Original Research Article

**Cultivation-Driven Soil Degradation in Rice based Systems in Nalbari District, Assam, India: RSQI Thresholds for Sustainable Yield Maintenance**

|  |
| --- |
| **ABSTRACT:****Background:** Assessment of soil health has attracted a great deal of attention in recent years because of growing public interest in determining the effects of soil management practices on physical, chemical and biological soil properties and consequently on the soil quality relative to soil sustainability.**Aims:** The present investigation was carried out to assess Relative Soil Quality Index (RSQI) for grouping of soils of two land use system viz. rice-fallow and rice-oilseed as good, medium and poor categories. **Place and Duration of Study:** Assam Agricultural University, Jorhat, Assam, during 2016.**Methodology:** Geo-referenced soil samples were collected from rice-fallow and rice oilseed (toria) cropped fields continuously cultivated for the last ten years and from adjacent uncultivated soils in Nalbari district of Assam and analyzed for selected physical, chemical and biological properties of soils following standard procedures. Soil management practices and crop yield data were recorded from identified farmers. The RSQI based on 14 soil parameters (Water Holding Capacity, Soil texture, Bulk density, soil pH, CEC, OC, Available N, Available P, Available K, Available S, DTPA-Zn, Available B, Available Fe and MBC) were computed. **Results:** The results indicated that in rice-fallow system, 100% of the soils transformed to medium categories (RSQI value 50 – 70%) whereas 43% and 57% soils remained as medium (RSQI value 50 – 70%) and good category (RSQI value >70%) respectively in adjacent uncultivated soils. In rice-oilseed crop sequence, the RSQI values exhibited that 93% and 7% soils remained in the medium and good category (RSQI value>70%), respectively as compared to 29% medium category and 72% good category soils under adjacent uncultivated soils. The regression lines weredrawn between RSQI and % Relative yield of rice in rice-fallow system and yield of rice–oilseed system expressed in terms of equivalent yield of rice to sustain > 80% *infield* crop yield and optimum RSQI values obtained were > 51.8% and >51.15% for rice-fallow and rice-oilseed cropped soils. **Conclusion:** It was evident that continuous cultivation without proper soil management practices shifted the good-quality soils towards medium-quality soils. The RSQI study is important in reviewing the current fertility status of the soil as it will tells either the management or activities conducted are sustainable or not. Hence proper management practices are essential to sustain soil quality and secure agricultural production for increasing farmers’ income. |

*Keywords: Rice-fallow, rice-oilseed, RSQI, soil degradation, soil Quality, sustainable management*

1. INTRODUCTION

“Soil constituents such as clay, humus, and microorganisms are the most important components for terrestrial ecosystems due to its multiple ecosystem services. The ability of soil to fulfill its functions depends on its physical, chemical, and biological properties” (Valenzuela-Balcázar et al., 2021). “Soil is a non-renewable natural resource and is subjected to various forces of degradation in its quality due to increasing demographic pressure, intensive land use and improper management practices. In a developing country like India, a large proportion of land area shows clear evidence of advanced and continued degradation affecting countries productive resource base” (Sehgal & Abrol, 1994). “Therefore, sustainability of agricultural systems has become a major challenging issue nowadays” (Minhus, 2012). Agricultural sustainability depends on the maintenance of improved soil quality therefore, management practices based on soil quality are essential in order to have a sustainable agricultural productivity and global food security (Rao and Lenka, 2020; Clelik et al., 2021). “The assessment of soil quality aims to evaluate the utility and health of soils” (Yadav et al., 2023). “Thus, its assessment and direction of change in quality with time is a primary indicator to ensure sustainable agriculture” (Karnel et al., 1997; Masto et al., 2007). “Soil quality concepts are commonly used to evaluate sustainable land management in agro agroecosystem” (Carter, 2000). “Hence, assessment of soil health has attracted a great deal of attention in recent years because of growing public interest in determining the effects of soil management practices on physical, chemical and biological soil properties and consequently on the soil quality relative to soil sustainability” (Yao et al.,2013; Schoenholtz et al., 2000). “The emphasis on sustainable agriculture and, more generally, on sustainable land use initiated the development of the soil quality concept. Soil Quality essentially means the continued capacity of soil to function as a vital living system within ecosystem boundaries to sustain biological productivity” (Doran & Parkin, 1994; Karnel et al., 1997). “The soil quality is a dynamic interaction between various physical, chemical and biological soil properties and can be assessed using those physical, chemical and biological properties” (Dengiz, 2020).

