International Journal of Environment and Climate Change

Volume 13, Issue 7, Page 646-659, 2023; Article no.IJECC.99972
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Assessment of Soil Quality of Selected Districts of Kaleshwaram Project Command Area of Telangana State, India

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Authors' contributions

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

Article Information

DOI: 10.9734/IJECC/2023/v13i71917

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/99972

Original Research Article

Received: 04/03/2023
Accepted: 08/05/2023
Published: 17/05/2023

ABSTRACT

A study was conducted with an objective to assess the soil quality of command areas of Kaleshwaram Project in Karimnagar, Nizamabad and Warangal districts. The assessment was made by developing a soil quality index (SQI) based on relationships among pairs of soil parameters, followed by principal component analysis. The study indicated about superiority of soil pH, available Cu, Mn, P, K and Fe that have significantly contributed to the SQI. Four leading

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principal components were significant based on eigenvalue of 'more than 1' and explained 62.11% of variance in soil parameters. All Kaleshwaram project command areas in Karimnagar, Nizamabad and Warangal were found to have SQIs in the medium range (0.35-0.55) when soil quality was evaluated by looking at the variability present in soil parameters.

Keywords: Soil quality; SQI; Kaleshwaram; principal component analysis; pH.

1. INTRODUCTION

Among different natural resources, soil is the most important one and would be the topmost layer of the earth. It has originated from the parent rock and would contain both organic and inorganic substances, which would support life on this planet through supply of essential nutrients and act as a medium for growth. Yet recent soil resources are under severe stress, due to different types of degradation in rainfed areas, apart from competing demands of different land uses due to continuous agriculture. Lack of suitable management practices, indiscriminate use of input resources and use of land principally by small holders for agriculture which lead to land degradation, low yields and low productivity. The effect of agriculture on soil would cause structural changes that would affect water, temperature, species community structure and soil ecosystem services. The capacity of soil to support plant growth could be measured and used for assessing sustainability of resources by assessment of soil quality. Soil quality is defined as ''the capacity of a soil to function within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental quality and promote plant, animal and human health''. Several conceptual frameworks for monitoring soil quality have been proposed by various researchers [1,2]. Geospatial techniques involving the use of RS, Global Positioning System (GPS) and Geographic Information System (GIS), provide new approaches for studying various soil quality aspects in different spatial as well as temporal domains [3].

Soil Quality Index (SQI) estimation is an indirect method based on the weighted integration of soil quality indicators. SQI calculation involves three steps: soil quality indicator selection, scoring of indicator and weightage of each soil quality indicators, and then integration into a soil quality index. Principal component analysis (PCA) is a method used to identify suitable physical, chemical and biological indicators in the ecosystem for soil quality assessment [4]. Soil quality indicators, which reflect the changes due to land management practices, may include various chemical, physical and biological soil properties. Arriving at proper soil quality index (SQI) can help to determine the degraded soil properties and for help land management experts and scientists to reveal sustainable land management operations which can control soil degradation. It would also help in proper interpretation of soil resources for growing crops, apart from developing fertilizer recommendations [5].

Telangana State is situated in the central stretch of the Indian Peninsula on the Deccan Plateau. It is the state 29th of India and twelfth-largest state in the country with an extent of 1,14,840 Km^2 and a population of 35.3 Millions. The region is drained by two major rivers namely Godavari and Krishna. The gross area irrigated in the state during 2013-14 is 31.64 lakh hectares which is increased by 23.74% from 2012-13. The net area irrigated is 22.89 lakh hectares (30.43% of cultivable area) during the 2013-14 which increased by 29% from previous year [6]. In the state there are 12.83 lakh irrigation sources (Bore wells/Tube wells 6.53 lakhs and Dug wells: 6.3 lakhs) and 0.5 lakh surface flow and lift irrigation schemes. Ground water contributes ~75% of gross irrigated area and 25% by surface water like tanks, canals and lift irrigation. The use of ground water of marginal (saline or sodic) and poor (highly saline, highly sodic or both) quality for irrigation may degrade the soils especially at the tail end of the canal system. This practice may also give rise to some apparent and hidden soil problems directly or indirectly associated with tube well irrigation. To enhance the irrigated area and stabilize ayacut areas, major projects in the state of Telangana were formulated one among is Kaleshwaram project. Kaleshwaram Project has been conceived from the erstwhile Dr. B.R. Ambedkar Pranahita-Chevella Sujala Sravanthi project. It is one of the world's biggest irrigation project that is set to end water woes of the state where many regions are parched. This project aims at an ambitious target of diverting 195 TMC of water to the backward areas in the state of Telangana to restore the ground water level to its

original state by the way of shifting from usage of groundwater for irrigation to usage of surface water and conjunctive use of groundwater for the same.

Kaleshwaram Project was formulated for irrigation of 7,38,851 ha (18,25,700 acres) in Karimnagar, Rajanna Siricilla, Siddipet, Medak, Yadadri, Nalgonda, Sangareddy, Nizamabad, Jagityal, Kamareddy, Nirmal, Medchal, Jayashankar Bhupalpalli, Manchiryala and Peddapalli districts of Telangana by diverting 180 TMC of water from River Godavari [6]. However, very little information is available in relation to soil quality status of command areas of Kaleshwaram Projects in Karimnagar, Nizamabad and Warangal (old districts). Hence, the present study was conducted with an objective: to assess the soil quality index of command areas of Kaleshwaram Project in Karimnagar, Nizamabad and Warangal.

2. MATERIALS AND METHODS

2.1 Location and Extent of Study Area

The Nizamabad district of Telangana, extending over an area of 7956 km^2 is bounded on the North by Godavari river, East by Karimnagar district, South by Medak district and West by Manjira river. It lies between north latitude 18°04´4.8"-19°00´54" and east longitude 77°31´41"-78°40´1.2". The Karimnagar district is located under Northern Telangana zone lies approximately between the latitudes 17° 50' and 19° 05' N and longitudes 78° 29' and 80° 22' E. The Warangal district lies in central Telangana Zone in Telangana state which lies between 17^o 19' and 18^o 36' N latitude and 78^o 49' and 80^o 43' E longitude.

