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Soil quality assessment using fuzzy modeling: A case study in rainfed cotton growing environs of Nilona micro-watershed in Yavatmal district, Maharashtra

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Abstract
The study was undertaken in rainfed cotton growing environs of Nilona micro-watershed in Yavatmal district, Maharashtra. Soil quality has been fuzzy modeling. Identification of minimum datasets was done using expert system followed by ranking of indicators according to the relative importance on influencing crop yield for calculating composite soil index. The results indicate out of 118 soils samples were classified 103 samples were grouped under class II, The highest composite soil index (CSI) was found to be 79.74. Whereas the lowest CSI were found to be 62.62. The remaining 15 surface soil sample were grouped under class I. The highest CSI were observed to be 93.99 whereas the lowest CSI was observed to be 80.34.

Keywords: Soil quality, fuzzy modeling, cotton, Nilona micro-watershed

Introduction

The concern for agricultural sustainability and food security that started growing in the twentieth century has assumed serious proportions in the 21st century. It has been due to, among other factors, the continually and rapidly limiting arable land resources as a result of their degradation, a major global issue, rapidly increasing world population especially in developing countries of tropics and subtropics, (Mis) use of agricultural land for non-agricultural purposes, persisting hunger and malnutrition in several regions of the world.

Nothing new is being said when one appreciates that soil resources are precious in terms of their ability to address food security (quality and quantity), environmental quality and biodiversity and last but not the least human health and welfare. Understandably, the concept of soil quality (SQ) and its significance have been recognised since ancient times. SQ has been defined as the capacity of soil to function within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental quality and promote plant, animal and human health (Carter *et al*., 1997; Karlen *et al*., 1998) [5, 12]. In context of agriculture, SQ is a measure of soil's fitness to support crop growth without becoming degraded or otherwise harming the environment (Acton and Gregorich, 1995) [1].

The process of evaluating soil quality is undertaken through a number of approaches and "land evaluation" has much to offer to the process. Land evaluation is the assessment of performance (suitability or otherwise) of land for defined uses (Rossiter, 1973) [21].

In general terms, the traditional land evaluation systems follow a Boolean or rule-based approach adapted to the principle of maximum limiting factors. There is a growing concern regarding failure of this method to incorporate the inexact or fuzzy nature of much of the land resource data. In recent years, there has been marked interest in the use of fuzzy modelling-based methodology (a mathematical approach) in land evaluation, and it can be considered as a new phase in the quantification trend. The use of strict Boolean algebra with a simple true/false logic in combination with a rigid, exact model is often inappropriate for land evaluation because of the continuous nature of soil variation, the uncertainties associated with describing the phenomenon itself or in the measurements made on it, or because of inexactness of much of the land resource data (Burrough, 1989; Chatterji, 2000) [4, 7].

Often land evaluation methods use a number of parameters (land quality indicators) that are neither mutually exclusive nor locally relevant. There arises a need of identifying a minimum set of data i.e. a MDS on land quality indicators to enable assess land quality appropriately, effectively and meaningfully. In concept, the development of MDSs involves selection of a small subset of attributes that will comprise locally relevant indicators and be exclusive.

The major states growing cotton in 2016 in order of hectarage were Maharashtra (38.06 lakh ha) representing almost half of the total area growing cotton, or 40%, of all cotton area in India in 2012, followed by Gujarat (2.36 m ha or 20%), Andhra Pradesh (2.14 m ha or 16%), Northern Zone (1.56 m ha or 15%), Madhya Pradesh (608,000 ha or 8%), and the rest in Karnataka, Tamil Nadu and other states. The production and productivity of Maharashtra, during 2016-17 was 89.0 lakh bales and 398 kg/ha respectively (CCI, 2016). Vidarbha is an important cotton growing region in Maharashtra, where a continuous increase in area under cotton crop area under cotton is 13.60 lakh ha with a production of 24 lakh bales with productivity of 310 kg lint ha^{-1} (Anonymous, 2018) [2].