“Rice is an important crop in the South East Asian countries, more particularly in the Indian subcontinent. Assam, a north-east state of India has an area of 2.7 million ha under rice cultivation and about 55% of it as mono crop. Rice is grown in different season in Assam, and Sali rice (winter rice) covers 63.0 % of total area. In Assam, rice is still being cultivated using traditional practices like artificial submergence, ploughing and puddling, straw incorporation after harvest, etc. These practices have resulted in decline in productivity and deterioration of soil health, which has affected crop yield” (Gayan et al., 2020).

Soil quality is considered a key element of Sustainable agriculture because it is essential to support and sustain crop production and helps to maintain other natural resources such as water, air and wildlife habitat. Soil quality indices are a way to incorporate multiple points of information into one tool that can be used for decision making. It would appear to be an ideal indicator of Sustainable land management and helps to assess the change in dynamic soil properties. The present experiment was designed with the objective to assess the Relative Soil Quality Index (RSQI) under long-term land use systems viz. rice-fallow and of rice –oilseed systems of Nalbari district of Assam.

2. material and methods

2.1 Collection of soil samples

Geo reference ( N: 26o31.882’ to 26o 18.224’ and E: 091o30.536’ to 091o 15.750’) soil samples (0-15cm) were collected from Rice-fallow and rice-oilseed cropping systems after harvest of rice for Rice-fallowsystem and after harvest of the second crop (toria) in the rice-oilseed cropping system, followed in seven blocks covering 23 villages of Nalbari district of Assam. For comparison, the soil samples from adjacent uncultivated sites were collected. The sampling was focused on the plough layer because this is where most soil quality changes are expected to occur due to long-term land use and soil management practices. Four soil samples from each unit were collected randomly and mixed to form a single composite sample, which was again divided into two parts for analysis of soil physical, chemical and biological parameters. The samples for analysis of biological properties were kept at 40C in poly pouch after collection. Tube core sampler was used separately for the collection of soil sample for the determination of bulk density. At the time of collection of soil samples the crop history, including management practices, was recorded from respective farmers. In total 60 composite soil samples were collected from each of the cultivated and uncultivated soils of rice- fallow system and 63 composite soil samples were collected from each of the cultivated and uncultivated soils of the rice-oilseed cropping system. Analysis of physical, chemical and biological properties was done using standard procedures.

**2.2 Analysis of Physical, Chemical and Biological properties of soils**

Physical properties viz. Bulk Density (BD), soil moisture content, soil texture and Water holding capacity (WHC) were analyzed. For the determination of bulk density, undisturbed soil samples were collected from the field in natural condition using a tube core sampler (5.2cm diameter and 9cm length) following the standard method (Black & Hartge, 1986). The soil moisture content (MC) was determined using the gravimetric method for field moist soils by drying at 1050C for 24 hours (Gardner, 1986). The texture of the soil samples was determined by International Pipette Method (ISSS, 1929). Maximum water holding capacity in percentage was determined by using Keen Rackzowski Box described by Baruah & Barthakur (1997).

The chemical properties such as soil pH, electrical conductivity, organic carbon, CEC, available N, P, K, exchangeable Ca and Mg, available S, micronutrients such as available zinc, boron and iron were estimated following a standard procedure (Jackson, 1973).