The climate of the area is semi-arid. In summer average maximum temperature is 42^oC, whereas, in winter generally minimum temperature is to 13°C. The mean annual rainfall is 900 to 1500 mm in northern Telangana and 700 to 900 mm in southern Telangana. Most of this, is received during monsoon season. The major rock types in Nizamabad district are Granites, Granite-Gneisses and Basalts. The important soils prevailing in the district are black and red chalka (Sandy loams) soils covering 55% and 45% respectively of the total area. The soils of Karimnagar district are highly heterogeneous in nature. The major rock types occurring in the district are granites, gneisses, sandstone, limestone, shale, quartzite etc. The major soil types in this district are black soils (55%) and red sandy loam soils (45%). The topography of the Warangal district consists of isolated hills, rainfed tanks, lakes and shrubby forests. The geological formation of the district mainly developed from the granite and genesis of arachean period and dharwars of Precambrian period.

2.2 Collection and Analysis of Soil Sample

150 geo-referenced composite surface soil samples (0-15 cm) were collected from fields. Samples were air dried, grind and passed through 2 mm sieve and stored in properly label polythene bags. Soil samples were analyzed for pH (1:2.5 water), EC (1:2.5 water suspension), available N, available P, available K, DTPA-Zn, DTPA-Cu, DTPA-Fe and DTPA-Mn using standard procedures of Jackson (1973) [7].

2.3 Principal Components of Soil Parameters for Assessment of Soil Quality

A statistics-based model was used to estimate SQI using principal component analysis (PCA) [7,8,9,10,11,12,13,14]. The PCA-model is used to create a minimum data set (MDS) to reduce the indicator load in the model and avoid data redundancy [9]. The PCA method is more objective of using a number of statistical tools (multiple correlation, factor and cluster analyses) which could avoid any biasness and data redundancy by choosing an MDS using mathematical formulae [9,15]. The preliminary function of PCA is to reduce the dimensionality of the entire data set consisting of a large number of interrelated variables, while retaining as much as possible of the variations present in the data set. This is achieved by transformation to a new set of variables, the principal components (PCs), which are uncorrelated and ordered so that the first few retain most of the variation present in all of the original variables [16,17]. In other words, the PCA method was chosen as a data reduction tool to select the most appropriate indicator(s) to represent and estimate SQI [12,18].

Principal components (PC) for a data set are defined as linear combinations of the variables that account for maximum variance within the set by describing vectors of closest fit to the n

observations in p-dimensional space, subject to being orthogonal to one another.This study uses the approach described by [9]. While most studies have assumed to PCs with high eigenvalues and variables with high factor loading were assumed to be variables that best represented system attributes. Therefore, the PCs with eigenvalues >1 and those that explained at least 5 % of the variation in the data were selected. Under a given PC, each variable had corresponding eigenvector weight value or factor loading. Only the 'highly weighted' variables were retained to include in the MDS. The 'highly weighted' variables were defined as the highest weighted variable under a certain PC and absolute factorloading value within 10% of the highest values under the same PC [19]. However, when more than one variable was retained under a particular PC, multivariate correlation matrix (Table 5) was used to determine the correlation coefficients between the parameters [9,10]. If the parameters were significantly correlated ($r>0.60$, $p<0.05$), then the one with the highest loading factor was retained in the MDS and all others were eliminated from the MDS to avoid redundancy. The non-correlated parameters under a particular PC were considered important and retained in the MDS [20,21,9].

After selecting the variables composing the MDS all selected observations were transformed by using the three linear score functions: (a): "more is better" (e.g., N, P, K, Fe, Mn, Cu) (b) "less is better" (e.g., EC), and (c) "optimum" (e.g., pH). Afterwards, the selected observations were transformed in numerical scores (ranged 0–1) and a weighted additive approach was used to integrate them into indices for each soil sample. In order to get a certain weightage value for each PC the variance explained by each PC was divided by the maximum total variation of the all PCs created with the PCA (Table 2).

SQI= Σ Principal Component Weight * Individual soil parameter score

The use of PCA in order to derive a SQI has the potential to integrate soil biological, chemical and physical data for ecological management application where such integration has often been lacking [19]. All values were presented as means ± standard deviations. PCA and Descriptive statisticswere performedwith SPSS ver. 26 and Microsoft Excel ver. 16 were used to calculate the soil quality indices.

3. RESULTS

3.1 Derivation of MDS by PCA

To determine the SQI, the following four main steps were used: (i) define the goal(s); (ii) select a minimum data set (MDS) of indicators that best represent soil function: (iii) score the MDS indicators based on their performance for the soil function; and (iv) integrate the indicator score into an index of soil quality. The MDS was selected following PCA of 9 soil properties (Table 2). All 9 variables were subjected to PCA because all the variables had limitations for at least one sampling site. The PCA of the 9 variables resulted in 4 PCs, which had eigen values > 1 and accumulated to account for 62.115 % of the variance in the data (Table 1). The principal components analysis (PCA) identified six soil attributes contained in four PCs. The eigen values ranged from 1.054 (PC4) to 1.843 (PC1) with variance in the range of 11.712 (PC4) to 20.474 (PC1). Thus, PC1 had a weighted factor of 0.3296, followed by PC2 with 0.2577, PC3 with 0.224 and PC4 with 0.1885.

To determine this, we added the absolute value of the factor loadings in each of the 4 PCs for each variable. Variables having an absolute summation value within 10% of the variable with the highest absolute sum were included in the MDS. These six soil attributes constituted the soil quality indicators for the minimum data sets (MDS), which were used to construct the soil quality index (SQI). Highly weighted variables, which are loaded on first principal component (PC1), included available Mn and Cu. Among these two parameters available Mn is highly weighted variable (0.765), available Cu had a weighted valueof 0.723 which is absolute factor loading value within 10% of the highest values under the same PC. However multivariate correlation between these parameters indicated $r < 0.60$. Hence, both parameters were considered important and retained in the MDS (Table 3). Similarly, PC3 contains both available P and K. pH and available Fe were highly loaded variables on PC2 and PC4 respectively.

