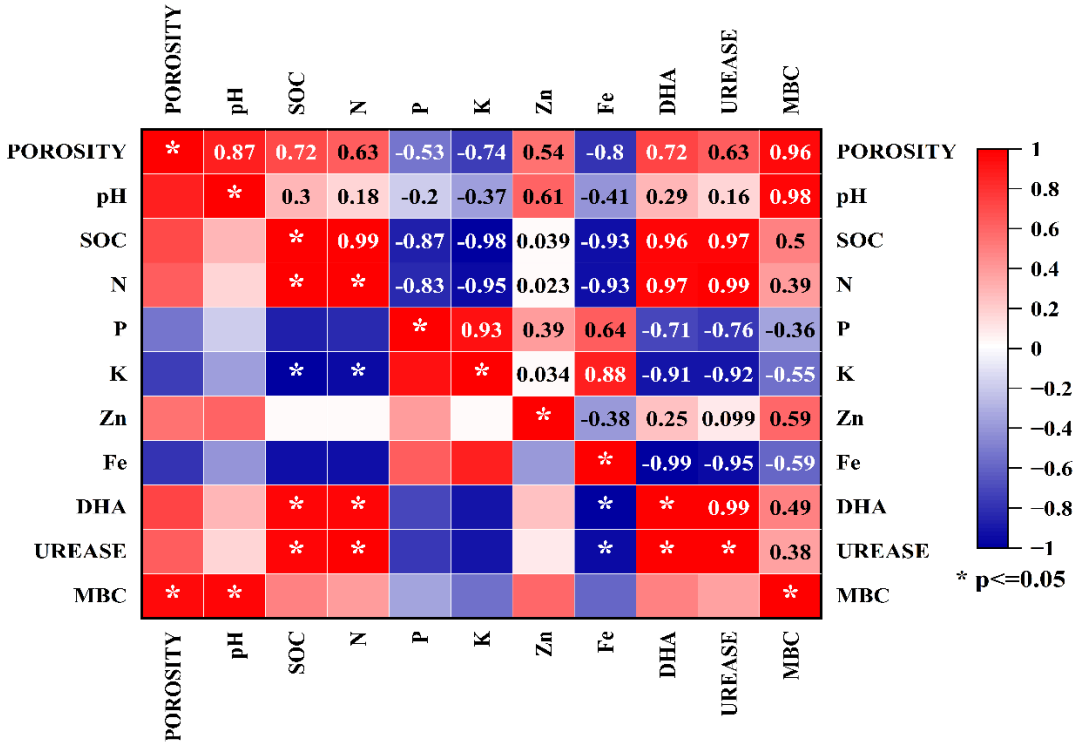

Fig. 1. Correlation matrix of significant soil indicators under diverse LUSs

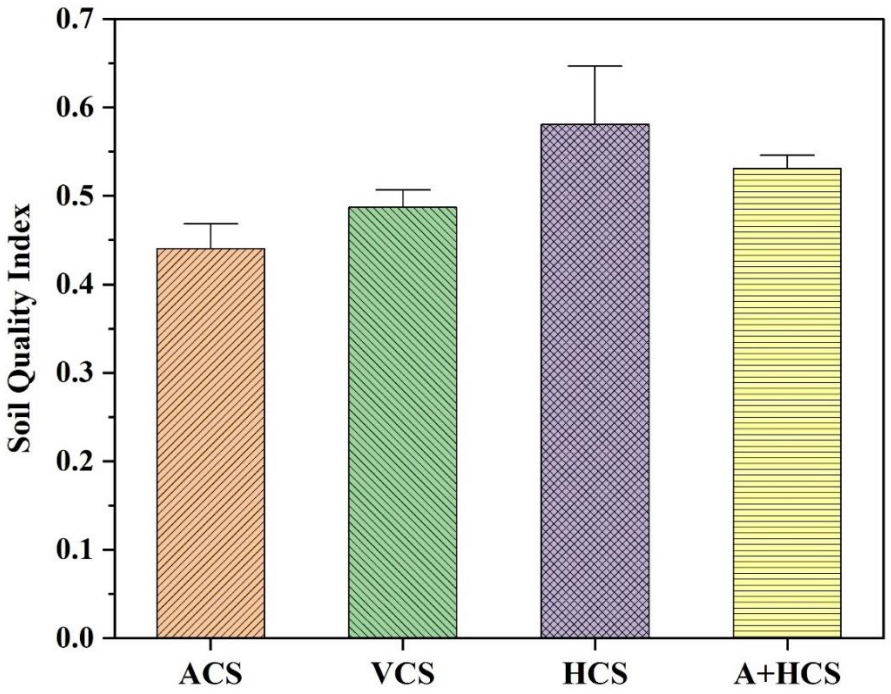

Fig. 2. Soil quality indices in various LUSs

moderate SQI values, which fell within the range of 0.45–0.54 (Grade III). In the A+HCSs, the contributions of the indicators to soil quality, in terms of percentage, were ranked as follows: pH (20.7%) > N (20.6%) > SOC (19.9%) > urease (19.6%) > dehydrogenase (19.2%). In the VCSs, pH (21.3%) was the highest contributor, and urease (18.9%) was the lowest contributor. The