Biological properties viz. enumeration of bacteria, fungi, *Azotobacter*, *Azospirillum* and Phosphate-solubilising bacteria (PSB), Microbial biomass carbon (MBC), Dehydrogenase activity (DHA), Phosphomonoesterase (PME) activity, fluorescien diacetate hydrolysis (FDA) activity, arylsulphatase (ARYL) activity, were analyzed following standard procedures. The classical serial dilution technique was used for enumeration of bacteria, fungi, *Azotobacter*, *Azospirillum* and phosphate-solubilising bacteria (PSB) from the soil by spread plate technique on appropriate media. Nutrient agar (NA) and Martin Rose Bengal (MRB) media were used for the enumeration of bacteria and fungi, respectively. The soil sample of 1 g was suspended in 9 ml water blank followed by serial dilution up to 10-5. Aliquot of 10 µl from 10-3, 10-4 and 10-5 dilution were spread over solidified media in triplicates and plates were incubated at 30±10C for bacteria and fungi population.

 For the enumeration of *Azotobacter*, *Azospirillum* and PSB the media used were that of Burk’s, nitrogen free bromothymol blue (NFb) and Pikovskaya’s media respectively. 100 µl aliquot of 10-4 and 10-5 dilutions were spread over the solidified media in triplicates and plates were incubated at 30±10C for *Azotobacter* and PSB while NFb plates were incubated at 35±10C for 3- 5 days. The microbial numbers were estimated as colony forming unit per gram (cfu g-1) soil on dry weight basis and transformed to log10cfu g-1.

Microbial Biomass carbon was determined by chloroform fumigation extraction technique following the method of Vance et al. (1987). Dehydrogenase activity (DHA) was determined by the reduction of tri phenyl tetra zolium chloride (TTC) to tri phenyl formazan (TPF) as described by Casida *et al.* (1964). Phosphomonoesterase (PME) activity was measured colorimetrically following the method of Tabatabai & Bremner (1969).

 Fluorescein di acetate (FDA), hydrolysis activity was estimated colometrically following the method described by Adam & Duncan (2001) using a Nano Drop 1000 spectrophoto meter (Thermo Fisher Scientific Country, USA). The assay for Arylsulphatase (ARYL) activity was carried out by using *p*-nitro phenyl sulphate (*p* -NPS) as substrate (Tabatabai & Bremner, 1970).

**2.3Statistical Analysis**

For assessment of RSQI, 14 important and known physical, chemical and biological indicators with uniform weightage and scoring values were selected (Table1). Each of the indicators was divided into four classes namely, class-I, class-II, class-III, and class-IV with an assigned mark of 4, 3, 2 and 1 respectively. The SQI was calculated using the following equation as

 SQI=∑ Wi Mi

Where, Wi is the weight of the indicator and Mi is the mark of the indicator classes. Thus summing up of all the 14 indicators provided the SQI value for a particular soil of the farmer’s field. As per table 1, the maximum value of SQI is 400 (best quality soil) and the minimum value is 100 (poor quality soil) (Wang & Gong, 1998). In order to judge the SQI (*i.e.* 400), the concept of RSQI was used as described by Karlen & Stott (1994).

 Observes SQI of the given site

RSQI= ----------------------------------------------- X100

 Maximum value of SQI (*i.e.* 400)

**2.4 Mean per cent relative yield computation**

The mean per cent relative yield of rice and toria crop included in the cropping sequence was computed with the following equation. The yield of toria grown after rice was expressed in terms of rice equivalent yield.

 Observed rice yield of a given site

Mean per cent relative yield = --------------------------------------------------------- X 100

 Maximum yield among the sites

**2.5 Correlation coefficient and simple linear regression analysis:**

Correlation coefficient and simple linear regression was drawn between RSQI and mean per cent relative yield, and the best fit was graphically presented as scatter diagram.