The major district of interest in the present investigation is Yavatmal district is located in the south west part of Vidarbha region of Maharashtra state. It is one of the important districts of the Vidarbha region. Yavatmal is a major cotton growing area. The district has a geographical area of 13582 sq km (4.41% of the state) with population of 20,77,144 (2.63% of the state) and with 43 per cent of rural families living below poverty line. The land holding of 2-5 ha constitutes 40.12% of entire district followed by 28.26% of 5-10 ha holding. The total cultivated land is 8.84 lakh ha with double cropped area of 9475 ha and a cropping intensity of 101%. The cotton growers are facing severe economic crisis that is resulting in their committing suicide. Yavatmal district accounts for 32 per cent of suicides in Vidharbha region suggesting that Yavatmal seems to be epicenter of the recent spate of farmers suicides (NBSS & LUP, 2015) [3]. This region is a hotspot for critical analysis of land use activity where economic dependence of farmers is solely on cotton and where, more than 50 per cent of the total net sown area has been under single crop over years. The poor agriculture productivity and low level of food grain outputs resulting from the low level introduction of agriculture crop technologies, poor rural infrastructure, and high vulnerability of crop production to natural disasters such as droughts and high rates of unemployment and poverty, are some of the reasons for the high degree of food insecurity in some parts of the district. (Bhaskar *et al.*, 2014) [3].

Materials and Methods

Study Area

The Nilona micro-watershed is located between 20º 15’ 43” to 20º 17’ 39” N latitude and 77º 38’ 41” to 77º 41’ 10” E longitude, covering an area of 1297.35 ha in Darwha tehsil of Yavatmal district, Maharashtra. The elevation of the area ranges from 360 to 467 m above MSL. The study area falls under North Deccan (Maharashtra) Plateau and is agro-climatically placed under hot moist to semi-arid eco-sub-region. The climate of the area is subtropical, dry sub-humid with well-expressed summer (March-May), rainy season (June-October) and winter season (November-February). The mean maximum temperature varies from 33 ºC to 46 ºC in summer season; mean daily minimum temperature is 13 ºC to 15 ºC with a mean annual temperature of 29 ºC. The average annual rainfall of the district is 930 mm some of the area is under cultivation and mostly under cotton, soybean, pigeon pea, gram and vegetables. The mean monthly climatic parameters like rainfall, maximum and minimum temperature of the study area.

Information was collected from farmers on crop yield data (Fig.1) and the yield considered for correlating it with soil quality index was average of five year (2011-12, 2012-13, 2013-14, 2014-15, 2015-16 year) yield data were collected from farmers’ fields. Horizon-wise soil samples were collected for determining physical and chemical properties surface samples (0-20 cm) were taken freshly. A minimum dataset (MDS) comprising

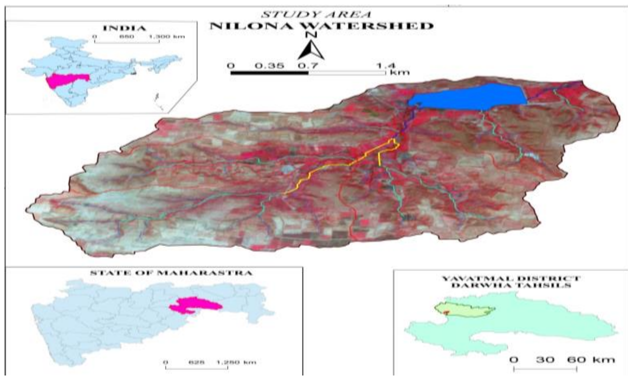

Fig 1: Location map of Nilona micro-watershed, Darwha block, Yavatmal district

physical parameters (saturated hydraulic conductivity and clay), chemical (exchangeable sodium percent and OC) parameters were developed for SQ assessment. Soil samples were analyzed for these physical and chemical properties following standard procedures. Particle-size distribution (sand, silt and clay) was determined as per international pipette method (Jackson, 1979) [8]; saturated hydraulic conductivity (sHC) was determined by constant head methods as per Richards (1954); exchangeable sodium percentage (ESP) was determined by formula as the ratio of exchangeable Na with CEC by Jackson (1967) [8] and OC content of the soil was determined by Walkley and Black method (Nelson and Sommers, 1982) [17].