PCS soils displayed a low SQI (0.44), which fell within the range of 0.38–0.44 (Grade IV), indicating poor soil quality maintenance. In the PCS, the contributions of the indicators to soil quality, in terms of percentage, were ranked as follows: pH (21.8%) > SOC (20.9%) > N (20.2%) > dehydrogenase (19%) > urease (18.1%).

4. DISCUSSION

4.1 Effects of Different LUSs on Soil Properties

The high moisture content in HCSs and A+HCSs can be attributed to two factors: first, they are generally irrigated, unlike pulse crops; second, the greater canopy cover of perennial horticultural crops reduces soil moisture evaporation. Similar trends in these soil physical traits were reported by Scharenbroch et al. [22], corroborating our findings. The high SOC content may be attributed to the deposition of large quantities of litter in mixed cropping systems (A+HCSs). In contrast to croplands, perennial crops sustain continuous vegetation cover and undergo frequent root turnover, thereby augmenting the input of SOC. In general, crops characterized by high biomass export and the reintroduction of crop residues into the soil directly impact SOC levels [23]. This low N status in PCS could be due to intensive cultivation leading to increased N mineralization. High P fertilizer application in the PCS enhances rhizobial activity in the root zone. Agricultural crops require high amounts of K fertilizer to achieve higher grain and protein yields [24]. Dehydrogenase activity, an indirect indicator of overall microbial soil activity, and urease activity, which catalyzes the hydrolysis of urea to CO_2 and NH_3, also varied significantly among the LUSs and followed a similar pattern. Tillage treatments were found to significantly influence urease activity, with a decrease in activity associated with increased soil disturbance in the PCS [25].

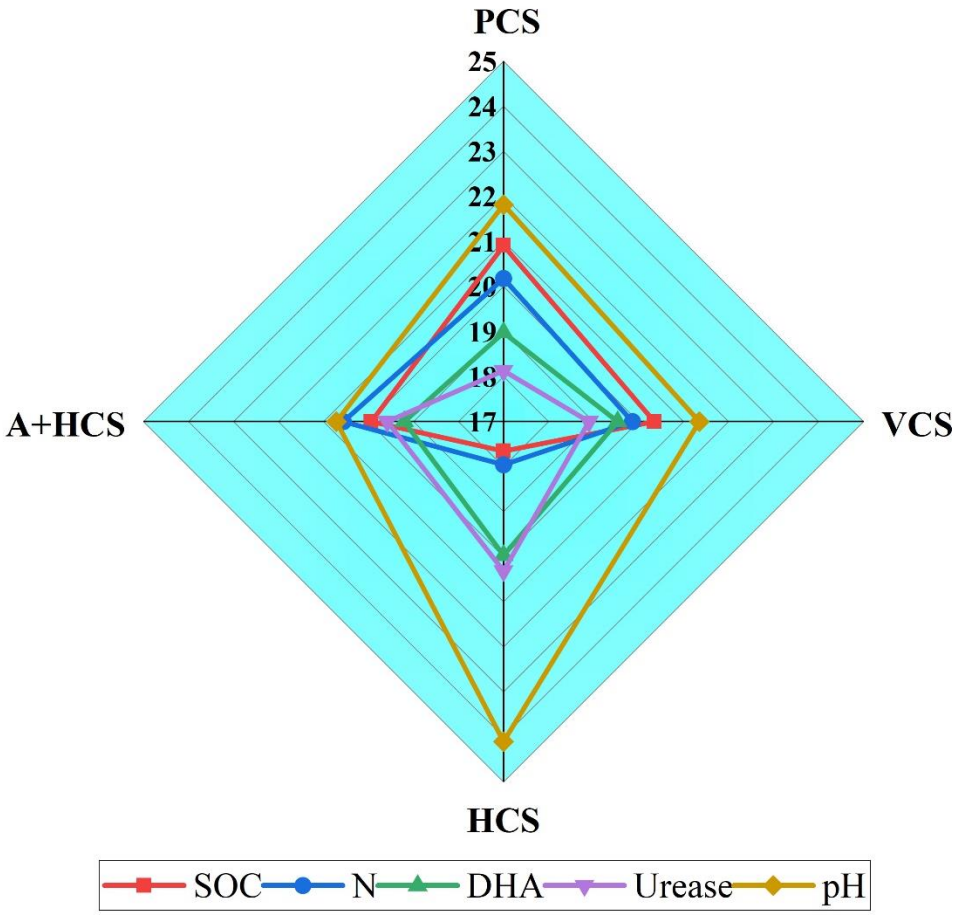

Fig. 3. Contributions of selected soil indicators of the MDS to soil quality indices under different LUSs