**Table 1. Soil quality indicators and their weights and classes for the evaluation of relative soil quality index (RSQI)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Soil quality indicators | Weights | Class I with score 4 | Class II with score 3 | Class III with score 2 | Class IV with score 1 |
| Physical indicators |
| 1. Water holding capacity (%)
2. Texture
3. Bulk density (Mg m-3)
 | 155 5 | ˃30Loam1.3-1.4 | 20-30LS/CL/SL/SiCL/SiL1.2-1.3/1.4-1.5 | 8-20C/S/SCL1.1-1.2/1.5-1.6 | < 8Grit<1.1/˃1.6 |
| Chemical indicators |
| 1. Soil pH (1:2.5)
2. CEC [ C mol (p+)kg-1)]
3. Av. N (kg ha-1)
4. Av. P (kg ha-1)
5. Av. K (kg ha-1)
6. Av. S (kg ha-1)
7. DTPA-Zn (mg kg-1)
8. Av. B (mg kg-1)
9. Av. Fe (mg kg-1)
 | 55101055433 | 6.5-7.5˃18˃545˃56˃337˃25˃1.2˃1.5˃10 | 6.0-6.5/7.5-8.018-15545-44556-40337-23715-251.2-0.60.7-1.55.5-10 | 5.5-6.0/8.0-8.515-10445-27240-22.5237-13610-150.6-0.40.3-0.72.5-5.5 | <5.5/˃8.5<10<272<22.5<136<10<0.4<0.3<2.5 |
| Biological indicators |
| 1. Organic Carbon (%)
2. MBC (mg kg-1)
 | 1510 | ˃1˃400 | 1-0.75400-300 | 0.75-0.5300-100 | <0.5<100 |
| Total | 100 | 400 | 300 | 200 | 100 |

Based on RSQI value soils are classified as good (RSQI ˃70%), medium (RSQI 50-70%) and poor (RSQI <50%) category.

3. results and discussion

**3.1. Computation of RSQI and categories of soils:**

The RSQI based on 14 soil indicators viz. water holding capacity (%), soil texture, bulk density (Mg m-3), soil pH (1:2.5), CEC [C mol (p+)kg-1)], Av. N (kg ha-1), Av. P (kg ha-1), Av. K (kg ha-1), Av. S (kg ha-1), DTPA Zn (mg kg-1), Av. B (mg kg-1), Av. Fe (mg kg-1), Organic Carbon (%) and MBC (mg kg-1) which were known to exert significant influence on soil health, were computed (Table 2). The result illustrated that in Rice- Fallow system 100% of the soils belonged to medium (RSQI-50-70%) category while in the case of uncultivated soils, without the poor category, 43.33% and 56.67% belonged to medium (RSQI-50-70%) and good (RSQI >70%) category correspondingly. In rice-oilseed crop sequence, the RSQI value exhibited that only 6.30% soils belonged to the good category (RSQI >70%) under cultivation compared to 71.43% good category (RSQI >70%) under uncultivated situation. It indicated that soil properties deteriorated in cultivated soils, which might be due to inappropriate soil management practices. Similar trends of results were also observed in AESR 10.1, where the majority of cultivated soils (rice-wheat, Soya bean-wheat and Soya bean-chickpea) fell under the medium (RSQI value=77.5%) and poor (RSQI value=11.20%) (Kundu et al., 2012). RSQI value computed for soil samples from the rice ecosystem of Upper Brahmaputra Valley Zone of Assam indicated that the majority of the soils belonged to medium category (RSQI value 58.9%) as reported by Gayan et al., 2020.