Soil quality assessment

Often SQ assessment methods use a number of parameters (SQ indicators) that are neither mutually exclusive nor locally relevant and hence fail to produce results that are of pragmatic value. There arises a need of identifying a minimum set of data i.e. a MDS of SQ indicators that are mutually exclusive and locally relevant to enable assess SQ appropriately, effectively and meaningfully..

Selection of the attributes for developing MDS comprising physical and chemical properties of soils (that best represent soil functions) was carried out using expert knowledge. The MDS of attributes so developed through expert knowledge were used for assessing SQ.

This method consists of six steps like generation of membership values for the soil characteristics, determination of weights for the membership values, and computation of weighted membership values to produce a composite soil index (CSI) (Burrough, 1989 and Chatterji, 2000) [4, 7].

a. Computation of membership functions

$$\underset{A}{\Sigma\mu(z)} = \frac{1}{1 + a_i (z_i - c_i)} \quad 2 \text{for } 0 \le z \le £ \ \ldots\ldots (1)$$

Where A is the soil characteristic set; a is the dispersion index that determines the shape of the function, c (called the ideal point or standard index) is the value of the property z at the center of the set and £ is the maximum value that z can take.

b. The Joint Membership function (JMF) for each pedon and for each parameter was computed using the convex combination rule, which is a linear weighted combination of membership values of each land characteristic A_i

$$I = \sum_{i=1}^{N} w_i \mu \quad \text{…….(2)}$$

Where I is the joint membership function and w_i are the weights of the memberships value μ

The membership functions (or values) indicate the degree of suitability at a given location with respect to a given land characteristic. On a 0~1 scale, any parameter having a membership of 1 (highly suitable class) in any land unit suggests that the parameter has the complete belongingness to a particular class.

c. To ensure that weights sum up to unity, the rank r_i of a land characteristic, A was converted to weight W_i using the equation:

$$Wi = \frac{r_i}{\sum_{i=1}^{n} r_i} \quad \text{............. (3)}$$

Equation (2) shows that the choice of weights W_i is crucial in the determination of the overall land suitability index.

Simple ranking procedure was used in deriving weights. This ranking was based on literature (Sys 1985; NBSS & LUP, 1994; Kadu *et al*., 2003; Naidu *et al*., 2006) [22, 3, 11, 14] which indentified the relative importance of a particular parameter to the cultivation of cotton crop.

d. The composite soil index (CSI) of a SQ parameter was determined as the average of the aggregated JMF values of the parameters for a particular pedon which in concept and for all practical purposes holds the same implication as that by SQI.

e. Determination of suitability classes: The suitability classes for the crops were identified by placing the CSI values in a set of equally-spaced classes on a 0-100 scale, with a 20 unit gradation. CSI lying between 100-80 comes under class I, CSI lying between 80-60 comes under class II, CSI lying between 60-40 comes under class III, CSI between 40-20 comes under class IV and class V has CSI values ranging from 20-0.

f. The composite soil index (CSI) values were correlated with average yield for validation.

Results and Discussion

Seed cotton yield

Under identical set of management, crop yield can be an important indicator of soil quality, because it serves as a plant bioassay of the interacting soil characteristics. Otherwise also, the ultimate outcome of good soil quality is yield or economic produce.

The five year (2011-12, 2012-13, 2013-14, 2014-15, 2015-16 year) yield data were collected from farmers' fields and average yield (23.91, 21.47, 20.35, 20.17, 23.07 q /ha) respectively was determined (Table 1). The micro-watershed had the highest average yield of 32.0 q ha^{-1} and the lowest average yield of 13.0 q ha^{-1}. The cotton yield (average yield of 5 years) has been correlated with sustainable yield index (SYI). The correlation of cotton yield and sustainable yield index was positive with R^2 value of 0.701** (Fig.4.6).