3.2 Soil Quality Index

Soil quality index was developed by transforming soil attributes into scores by using linear scoring functions so that each variable had a score between 0 to 1 and those values multiplied with weighted factors respective PCs. The soil quality index of Nizamabad District command area

ranged from 0.342 to 0.758 with a mean of 0.504 ± 0.077. Karimnagar District command area have SQI values ranged from 0.356 to 0.923 with a mean of 0.519 ±0.121.Warangal District command area SQI ranged from 0.357 to 0.856 with a mean of 0.507 ± 0.121.

SQI is a product of few selected soil indicator properties and it warrants selection of most appropriate properties, which have dominant influence on soil function. It can be argued that using complete data set or selection of more indicators may best represent soil quality but when there is high correlation between selected indicators it results in duplication of data. Available Mn and Cu in PC1, available P and K in PC3, were included as indicators from PCA method in this study. This study assessed the variability of soil quality index of three districts of Kaleshwaram project command area. Soil quality of this study area comes under medium category of SQI (0.35-0.55). The large variations of the soil quality (Tables 4, 5, 6) is due to soil heterogeneity and soil degradation caused by improper agricultural practices and erosion. pH, available P, K, Mn, Cu and Fe are the soil quality indicators related three districts of Kaleshwaram project command area. A critical review by [22] also recommended that, with the PCA technique, the number of indicators selected typically ranges between 6 and 8. This study's findings are like those of [23,24] indicated the significant contribution of soil pH, exchangeable Ca, DTPA extractable Zn, OC and available N towards assessment of SQI of Channegowdarapalya micro-watershed.

Table 1. Eigen values and variance (%) explained by significant principal components (154 observation's)

Principal component	Eigen values	% of Variance	Cumulative %	Weightage factor
PC 1	1.843	20.474	20.474	0.3296
PC 2	1.441	16.013	36.487	0.2577
PC 3	1.252	13.916	50.403	0.2240
PC4	1.054	11.712	62.115	0.1885

Table 2. Loadings of soil parameters on significant principal components (154 observation's)

Rotated Component Matrix				
	Principalcomponents			
Parameters	PC-1	PC-2	PC-3	PC-4
pH	-0.231	0.606	-0.114	-0.098
EC	0.298	0.347	-0.427	0.084
Available N	0.508	0.488	-0.092	0.301
Available P	-0.304	0.107	0.731	0.252
Available K	0.432	0.025	0.712	-0.203
Available Zn	0.040	-0.797	-0.177	0.124
Available Cu	0.723	-0.101	0.024	0.191
Available Fe	0.047	-0.143	0.016	0.885
Available Mn	0.765	-0.144	-0.130	-0.184
Highest factor (HF)	0.765	0.606	0.731	0.885
10 % of HF	0.688	0.545	0.658	0.796

Table 3. Correlation between the highly weighted variables of PC at 0-15 cm depth of soil

Parameters	pH	EC	Ava.N	Ava.P	Ava.K	Ava.Zn	Ava.Cu	Ava.Fe	Ava.Mn
pH	1								
EC	0.097	1							
Ava.N	-0.024	.197*	1						
Ava.P	0.034	-.182*	-0.067	1					
Ava.K	-0.066	-0.011	0.010	.189*	1				
Ava.Zn	-.271**	-0.033	-.235**	-0.062	-0.080	1			
Ava.Cu	-0.127	0.132	.221**	-0.127	.167*	0.096	1		
Ava.Fe	-0.063	-0.012	0.062	0.054	-0.025	0.143	0.129	1	
Ava.Mn	-0.084	0.097	.237**	-.298**	.185*	0.129	.373**	-0.007	1

***. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed)*

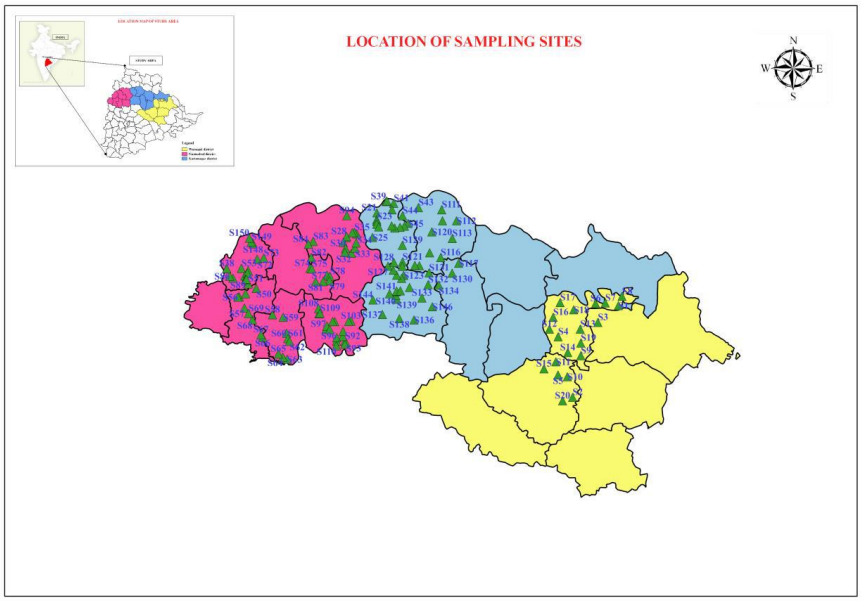

Fig. 1. Location of sampling sites

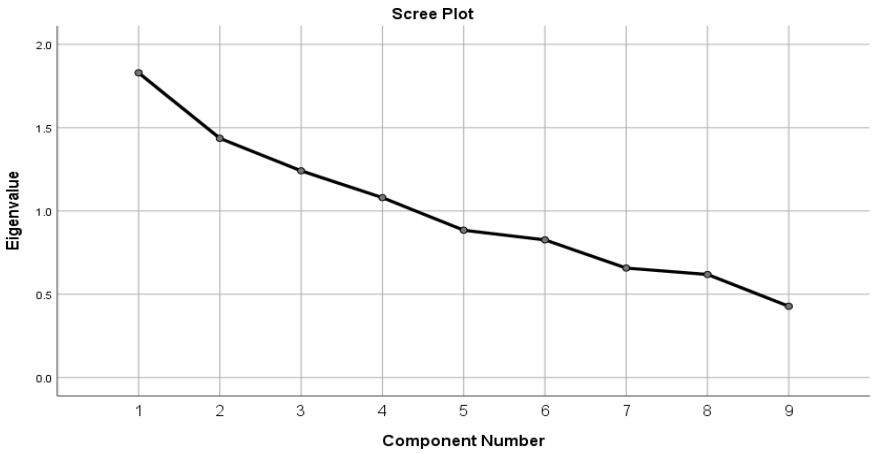

Fig. 2. Scree plot explaining the relationship of eigenvalue and principle component for 0-15 cm depth of soil