4.2 Assessment of the SQI through PCA of Different LUSs

Dehydrogenase activity is considered an important soil quality indicator [26,27]. Soil nutrient availability, organic compound oxidation, and microbial activity related to N cycling are crucial indicators of SQ [28,1]. N is vital for plant growth, exclusive biomass production, and leaf area increase [29]. A decrease in SOC leads to a decrease in crop yield, aggregate stability, and soil cation exchange capacity, which makes SOC a key soil quality component [30]. Soil pH controls numerous soil properties (physicochemical and biological) and processes (nutrient regulation and microbial activity) [31,19].

This high SQI under HCSs can be attributed to factors such as high SOC levels and optimal biological enzymatic activities. Reduced soil disturbance and litter accumulation in HCSs promote the growth of soil microorganisms and mesofauna, favoring high SQIs [7]. Soil pH has emerged as a primary indicator for these soils, regulating various physicochemical and biological properties, microbial activity and OM turnover [31]. Despite containing an optimal amount of soil chemical and biological properties, A+HCSs and VCSs face challenges due to the short duration of agricultural and vegetable crop cultivation, necessitating the use of heavy equipment in farming practices, pesticide management, and fertilization, all of which can diminish soil quality. Anthropogenic activities such as land practices can lead to changes in soil quality in agroecosystems, affecting soil functions [32]. Larger soil organisms such as worms and arthropods contribute nutrients to the soil through their waste as they feed on SOM. Sathish and AS [7] also noted a lower population of soil fauna in the PCS due to mechanized farming and high disturbance. SOC and soil pH are crucial indicators of soil quality because they influence the nutrient supply capacity and nutrient availability in soil [33].

5. CONCLUSION

The study revealed that soil quality is significantly influenced by different LUSs. HCSs demonstrated the highest SQI due to their high SOC content and optimal biological activities, with pH emerging as a critical indicator. The A+HCSs and VCSs had moderate SQIs, which were affected using heavy farming equipment and management practices. The PCS had the lowest SQI and was impacted by mechanized farming and high soil disturbance. SOC, pH, dehydrogenase, N, and urease are the crucial soil quality indicators for different LUSs derived from the MDS for PCA. These findings highlight the need for efficient land use and management practices to improve soil quality across different cropping systems.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICAL RESPONSIBILITIES OF AUTHORS

All the authors have read, understood, and complied with the statement on "Ethical responsibilities of Authors", as found in the Instructions for Authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Uthappa AR, Devakumar AS, Das B, Mahajan GR, Chavan SB, Jinger D, et al. Comparative analysis of soil quality indexing techniques for various tree based land use systems in semi-arid India. Frontiers in Forests and Global Change. 2024;6:1322660.
2. Jinger D, Kaushal R, Kumar R, Paramesh V, Verma A, Shukla M, et al. Degraded land rehabilitation through agroforestry in India: Achievements, current understanding, future prospectives. Frontiers in Ecology and Evolution. 2023;11:1088796.
3. Tauqeer HM, Turan V, Farhad M, Iqbal M. Sustainable agriculture and plant production by virtue of biochar in the era of climate change in Managing plant production under changing environment. eds. M. Hasanuzzaman, G. J. Ahammed