Table 1: Descriptive statistics of cotton yield of 5 years

Sr. No.	Year	Min	Max	Mean	SD	CV	Skew-ness	Kurtosis
1	2011-12	15	32	23.91	4.10	0.17	0.35	-0.29
2	2012-13	14	29	21.47	3.33	0.15	0.14	-0.66
3	2013-14	14	27	20.35	3.50	0.17	0.30	-0.68
4	2014-15	14	29	20.17	3.82	0.18	0.43	-0.63
5	2015-16	16	32	23.07	4.30	0.18	0.23	-1.03

Soil quality assessment

Selection of attributes: Selection of the attributes comprising physical and chemical properties of soils that best represent soil functions is made using expert knowledge (Sys, 1985; NBSS & LUP, 1994; Chatterji, 2000; Chatterji *et al*., 2002; Kadu *et al*., 2003; and Naidu *et al*., 2006 Venugopalan *et al*., 2009) [7, 11, 14, 24]. The soil parameters *viz*., sHC, clay, ESP and OC were selected as indicators for cotton. Fuzzy modeling-based mathematical approach is a method of land evaluation and considers only physical and chemical properties of soils. sHC is an important parameter of soil which governs movement of water in the soils. Soils with high sHC allow movement of water to the deeper soils which can be utilized by the cotton roots. The saturated hydraulic conductivity of soils is a good indicator of internal drainage conditions. Influenced by texture, structure, bulk density and pH of the soils. it affects movement of water in the soils and hence affects crop growth (Vaidya and Pal, 2002; Pawar *et al*., 2014) [11, 18].

Clayey soils (vertic properties) are preferable as it can hold more water. The clay content, in general, increased with depth which might be due to the downward translocation of finer particles from the surface soils. The high amount of ESP in soils cause poor physical properties of cracking clay soils (Balpande *et al*., 1996) [11]. However, these soils are not expected to have any adverse effect on crops due to sodicity. The highest ESP did not reach the limiting value (Kadu *et al*, 1993) [11]. High sodium percentage leads to structural decline e.g. dispersion of soil aggregates into individual soil particles leading to reduced water availability, low sHC, low permeability and reduced crop yield as a result of reduced availability of other nutrients. The soil organic carbon (OC) is an indicator of soil fertility. The organic fraction in soils is formed from the microbial decomposition of organic residues. In addition to this, it also improves soil structure, infiltration rate, water and nutrient storage capacity and reduces soil erosion (Smith and Elliot, 1990) [21].

Computation of membership functions

The ranks and statistics of standard indices, the dispersion indices and weightages (computed through ranking approach) for cotton are presented (Table 2). The same were required for developing membership functions.

Table 2: Ranks, values of different indices for selected parameters (MDS) and weightages for computing membership functions

Selected Parameters	Rank	Standard index (X_i)	Dispersion Index (a_i)	Weightage (W_i)
sHC (cm hr^{-1})	4	>1.5	0.5152	0.4
Clay (%)	3	< 27.5	0.0025	0.3
ESP (%)	2	< 0.5	0.0580	0.2
OC (%)	1	> 0.8	0.8182	0.1

Standard indices (Xi) for the MDS components for cotton were finalized on the basis of their point/range values in the highly suitable class (Naidu *et al.*, 2006) [14] and knowledge of experts on the soils in relation to the crop (NBSS & LUP, 1994). The standard indices considered for sHC were >1.5 mm hr^{-1}, for clay < 27.5 %, for ESP < 5 and OC were > 0.8.

A value of dispersion index (a_i) 0.0004 developed for depth (Table 3), implies that the various soil units have their depth belongingness to the ideal value scattered within a band of 0.0004 measure. Similar interpretation of dispersion indices holds good for other properties as well. Ranking was assigned to each parameter based on the relative importance of that parameter to the cultivation of cotton crop and was based on local experts' knowledge (Chatterji, 2000; Chatterji *et al*., 2002; Kadu *et al*., 2003; Venugopalan *et al*., 2009) [7, 11, 24] and available literature and the weightages were derived using the relationship in eq^n(1) mentioned in the chapter on Materials and Methods. Depth, being the most important parameter for cotton, was assigned the highest rank of 4, sHC 3, clay 2 and ESP was assigned the lowest rank of 1. The weightages derived from the ranking were 0.4 for depth, 0.3 for sHC, 0.2 for clay and 0.1 for ESP with their total normalized to unity (1).