Fig. 3. Soil quality index (SQI) in selected districts of Kaleshwaram project area of Telangana state

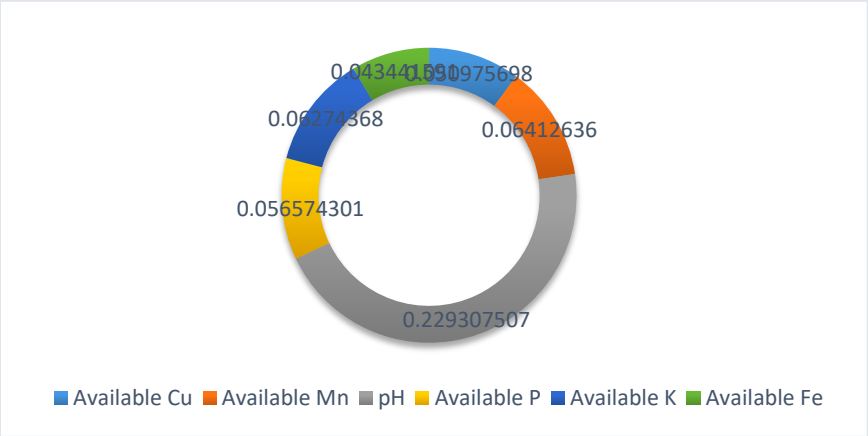

Fig. 4. Contributions of significant soil parameters to SQI (Warangal)

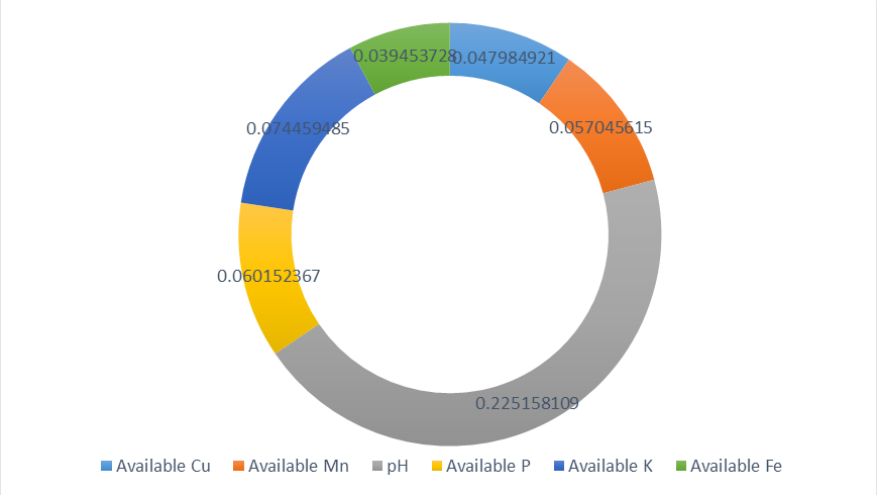

Fig. 5. Contributions of significant soil parameters to SQI (Nizamabad)

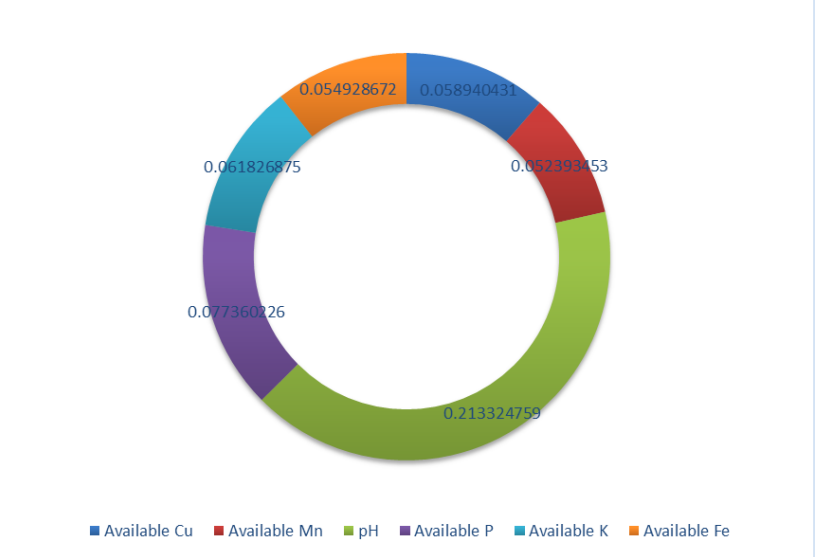

Fig. 6. Contributions of significant soil parameters to SQI (Karimnagar)

Table 4. Soil quality index of soil quality parameters of Kaleshwaram project command area of erstwhile Nizamabad district