and K. Nahar (Singapore: Springer). 2022; 21–42.
4. Bel-Lahbib S, Ibno Namr K, Rerhou B, Mosseddaq F, El Bourhrami B, Moughli L. Assessment of soil quality by modeling soil quality index and mapping soil parameters using IDW interpolation in Moroccan semi-arid. Modeling Earth Systems and Environment. 2023;9(4):4135-4153.
5. Karlen DL, Parkin TB, Eash NS. Use of soil quality indicators to evaluate conservation reserve program sites in Iowa. Methods for Assessing Soil Quality. 1997;49:345-355.
6. Raiesi F. A minimum data set and soil quality index to quantify the effect of land use conversion on soil quality and degradation in native rangelands of upland arid and semiarid regions. Ecological Indicators. 2017;75:307-320.
7. Sathish K, As D. Composition of soil mesofauna in changing cropping systems due to urbanization in Bengaluru, India. Environmental Monitoring and Assessment. 2024;196(4):335.
8. Jackson ML. Soil chemical analysis-advanced course; 1969.
9. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter, a proposed modification of the chromic acid titration method. Soil Science. 1934;37(1):29-38.
10. Subbiah BV. In addition, Asija GL. A rapid procedure for estimation of available N in soil. Curr. Sci. 1956;25:259-260.
11. Bray RH, Kurtz LT. Determination of total, organic, available forms of phosphorus in soils. Soil Science. 1945;59(1):39-46.
12. Piper CS. Soil and plant analysis. Scientific Publishers; 2019.
13. Black CA, Evans DD, White JL, Ensminger LE, Clarke FE. Methods of soil analysis. American Society of Agronomy. Madison, Wisconsin. 1965;part I:1-770.
14. Vance ED, Brookes PC, Jenkinson DS (1987) An extraction method for measuring soil microbial biomass C. Soil Biol Biochem 19:703–707
15. Casida Jr, LE, Klein DA, Santoro T. Soil dehydrogenase activity. Soil Science. 1964;98(6):371-376.
16. Brookes PC, Kragt JF, Powlson DS, Jenkinson DS. Chloroform fumigation and the release of soil nitrogen: The effects of fumigation time and temperature. Soil Biology and Biochemistry. 1985;17(6):831-835.
17. Kandeler E, Gerber H. Short-term assay of soil urease activity using colorimetric determination of ammonium. Biology and fertility of Soils. 1988;6:68-72.
18. Andrews SS, Karlen DL, Mitchell JP. A comparison of soil quality indexing methods for vegetable production systems in Northern California. Agriculture, Ecosystems & Environment. 2002;90(1): 25-45.
19. Tejashvini A, Ramamurthy V, Thimmappa Subbarayappa C. Soil quality assessment of different land use systems of peri-urban-rural landscape of Deccan plateau, hot semi-arid agro-ecosystem. Archives of Agronomy and Soil Science. 2023;69(14): 3060-3072.
20. Vasu D, Singh SK, Ray SK, Duraisami VP, Tiwary P, Chandran P, et al. Soil quality index (SQI) as a tool to evaluate crop productivity in semi-arid Deccan plateau, India. Geoderma. 2016;282:70-79.
21. Li X, Li H, Yang L, Ren Y. Assessment of soil quality of croplands in the Corn Belt of Northeast China. Sustainability. 2018; 10(1):248.
22. Scharenbroch BC, Lloyd JE, Johnson-Maynard JL. Distinguishing urban soils with physical, chemical, biological properties. Pedobiologia. 2005;49(4):283-296.
23. Graham MH, Haynes RJ, Meyer JH. Soil organic matter content and quality: Effects of fertilizer applications, burning and trash retention on a long-term sugarcane experiment in South Africa. Soil Biology and Biochemistry. 2002;34(1):93-102.
24. Srinivasarao C, Masood A, Ganeshamurthy AN, Singh KK. Potassium requirements of pulse crops. Better Crops Int. 2003;17(1):8-11.
25. Lorenz K, Kandeler E. Biochemical characterization of urban soil profiles from Stuttgart, Germany. Soil Biology and Biochemistry. 2005;37(7):1373-1385.
26. Biswas S, Hazra GC, Purakayastha TJ, Saha N, Mitran T, Roy SS, et al. Establishment of critical limits of indicators and indices of soil quality in rice-rice cropping systems under different soil orders. Geoderma. 2017;292:34-48.
27. Klimkowicz-Pawlas A, Ukalska-Jaruga A, Smreczak B. Soil quality index for agricultural areas under different levels of anthropopressure. International Agrophysics. 2019;33(4).

28. Bünemann EK, Bongiorno G, Bai Z, Creamer RE, De Deyn G, De Goede R, et al. Soil quality–A critical review. Soil Biology and Biochemistry. 2018;120:105-125.
29. Diaz C, Saliba-Colombani V, Loudet O, Belluomo P, Moreau L, Daniel-Vedele F, et al. Leaf yellowing and anthocyanin accumulation are two genetically independent strategies in response to nitrogen limitation in Arabidopsis thaliana. Plant and Cell Physiology. 2006;47(1):74-83.
30. Freixo AA, Machado PLO.A, Guimarãe CM, Silva CA, Fadigas FS. Carbon and nitrogen storage and organic fraction distribution of a cerrado oxisol under diferent cultivation systems. Revista Brasileira de Ciencia do Solo. 2002;26: 425-434.
31. Schoenholtz SH, Van Miegroet H, Burger JA. A review of chemical and physical properties as indicators of forest soil quality: Challenges and opportunities. Forest Ecology and Management. 2000; 138(1-3):335-356.
32. Yang T, Siddique KH, Liu K. Cropping systems in agriculture and their impact on soil health-A review. Global Ecology and Conservation. 2020;23:e01118.
33. Kuntoji A, Subbarayappa CT. Assessment of soil quality in Rural and Peri-urban Areas of Southern Transect of Bengaluru by using Principal Component Analysis. Indian Journal of Ecology. 2022; 49(6):2076-2081.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/122785