A value of dispersion index (a_i) 0.5152 developed for sHC (Table 2), implies that the various soil units have their sHC belongingness to the ideal value scattered within a band of 0.5152 measure. Similar interpretation of dispersion indices holds good for other properties as well. Ranking was assigned to each parameter based on the relative importance of that parameter to the cultivation of cotton crop and was based on local experts' knowledge (Chatterji, 2000; Chatterji *et al*., 2002; Kadu *et al*., 2003; Venugopalan *et al*., 2009) [7, 11, 24] and available literature and the weightages were derived using the relationship in eq^n (1) mentioned in the chapter on Materials and Methods. sHC, being the most important parameter for cotton, was assigned the highest rank of 4, clay 3, ESP 2 and OC was assigned the lowest rank of 1. The weightages derived from the ranking were 0.4 for sHC, 0.3 for clay, 0.2 for ESP and 0.1 for OC with their total normalized to unity (1).

The membership functions of the relevant parameters in the given grid sample for cotton are presented. The membership functions (or values) indicated the degree of suitability at a given location with respect to a given land characteristic. On a 0~1 scale, any parameter having a membership of 1 (highly suitable class) in any land unit suggests that the parameter has the complete belongingness to a particular class. The membership value of clay for sample 1 is 1.0 implies that the parameter has a belongingness of 100 percent to that class. Similarly, membership value of 0.96 for sHC for that of 1.00 for Clay, 0.96 for ESP and that of OC for 1.00 percent belonged to that class.

The joint membership function (JMF) is sum of the product of MF and weightage (Table 3). The composite soil index (CSI) of a SQ parameter is the average of the aggregated JMF values of the parameters for particular samples which conceptually and for all practical purposes holds the same implicatios as that by SQI.

Table 3: Joint membership functions (JMFs), composite soil index (CSI) and land classes for cotton in fuzzy modelling.

Sample No.	sHC	Clay	ESP	OC	CSI	Land Classes
0	0.16	0.30	0.15	0.07	68.31	II
1	0.26	0.31	0.19	0.10	86.00	I
2	0.21	0.30	0.16	0.09	76.07	II
3	0.24	0.27	0.13	0.10	73.52	II
4	0.20	0.30	0.16	0.07	73.26	II
5	0.21	0.30	0.19	0.10	79.74	II
6	0.20	0.30	0.17	0.07	73.58	II
7	0.20	0.30	0.15	0.10	74.72	II
8	0.20	0.30	0.17	0.07	73.80	II
9	0.21	0.30	0.13	0.10	73.72	II
10	0.21	0.30	0.15	0.09	75.18	II
11	0.21	0.30	0.13	0.10	73.45	II
12	0.25	0.30	0.19	0.10	83.68	I
13	0.22	0.29	0.15	0.09	74.74	II
14	0.22	0.30	0.13	0.10	74.45	II
15	0.23	0.30	0.11	0.10	73.63	II
16	0.21	0.30	0.11	0.10	72.27	II
17	0.21	0.30	0.11	0.10	71.65	II
18	0.22	0.30	0.12	0.09	72.74	II
19	0.21	0.30	0.12	0.10	73.05	II
20	0.24	0.30	0.17	0.10	80.66	I
21	0.22	0.30	0.13	0.09	73.83	II
22	0.21	0.29	0.13	0.07	70.70	II
23	0.21	0.30	0.13	0.07	70.52	II
24	0.24	0.30	0.13	0.09	76.29	II
25	0.22	0.30	0.13	0.09	73.87	II
26	0.26	0.30	0.11	0.07	74.32	II
27	0.22	0.27	0.14	0.07	70.19	II
28	0.21	0.30	0.12	0.08	70.90	II
29	0.21	0.27	0.11	0.10	68.82	II
30	0.21	0.27	0.11	0.07	66.00	II
31	0.23	0.30	0.11	0.07	70.97	II
32	0.31	0.30	0.10	0.07	77.31	II
33	0.27	0.27	0.10	0.07	71.00	II
34	0.20	0.30	0.15	0.10	75.52	II
35	0.35	0.30	0.16	0.10	90.74	I
36	0.32	0.30	0.15	0.10	86.67	I
37	0.24	0.30	0.16	0.08	77.14	II
38	0.24	0.30	0.16	0.07	75.92	II
39	0.25	0.30	0.14	0.10	78.65	II
40	0.32	0.30	0.16	0.10	87.95	I
41	0.24	0.30	0.16	0.07	76.70	II
42	0.23	0.30	0.11	0.07	71.24	II
43	0.23	0.27	0.11	0.07	67.62	II
44	0.23	0.27	0.11	0.07	67.62	II
45	0.33	0.30	0.11	0.06	80.93	I
46	0.21	0.26	0.11	0.07	64.62	II
47	0.24	0.30	0.15	0.07	75.60	II
48	0.21	0.24	0.11	0.07	62.62	II
49	0.22	0.30	0.16	0.10	77.93	II
50	0.20	0.30	0.15	0.07	71.93	II
51	0.21	0.30	0.12	0.10	73.29	II
52	0.20	0.30	0.12	0.10	72.42	II
53	0.22	0.30	0.15	0.07	74.00	II
54	0.21	0.30	0.13	0.07	69.96	II
55	0.22	0.30	0.14	0.07	71.99	II
56	0.26	0.27	0.11	0.07	70.62	II
57	0.25	0.30	0.13	0.07	74.39	II
58	0.23	0.28	0.13	0.10	73.42	II
59	0.23	0.30	0.12	0.07	71.32	II
60	0.22	0.30	0.11	0.10	72.85	II
61	0.28	0.26	0.11	0.07	72.10	II