	Cu	S.F*W.F	Mn	S.F*W.F	pH	S.F*W.F	Avalable P	S.F*W.F	Avalable K	S.F*W.F	Fe	S.F*W.F	SQI
1	0.79	0.039	10.07	0.073	7.36	0.228	24.92	0.016	375.00	0.076	6.43	0.028	0.459
2	1.20	0.059	15.96	0.115	7.28	0.230	24.52	0.015	485.00	0.099	6.68	0.029	0.547
3	1.02	0.050	16.23	0.117	7.23	0.232	31.90	0.020	306.00	0.062	6.58	0.029	0.509
4	0.68	0.033	7.46	0.054	7.10	0.236	27.89	0.017	384.00	0.078	6.70	0.029	0.448
5	1.01	0.050	17.96	0.129	7.75	0.216	27.68	0.017	475.24	0.097	6.25	0.027	0.536
6	1.46	0.072	12.59	0.091	7.42	0.226	32.30	0.020	406.72	0.083	7.09	0.031	0.522
7	1.24	0.061	11.18	0.081	7.48	0.224	32.67	0.020	342.00	0.069	7.56	0.033	0.488
8	1.26	0.062	11.47	0.083	7.57	0.221	18.90	0.012	364.40	0.074	7.94	0.035	0.486
9	0.38	0.019	15.28	0.110	7.62	0.220	25.46	0.016	312.00	0.063	6.97	0.030	0.458
10	0.45	0.022	13.60	0.098	7.50	0.223	36.72	0.023	302.00	0.061	6.42	0.028	0.456
11	1.30	0.064	12.65	0.091	7.69	0.218	18.90	0.012	328.00	0.067	6.72	0.029	0.480
12	0.79	0.039	9.21	0.066	7.87	0.213	90.00	0.056	418.35	0.085	6.74	0.029	0.489
13	1.17	0.057	16.29	0.117	7.25	0.231	97.86	0.061	504.39	0.102	7.29	0.032	0.601
14	1.52	0.075	10.22	0.074	7.47	0.224	38.33	0.024	303.75	0.062	16.22	0.071	0.529
15	0.56	0.027	10.48	0.076	7.68	0.218	152.14	0.095	457.69	0.093	7.20	0.031	0.540
16	0.78	0.038	19.78	0.143	7.77	0.216	114.29	0.071	487.52	0.099	7.12	0.031	0.598
17	0.54	0.026	3.00	0.022	7.60	0.220	89.29	0.056	236.25	0.048	12.45	0.054	0.427
18	0.32	0.016	2.90	0.021	7.70	0.218	37.12	0.023	337.50	0.069	4.21	0.018	0.364
19	0.47	0.023	2.66	0.019	7.50	0.223	70.70	0.044	528.75	0.107	5.30	0.023	0.440
20	0.35	0.017	2.99	0.022	7.50	0.223	175.71	0.110	281.25	0.057	5.47	0.024	0.453
21	0.65	0.032	7.13	0.051	6.70	0.250	152.86	0.095	303.75	0.062	10.65	0.046	0.537
22	0.55	0.027	3.30	0.024	7.13	0.235	275.00	0.172	123.50	0.025	16.65	0.073	0.555
23	0.90	0.044	8.59	0.062	7.24	0.231	33.00	0.021	135.00	0.027	17.26	0.075	0.461
24	1.33	0.065	11.23	0.081	7.59	0.221	49.29	0.031	393.75	0.080	3.99	0.017	0.495
25	0.79	0.039	10.19	0.073	8.03	0.209	30.45	0.019	337.50	0.069	6.72	0.029	0.438
26	1.64	0.080	7.42	0.053	7.68	0.218	50.00	0.031	157.50	0.032	5.66	0.025	0.440
27	2.08	0.102	14.55	0.105	7.67	0.218	66.43	0.041	292.50	0.059	6.97	0.030	0.557
28	1.18	0.058	7.04	0.051	7.20	0.233	175.00	0.109	135.00	0.027	16.25	0.071	0.549
29	0.96	0.047	3.24	0.023	7.70	0.218	97.14	0.061	258.75	0.053	7.53	0.033	0.434
30	1.43	0.070	5.04	0.036	7.35	0.228	128.57	0.080	146.25	0.030	12.16	0.053	0.497
31	1.04	0.051	12.68	0.091	7.02	0.239	53.57	0.033	90.00	0.018	6.89	0.030	0.463
32	0.83	0.041	3.21	0.023	7.53	0.222	114.30	0.071	247.50	0.050	11.01	0.048	0.456
33	0.55	0.027	1.96	0.014	7.42	0.226	68.57	0.043	213.75	0.043	9.94	0.043	0.396
34	0.97	0.048	4.20	0.030	7.73	0.217	154.29	0.096	247.50	0.050	14.29	0.062	0.503
35	1.06	0.052	7.87	0.057	7.51	0.223	96.43	0.060	180.00	0.037	6.57	0.029	0.457
36	1.78	0.087	19.65	0.142	7.10	0.236	112.86	0.070	933.75	0.190	7.59	0.033	0.758