**Table 2. Grouping of soils based on Relative soil quality Index (RSQI) values for rice-fallow and rice-oilseed crop sequence**

|  |  |  |  |
| --- | --- | --- | --- |
| RSQI (%) | Quality Rating | Rice-fallow system | Rice-oilseed sequence |
|  | Cultivated | Uncultivated | Cultivated | Uncultivated |
| <50 | Poor | - | - |  |  |
| 50-70 | Medium | 60 (100%) | 26(43.33%) | 59(93.65%) | 18 (28.57%) |
| >70 | Good | - | 34 (56.67%) | 4 (6.34%) | 45 (71.43%) |
| Total |  | 60 (100%) | 60 (100%) | 63 (100%) | 63 (100%) |

**3.2. Correlation coefficient and simple linear regression**

The regression lines were drawn to observe the effectiveness of RSQI, and the relationship was in the form of y=0.4127x+38.559 (R2=0.2113) in between % relative yield of rice and RSQI (Fig1) under the rice fallow system. The regression line was used to work out the optimum value of RSQI to sustain 80% (4.24 t ha-1) or more of the existing *infield* maximum rice yield (5.3 t ha-1). Thus, the optimum RSQI value for attaining 80% or more of the maximum yield is computed as >51.8% in the rice-fallow system.

In rice-oilseed crop sequence, the regression line was in the form of Y=0.3784x +48.188 (R2=0.1001 in between mean equivalent %RY of rice and RSQI (Fig2). The regression line was used to work out the optimum value of RSQI to sustain 80% (6.17tha-1) or more of the existing *infield* maximum rice equivalent yield of crops (rice and toria) (7.72 t ha-1). Thus the optimum RSQI value for attaining 80% or more of the maximum yield is computed as >51.15% in the rice-oilseed crop sequence.

**Fig.1 Relationship between % Relative yield of rice with RSQI in Rice-Fallow system**

**Fig.2 Relationship between% Relative Yield (rice equivalent yield) of rice-toria with RSQI in Rice-oilseed crop sequence**

4. Conclusion

Agricultural land use and improper soil management practices deteriorate the soil quality over a long period of time. RSQI method is suitable to determining soil quality deterioration under different land use system. Moreover, RSQI study is important in reviewing the current fertility status of the soil as it will tell either the management or activities conducted are sustainable or not. Proper management practices based on RSQI values should be adopted to sustain soil health and optimise crop production in order to enhance the farmers’ income.

**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 the writing or editing of this manuscript.

References

Adam, G. & Duncan, H. (2001).Development of a sensitive and rapid method for the measurement of total microbial activity using fluorescein diacetate (FDA) in a range of soils. *Soil Biology and Biochemistry,* **33** (7-8), 943-951.

Baruah, T.C., & Barthakur, H. P. (1997). A text book of Soil Analysis. Vikas Publishing House, New Delhi, India.

 Black, G.R. & Hartge, K.H. (1986). Bulk density. In: Klute, A. (Ed.) Methods of Soil Analysis. Part1. 2nd (Ed.) Agronomy Monograph Number 9 American Society of agronomy and Soil Science Society of America, Madison, WI, pp.363-375.

Carter, M. R. (2000). Soil quality for sustainable land management: organic matter and aggregation interactions that maintain soil functions, *Agronomy Journal,* 94 (1), 38-47.

Casida, L. E., Klein, D. A. & Santoro, R. (1964). Soil dehydrogenase activity. *Soil Science,* 98 (6), 371-76

Celik, I., Gunal, H., Acir, N., Barut, Z. B., & Budak, M. (2021) Soil quality assessment to compare tillage systems in Cukurova Plain, Turkey. *Soil and Tillage Research*. 208, 104892. Doi: 10.1016/j.still.2020.104892

Dengiz, O. (2020) Soil quality index for paddy fields based on standard scoring functions and weight allocation method. *Archives of Agronomy and Soil Science*, 66, 301-315.

Doran, J. W. & Parkin, T.B. (1994). Defining and assessing soil quality. In: Defining Soil Quality for a Sustainable Environment. *Soil Science Society American* (Special publication) No.35, 3-21.

Gardner, W. H. (1986). Water Content. In: Klute, A. (Ed.), Methods of Soil Analysis, Part1, 2nd Edition. ASA and SSSA Madison, WI, pp494-544

Gayan, A., Nath, D.J., Bhattacharyya, B. & Dutta, N. (2020). Assessment of soil quality indicators under rice ecosystem of Assam, *Indian Journal of Environmental Biology*, 41, 1655-1664.