62	0.28	0.30	0.11	0.09	78.28	II
63	0.24	0.30	0.11	0.07	72.15	II
64	0.23	0.30	0.12	0.10	74.36	II
65	0.23	0.30	0.12	0.06	70.72	II
66	0.21	0.30	0.12	0.09	72.80	II
67	0.22	0.30	0.12	0.09	73.65	II
68	0.21	0.30	0.14	0.10	74.30	II
69	0.22	0.30	0.14	0.09	74.78	II
70	0.21	0.27	0.11	0.07	65.62	II
71	0.26	0.30	0.15	0.07	77.13	II
72	0.25	0.30	0.14	0.07	75.31	II
73	0.24	0.30	0.17	0.07	77.56	II
74	0.23	0.30	0.11	0.07	70.79	II
75	0.37	0.30	0.17	0.10	93.99	I
76	0.30	0.30	0.16	0.10	85.92	I
77	0.26	0.30	0.11	0.10	77.23	II
78	0.26	0.30	0.12	0.07	74.78	II
79	0.30	0.30	0.13	0.07	79.89	II
80	0.30	0.30	0.14	0.07	80.34	I
81	0.25	0.30	0.15	0.07	75.89	II
82	0.25	0.30	0.12	0.09	75.68	II
83	0.22	0.30	0.13	0.07	70.80	II
84	0.25	0.30	0.13	0.07	74.92	II
85	0.27	0.30	0.14	0.07	76.68	II
86	0.21	0.24	0.11	0.07	62.62	II
87	0.21	0.24	0.12	0.07	64.09	II
88	0.21	0.24	0.11	0.07	62.62	II
89	0.22	0.30	0.12	0.10	73.83	II
90	0.26	0.30	0.12	0.10	78.71	II
91	0.24	0.30	0.12	0.07	73.45	II
92	0.32	0.30	0.17	0.10	88.75	I
93	0.28	0.30	0.12	0.07	76.89	II
94	0.23	0.30	0.12	0.06	71.98	II
95	0.24	0.30	0.15	0.07	75.03	II
96	0.23	0.30	0.14	0.10	76.64	II
97	0.22	0.26	0.11	0.07	65.49	II
98	0.23	0.30	0.14	0.07	74.05	II
99	0.22	0.30	0.16	0.07	74.92	II
100	0.35	0.30	0.11	0.10	85.58	I
101	0.22	0.30	0.12	0.10	74.57	II
102	0.25	0.30	0.13	0.10	78.60	II
103	0.27	0.30	0.13	0.10	79.56	II
104	0.31	0.30	0.15	0.07	82.59	I
105	0.28	0.29	0.16	0.10	83.08	I
106	0.22	0.30	0.15	0.10	76.71	II
107	0.21	0.23	0.15	0.07	65.63	II
108	0.27	0.24	0.11	0.07	68.94	II
109	0.23	0.30	0.12	0.07	70.91	II
110	0.23	0.24	0.12	0.10	68.46	II
111	0.23	0.30	0.12	0.10	74.39	II
112	0.29	0.30	0.11	0.10	79.67	II
113	0.27	0.30	0.14	0.07	78.53	II
114	0.29	0.30	0.11	0.10	79.30	II
115	0.32	0.30	0.11	0.10	83.06	I
116	0.29	0.30	0.11	0.07	77.03	II
117	0.25	0.30	0.11	0.10	76.03	II