	Cu	S.F*W.F	Mn	S.F*W.F	pH	S.F*W.F	Avalable P	S.F*W.F	Avalable K	S.F*W.F	Fe	S.F*W.F	SQI
37	0.51	0.025	2.99	0.022	7.80	0.215	86.43	0.054	933.75	0.190	3.05	0.013	0.518
38	0.81	0.040	0.81	0.006	7.69	0.218	108.57	0.068	347.89	0.071	6.70	0.029	0.431
39	0.70	0.034	3.26	0.023	7.56	0.222	35.00	0.022	191.25	0.039	8.04	0.035	0.375
40	0.92	0.045	11.54	0.083	7.43	0.225	35.50	0.022	292.50	0.059	9.46	0.041	0.477
41	0.70	0.034	10.58	0.076	7.43	0.225	99.29	0.062	630.00	0.128	8.17	0.036	0.562
42	2.07	0.102	12.36	0.089	7.11	0.236	236.43	0.148	270.00	0.055	17.59	0.077	0.705
43	3.01	0.148	4.25	0.031	7.89	0.212	69.85	0.044	357.00	0.073	11.60	0.051	0.557
44	1.66	0.081	4.44	0.032	8.22	0.204	50.38	0.031	315.00	0.064	10.60	0.046	0.459
45	3.15	0.155	3.80	0.027	7.32	0.229	41.22	0.026	232.00	0.047	10.32	0.045	0.529
46	0.42	0.021	13.18	0.095	7.90	0.212	33.00	0.021	236.25	0.048	13.18	0.057	0.454
47	0.59	0.029	7.50	0.054	7.57	0.221	37.92	0.024	345.25	0.070	6.86	0.030	0.428
48	0.60	0.029	1.33	0.010	7.90	0.212	104.29	0.065	281.25	0.057	6.06	0.026	0.400
49	0.49	0.024	1.88	0.014	6.78	0.247	132.68	0.083	335.20	0.068	13.41	0.058	0.494
50	0.54	0.026	3.21	0.023	6.38	0.263	120.51	0.075	308.23	0.063	9.73	0.042	0.492
51	0.70	0.034	5.95	0.043	7.40	0.226	161.43	0.101	326.25	0.066	12.73	0.056	0.526
52	0.47	0.023	1.94	0.014	8.20	0.204	67.14	0.042	157.50	0.032	6.22	0.027	0.342
53	0.39	0.019	4.10	0.030	7.40	0.226	81.43	0.051	461.25	0.094	4.42	0.019	0.439
54	0.65	0.032	6.29	0.045	7.10	0.236	82.86	0.052	438.75	0.089	10.81	0.047	0.501
55	0.77	0.038	2.81	0.020	7.70	0.218	358.57	0.224	607.50	0.123	13.90	0.061	0.683
56	0.77	0.038	3.80	0.027	7.60	0.220	139.29	0.087	485.24	0.099	14.90	0.065	0.536
57	0.47	0.023	4.16	0.030	7.80	0.215	160.71	0.100	326.25	0.066	3.42	0.015	0.449
58	0.83	0.041	6.36	0.046	7.70	0.218	136.43	0.085	1102.50	0.224	7.21	0.031	0.645
59	1.23	0.060	12.25	0.088	7.56	0.222	282.86	0.177	458.00	0.093	6.07	0.026	0.666
60	0.88	0.043	12.34	0.089	7.71	0.217	34.89	0.022	497.45	0.101	18.54	0.081	0.553
61	1.62	0.079	13.28	0.096	7.40	0.226	178.57	0.111	180.00	0.037	7.29	0.032	0.581
62	0.72	0.035	3.78	0.027	7.40	0.226	217.86	0.136	618.75	0.126	3.85	0.017	0.567
63	0.57	0.028	2.27	0.016	7.50	0.223	152.86	0.095	326.25	0.066	7.94	0.035	0.464
64	0.37	0.018	11.56	0.083	6.70	0.250	29.29	0.018	225.00	0.046	8.20	0.036	0.451
65	1.23	0.060	4.37	0.031	8.00	0.209	166.43	0.104	562.50	0.114	14.05	0.061	0.581
66	0.20	0.010	4.13	0.030	7.20	0.233	192.14	0.120	236.25	0.048	3.63	0.016	0.456
67	0.74	0.036	10.01	0.072	6.45	0.260	132.14	0.082	168.75	0.034	19.44	0.085	0.570
68	0.45	0.022	9.23	0.066	6.90	0.243	201.43	0.126	517.50	0.105	10.37	0.045	0.607
69	2.76	0.135	2.86	0.021	7.40	0.226	39.87	0.025	360.00	0.073	15.55	0.068	0.548
70	0.57	0.028	6.38	0.046	6.90	0.243	36.19	0.023	487.00	0.099	8.24	0.036	0.474
71	1.10	0.054	4.68	0.034	7.65	0.219	30.00	0.019	483.75	0.098	4.90	0.021	0.445
72	1.75	0.086	7.15	0.052	7.35	0.228	40.12	0.025	452.76	0.092	7.55	0.033	0.515
Min	0.20	0.010	0.81	0.006	6.38	0.204	18.90	0.012	90.00	0.018	3.05	0.013	0.342
Max	3.15	0.155	19.78	0.143	8.22	0.263	358.57	0.224	1102.50	0.224	19.44	0.085	0.758

	Cu	S.F*W.F	Mn	S.F*W.F	pH	S.F*W.F	Avalable P	S.F*W.F	Avalable K	S.F*W.F	Fe	S.F*W.F	SQI
Mean	0.98	0.048	7.92	0.057	7.46	0.225	96.37	0.060	366.48	0.074	9.05	0.039	0.504
SD	0.60	0.029	4.88	0.035	0.36	0.011	71.74	0.045	182.59	0.037	4.01	0.017	0.077
CV	61.22	60.42	61.62	61.403	4.82	4.89	74.44	75.00	49.82	50.00	44.30	43.59	15.20

Table 5. Soil quality index of soil quality parameters of Kaleshwaram project command area of erstwhile Karimnagar district

	Cu	S.F*W.F	Mn	S.F*W.F	pH	S.F*W.F	Avalable P	S.F*W.F	Avalable K	S.F*W.F	Fe	S.F*W.F	SQI
73	0.82	0.040	7.98	0.057	7.46	0.225	53.48	0.033	487.96	0.099	27.59	0.120	0.575
74	6.72	0.330	20.57	0.148	8.01	0.209	81.68	0.051	517.81	0.105	5.68	0.025	0.868
75	3.26	0.160	4.53	0.033	7.52	0.223	91.26	0.057	493.78	0.100	27.65	0.121	0.693
76	0.43	0.021	4.89	0.035	7.90	0.212	111.57	0.070	521.81	0.106	18.91	0.082	0.526
77	0.43	0.021	11.02	0.079	7.51	0.223	73.50	0.046	137.15	0.028	2.52	0.011	0.408
78	0.35	0.017	10.84	0.078	7.82	0.214	62.33	0.039	173.89	0.035	2.65	0.012	0.395
79	2.68	0.131	0.87	0.006	7.56	0.222	88.21	0.055	239.47	0.049	5.89	0.026	0.489
80	2.57	0.126	45.75	0.330	8.24	0.203	70.35	0.044	389.58	0.079	2.03	0.009	0.791
81	1.07	0.052	15.80	0.114	7.96	0.210	79.42	0.050	415.78	0.084	10.78	0.047	0.558
82	0.43	0.021	38.08	0.274	8.03	0.209	90.34	0.056	242.19	0.049	11.62	0.051	0.660
83	0.69	0.034	12.85	0.093	7.92	0.211	69.98	0.044	365.28	0.074	9.78	0.043	0.498
84	4.01	0.197	17.06	0.123	6.67	0.251	40.21	0.025	247.29	0.050	2.58	0.011	0.657
85	4.02	0.197	16.89	0.122	7.59	0.221	56.59	0.035	276.89	0.056	2.54	0.011	0.642
86	2.56	0.126	10.05	0.072	8.14	0.206	34.10	0.021	253.45	0.051	6.24	0.027	0.504
87	0.85	0.042	5.62	0.040	7.13	0.235	57.20	0.036	237.98	0.048	4.72	0.021	0.422
88	1.67	0.082	20.89	0.150	7.56	0.222	86.86	0.054	278.46	0.057	8.59	0.037	0.602
89	0.38	0.019	3.58	0.026	7.62	0.220	81.00	0.051	145.35	0.030	2.64	0.012	0.356
90	1.01	0.050	2.14	0.015	8.29	0.202	219.29	0.137	360.00	0.073	14.20	0.062	0.539
91	1.12	0.055	2.15	0.015	8.15	0.206	210.00	0.131	326.25	0.066	15.40	0.067	0.540
92	0.39	0.019	0.92	0.007	8.05	0.208	131.43	0.082	213.75	0.043	10.64	0.046	0.406
93	0.88	0.043	2.73	0.020	8.27	0.203	87.86	0.055	258.75	0.053	14.11	0.062	0.434
94	1.11	0.054	1.78	0.013	8.16	0.205	149.29	0.093	191.25	0.039	14.34	0.063	0.467
95	0.55	0.027	1.05	0.008	8.20	0.204	145.00	0.091	135.00	0.027	13.99	0.061	0.418
96	0.71	0.035	0.92	0.007	8.03	0.209	66.43	0.041	157.50	0.032	15.40	0.067	0.391
97	0.86	0.042	2.30	0.017	8.33	0.201	163.57	0.102	258.75	0.053	14.84	0.065	0.479
98	0.83	0.041	2.21	0.016	8.01	0.209	5.00	0.003	191.25	0.039	14.68	0.064	0.372
99	0.81	0.040	2.14	0.015	8.20	0.204	147.14	0.092	348.75	0.071	13.02	0.057	0.479
100	0.56	0.027	2.00	0.014	7.77	0.216	73.57	0.046	168.75	0.034	13.51	0.059	0.397
101	0.57	0.028	1.99	0.014	7.45	0.225	148.57	0.093	146.25	0.030	15.59	0.068	0.458
102	1.71	0.084	2.38	0.017	8.15	0.206	165.00	0.103	247.50	0.050	15.2	0.066	0.526
103	1.40	0.069	2.02	0.015	8.18	0.205	182.14	0.114	225.00	0.046	15.23	0.066	0.514