International Society of Soil Science, (1929) Minutes of the first commission meetings, International congress of Soil Science, Washington, 1927. *Proceedings of International Society of Soil Science* 4:215-220.

 Jackson, M. L (1973). *In:* Soil Chemical Analysis. Prentice Hall of India Pvt. Ltd., New Delhi.

Karnel, D.L., Mausbach, M.J., Doran, J.W, Cline, R.G., Harres, R.F. & Schuman, G. E. (1997) Soil Quality: A concept definition and framework for evaluation. *Soil Science Society of American Journal* 61:4-10.

Karlen, D. L. and Stott, D.E. (1994) A framework for evaluating physical and chemical indicators of soil quality. *Soil Science Society American* (Special publication) No.35, 53-72.

Kundu, S., Coumar, M.V., Saha, J.K., Rajendiran, S., Hati, K. M., Biswas, A.K., Reddy, K. S. & Rao, A. S. (2012)Assessing soil health of vertisols AESR 10.1 using selected physical, chemical and biological attributes of soils. *Journal of the Indian Society of Soil Science* 60(4), 281-287.

Masto R.E., Chhonkar, P.K., Singh, D., Patra, A.K. (2007) Soil quality response to long term nutrient and crop management on semi- arid Inceptisol. *Agriculture, Ecosystems and Environment*, 118, 130-142.

Minhus, P.S. (2012). Adaphic Disabilities of degraded soils: A threat to food security. *Journal of Indian Society of Soil Science*, 60, S88-S90

Noviyanto A., Purwanto P., Minardi S., Supriyadi S. (2017): The assessment of soil quality of various age of land reclamation after coal mining: A chronosequence study. Journal of Degraded and Mining Lands Management, 5: 1009–1018.

Schoenholtz, S. H., Miegroet, H. & Van Burger, J. A. (2000). A review of chemical and physical properties as indicators of forest soil quality: challenges and opportunities. *Forest Ecology and Mqnagement,* 138, 335-356.

Subba Rao, A., & Lenka, N.K. (2020) Development of soil health management in India as mirrored through sustained researches and policy interventions. Indian Journal of Fertilizers, 16, 1230-1242.

Sehgal, J. & Abrol, I.P. (1994) Soil Degradation in India: Status and Impact, Oxford and IBH Publishing Co.

Tabatabai, M. A. & Bremner, J. M. (1969). Use of p-nitrophenyl phosphate for assay of soil phosphatase activity. *Soil Biology and Biochemistry*. 1(4), 301-307.

 Tabatabai, M. A. & Bremner, J. M. (1970). Arylsulphatase activity in soils. *Soil Science Society of America Proceedings,* 34, 225-229.

Vance, E. D., Brookes, P.C. & Jenkinson, D. S. (1987). An extraction method for measuring soil microbial biomass C. *Soil Biology and Biochemistry*,19, 703-707.

Wang, X. & Gong, Z. (1998). Assessment and analysis of soil quality changes after eleven years of reclamation in subtropical China. *Geoderma*, 81, 339-355.

Yadav, M. B. N., Patil, P. L. & Hebbara, M. (2023). Comperative studies on soil quality index estimation of a hilly zone sub-watershed in Karnataka. *Sustainability*, 15(24), 16576.

Yao, R., Yang, J., Zhang, J. & Jin, W. (2013). Determining minimum data set for soil quality assessment of typical salt-affected farmland in the coastal reclamation area. *Soil and Tillage Research*, 128, 137-148.

Valenzuela-Balcázar, I. G., Visconti-Moreno, E. F., Faz, Á., & Acosta, J. A. (2021). Soil organic carbon dynamics in two rice cultivation systems compared to an agroforestry cultivation system. Agronomy, 12(1), 17.

.