The suitability classes for the crops were identified by placing the CSI values (of the land units) in a set of equally-spaced classes on a 0-100 scale, with a 20 unit gradation. CSI lying between 100-80 comes under class I, CSI lying between 80-60 comes under class II, CSI lying between 60-40 comes under class III, CSI between 40-20 comes under class IV and class V has CSI value ranging from 20-0.

The data presented in fig. 3 out of 118 soils samples were classified 103 samples under class II, The highest composite soil index (CSI) was found to be 79.74. Whereas the lowest CSI were found to be 62.62. In another 15 surface soils sample were classified under class I. The highest CSI were observed to be 93.99 whereas the lowest CSI was observed to be 80.34.

High residual value is considered as an outlier while developing the relationship between CSI and average yield. In case of the outlier, in spite of CSI being high, the crop performed poorly. Hence, it might be interpreted from the results that proper management was lacking in this outlier surface soils to deliver optimum yield and hence site specific management must be improved in this site.

The use of the fuzzy technique is helpful for land suitability evaluation, especially in applications in which subtle differences in soil quality are of a major interest.

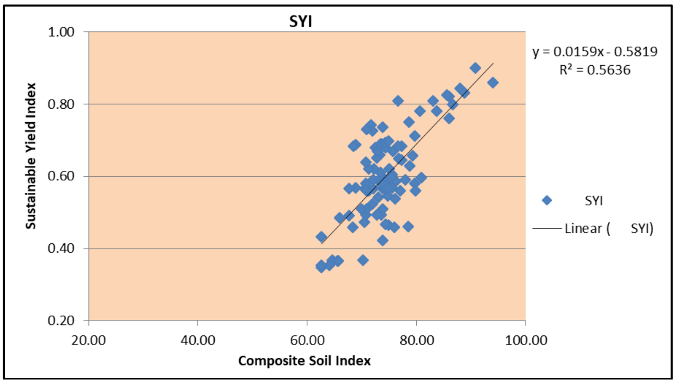

Fig 2: Relationship between Composite soil index (CSI) and SYI

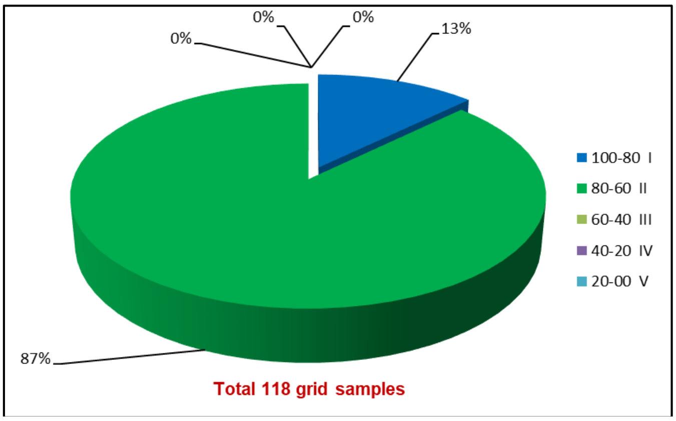

Fig 3: Composite Soil index (CSI) range suitability classes of Nilona micro-watershed

The linear regression lines were also drawn (Fig 2) using a CSI value (x) and the average yield (y) and their mathematical expressions were y=0.0159x –0.5819 and the correlation between CSI and average yield was R^2= 0.563**.

Conclusion

The use of the fuzzy technique is helpful for land suitability evaluation, especially in applications in which subtle differences in soil quality are of a major interest. This fuzzy model approach helps in overcoming limitations of abrupt boundary of land classes thus enables classification of land units on a continuous scale. As a result, it is found to be a sound technique for evaluating suitability of soils for the selected crop.

The successful application of this method provides us to suggest that whenever we have such datasets (as used in the present investigation) we could use this method for reliably assessing and monitoring soil quality for similar agro-ecological setups.

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