	Cu	S.F*W.F	Mn	S.F*W.F	pH	S.F*W.F	Avalable P	S.F*W.F	Avalable K	S.F*W.F	Fe	S.F*W.F	SQI
104	1.32	0.065	1.92	0.014	8.20	0.204	204.29	0.128	213.75	0.043	14.27	0.062	0.516
105	0.36	0.018	1.92	0.014	8.00	0.209	335.71	0.210	630.00	0.128	4.58	0.020	0.598
106	1.25	0.061	3.07	0.022	8.10	0.207	330.71	0.206	483.75	0.098	15.03	0.066	0.660
107	0.68	0.033	1.72	0.012	8.05	0.208	38.57	0.024	146.25	0.030	14.62	0.064	0.371
108	0.79	0.039	6.66	0.048	8.82	0.190	46.43	0.029	180.00	0.037	6.01	0.026	0.368
109	0.69	0.034	5.64	0.041	7.10	0.236	163.57	0.102	348.75	0.071	16.18	0.071	0.554
110	1.06	0.052	2.19	0.016	8.01	0.209	37.86	0.024	281.25	0.057	13.58	0.059	0.417
111	0.56	0.027	3.49	0.025	7.52	0.223	275.00	0.172	528.75	0.107	13.71	0.060	0.614
112	0.55	0.027	1.04	0.007	8.09	0.207	244.29	0.152	135.00	0.027	13.64	0.059	0.481
113	0.24	0.012	1.03	0.007	8.09	0.207	290.71	0.181	438.75	0.089	4.24	0.018	0.515
114	0.36	0.018	2.83	0.020	7.46	0.225	322.14	0.201	337.50	0.069	5.03	0.022	0.554
115	0.96	0.047	11.60	0.084	7.85	0.213	84.23	0.053	193.75	0.039	8.79	0.038	0.474
116	1.86	0.091	4.38	0.032	7.68	0.218	87.87	0.055	219.24	0.045	4.32	0.019	0.459
117	0.24	0.012	1.97	0.014	8.28	0.202	59.29	0.037	191.25	0.039	12.73	0.056	0.360
118	0.22	0.011	1.88	0.014	7.80	0.215	196.43	0.123	270.00	0.055	7.20	0.031	0.448
119	0.71	0.035	2.75	0.020	8.27	0.203	64.29	0.040	315.00	0.064	15.17	0.066	0.427
120	0.79	0.039	1.22	0.009	7.95	0.211	162.86	0.102	202.50	0.041	24.32	0.106	0.507
121	0.35	0.017	3.78	0.027	6.20	0.246	110.71	0.069	180.00	0.037	43.23	0.189	0.584
122	2.58	0.127	40.71	0.293	8.73	0.192	10.71	0.007	765.00	0.155	34.27	0.149	0.923
123	1.46	0.072	2.08	0.015	8.08	0.207	135.71	0.085	427.50	0.087	18.74	0.082	0.547
124	0.26	0.013	4.88	0.035	7.24	0.231	193.57	0.121	496.64	0.101	2.92	0.013	0.514
125	0.95	0.047	4.68	0.034	7.39	0.227	51.43	0.032	490.62	0.100	22.51	0.098	0.537
Min	0.22	0.011	0.87	0.006	6.20	0.19	5.00	0.003	135.00	0.027	2.03	0.009	0.356
Max	6.72	0.330	45.75	0.330	8.82	0.251	335.71	0.210	765.00	0.155	43.23	0.189	0.923
Mean	1.20	0.059	7.27	0.052	7.86	0.213	123.94	0.077	304.30	0.062	12.60	0.055	0.519
SD	1.19	0.058	9.95	0.072	0.46	0.012	83.19	0.052	143.35	0.029	8.26	0.036	0.121
CV	99.17	98.30	136.86	138.46	5.85	5.63	67.12	67.530	47.11	46.77	67.15	65.45	23.31

Table 6. Soil quality index of soil quality parameters of Kaleshwaram project command area of erstwhile Warangal district

	Cu	S.F*W.F	Mn	S.F*W.F	pH	S.F*W.F	Avalable P	S.F*W.F	Avalable K	S.F*W.F	Fe	S. F*W.F	SQI
126	0.36	0.018	4.25	0.031	7.85	0.213	76.63	0.048	156.45	0.032	3.69	0.016	0.357
127	0.29	0.014	6.45	0.046	7.05	0.238	80.56	0.050	289.62	0.059	5.87	0.026	0.433
128	0.41	0.020	8.92	0.064	6.43	0.261	148.30	0.093	345.48	0.070	4.89	0.021	0.529
129	0.32	0.016	5.89	0.042	6.92	0.242	79.25	0.049	378.68	0.077	6.19	0.027	0.454
130	1.24	0.061	9.24	0.067	7.48	0.224	112.35	0.070	458.27	0.093	6.14	0.027	0.541
131	0.38	0.019	7.31	0.053	7.48	0.224	55.71	0.035	146.25	0.030	5.62	0.025	0.384
132	0.35	0.017	6.99	0.050	7.80	0.215	52.86	0.033	236.25	0.048	5.09	0.022	0.385
133	0.49	0.024	10.49	0.076	7.53	0.222	47.14	0.029	180.00	0.037	7.12	0.031	0.419
134	0.55	0.027	5.83	0.042	7.53	0.222	166.43	0.104	585.00	0.119	5.98	0.026	0.540
135	2.77	0.136	14.81	0.107	5.87	0.233	111.43	0.070	765.00	0.155	18.59	0.081	0.781
136	0.36	0.018	5.34	0.038	7.76	0.216	123.46	0.077	292.78	0.059	4.56	0.020	0.428
137	0.42	0.021	4.75	0.034	7.85	0.213	52.86	0.033	247.50	0.050	8.23	0.036	0.387
138	1.23	0.060	5.69	0.041	6.75	0.248	116.72	0.073	297.46	0.060	5.78	0.025	0.508
139	0.62	0.030	9.08	0.065	7.46	0.225	54.29	0.034	196.58	0.040	12.04	0.052	0.447
140	0.83	0.041	7.20	0.052	7.93	0.211	64.29	0.040	159.43	0.032	14.61	0.064	0.440
141	1.05	0.052	4.82	0.035	6.84	0.245	82.15	0.051	182.37	0.037	6.89	0.030	0.449
142	1.03	0.051	6.28	0.045	6.52	0.257	88.29	0.055	258.56	0.053	7.23	0.032	0.492
143	4.00	0.196	15.29	0.110	5.74	0.228	96.48	0.060	888.75	0.181	18.61	0.081	0.856
144	3.57	0.175	15.03	0.108	5.67	0.225	151.43	0.095	180.00	0.037	18.69	0.081	0.721
145	0.33	0.016	10.57	0.076	7.66	0.219	61.43	0.038	247.50	0.050	9.07	0.040	0.439
146	0.53	0.026	6.75	0.049	7.63	0.220	79.29	0.049	540.00	0.110	4.10	0.018	0.471
147	0.83	0.041	9.64	0.069	7.00	0.239	57.86	0.036	45.00	0.009	18.41	0.080	0.475
148	0.96	0.047	4.96	0.036	6.92	0.242	120.71	0.075	303.75	0.062	5.09	0.022	0.484
149	1.30	0.064	13.08	0.094	7.65	0.219	55.71	0.035	101.25	0.021	18.04	0.079	0.511
150	0.81	0.040	12.86	0.093	7.59	0.221	61.43	0.038	213.75	0.043	13.51	0.059	0.494
151	0.56	0.027	11.56	0.083	6.95	0.241	57.86	0.036	135.00	0.027	9.47	0.041	0.457
152	0.86	0.042	12.81	0.092	7.12	0.235	60.71	0.038	123.75	0.025	18.54	0.081	0.514
153	2.66	0.130	14.48	0.104	6.95	0.241	145.00	0.091	382.50	0.078	20.78	0.091	0.735
154	1.03	0.051	7.76	0.056	7.89	0.212	167.86	0.105	618.75	0.126	6.09	0.027	0.576
Min	0.29	0.014	4.25	0.031	5.67	0.211	47.14	0.029	45.00	0.009	3.69	0.016	0.357
Max	4.00	0.196	15.29	0.110	7.93	0.261	167.86	0.105	888.75	0.181	20.78	0.091	0.856
Mean	1.04	0.051	8.90	0.064	7.17	0.229	90.64	0.057	308.82	0.063	9.96	0.043	0.507
SD	0.97	0.048	3.52	0.025	0.65	0.014	37.73	0.024	201.80	0.041	5.70	0.025	0.121
CV	93.27	94.12	39.55	39.060	9.07	6.11	41.63	42.11	65.34	65.08	57.23	58.140	23.87

S.F-Scoring factor; W.F-Weighted factor

Among selected soil quality indicators contribution of soil pH to soil quality index is more when compared with other indicators in all three districts of command area (Figs. 4, 5, 6). Because it is one of the important component, it controls the nutrients availability up to a greater extent [24,25,26]. The variation in the soil pH could be due to nature of parent material, micro relief, soil type and uneven application of manures and fertilizers by the farmers. Available P, K, Mn, Cu and Fe emerged as a key soil quality indicator based on the study, which plays a key role directly or indirectly in influencing quality of these soils by regulating plant growth. Though pH is congenial for nutrients availability, any slight increase may disrupt their equilibrium and soil availability.

4. CONCLUSION

Based on the study conducted in command areas of Kaleshwaram projects in Karimnagar, Nizamabad and Warangal (old districts), a wide range and variability was observed in soil parameters under different land use/land cover. Assessing soil quality by examining the variability existing in soil parameters clearly showed that all the command areas of the Kaleshwaram projects in Karimnagar, Nizamabad and Warangal has medium category of SQI (0.35-0.55). Examining relationships of parameters and analyzing principal component indicated that six parameters have significantly contributed to the SQI. Soil pH was most important key indicator of soil quality, followed by available Cu, Mn, P, K and Fe.

ACKNOWLEDGEMENT

Authors are acknowledging to PJTSAU and all researchers who supported for this project study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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