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Assessment of Soil Quality of Some Lands in Thanjavur and Tiruvarur Districts for Improved Cultivation of Rice and Sugarcane

M. Shanmuganathan[1] and A. Rajendran[2*]

[1]Department of Chemistry, Research and Development Centre, Bharathiar University, Coimbatore – 641 046, Tamilnadu, India.
[2]Department of Chemistry, Sir Theagaraya College, Chennai – 600 021, Tamilnadu, India.

Authors' contributions

This work was carried out in collaboration between both authors. Author MS wrote the protocol, designed the study, managed the analyses of the study and performed the statistical analysis and wrote the first draft of the manuscript. Author AR reviewed the experimental design and all drafts of the manuscript and approved. Both authors read and approved the final manuscript.

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ABSTRACT

Soil quality is defined as the soil's capacity to function within natural or managed ecosystem boundaries and to sustain plant productivity while reducing soil degradation. It can be assessed by selecting different indicators upon which the functions of soil depend. Researchers at Bishop Heber College, India have formulated a Soil Quality Index called after their names as Heber Soil Quality Index (HSQI) for the first time in India. In the present work, an attempt has been made to use the soil Heber Soil Quality Index (HSQI) to assess the suitability of a soil of a chosen area for the cultivation of rice and sugar cane. The quantity of soil quality parameters chosen in this study was determined using the proven methods given in the literature.The overall HSQI values of all samples ranged from 76.18 – 85.40, which reveals that the quality of soils studied in this investigation is good for the cultivation of rice and sugarcane. HSQI also provides the necessary information needed to maintain the optimum fertility year after year. It is a time saving and economically convenient process.

**Corresponding author: E-mail: annamalai_rajendran2000@yahoo.com;*

Keywords: Soil quality index; macro nutrients; Thanjavur; soil organic matter; bacterial content.

1. INTRODUCTION

Soil is one of the most valuable natural resources and to maintain its health is a moral responsibility. However, the urgency to produce more food and fuels is causing an irreparable damage on soil. Excessive mineral fertilization and irrational cultural practices contribute to reduce fertility and the organic matter contents. These circumstances have led many researchers to search new and better management strategies. The concept of soil quality evokes various responses, depending on our scientific and social backgrounds. Soil quality is an integration of soil processes and provides a measure of change in soil condition as related to factors such as land use, climate patterns, cropping sequences, and farming systems [1]. Presently, soil quality has been defined by some scientist as capacity of a soil to function [2]. Soil quality can be assessed by selecting different indicators upon which the functions of soil depend. A wide range of agricultural soils represents diversely managed arable lands while the main goal is to improve soil quality, crop yield, and reduce the ecological footprint [3,4]. Researchers at Bishop Heber College, India have formulated a Soil Quality Index called after their names as Heber Soil Quality Index (HSQI) for the first time in India. Thanjavur district popularly known as the rice bowl of Tamilnadu, India is an area where rice and sugarcane cultivation is being practised since ages. Therefore Thanjavur and the nearby Tiruvarur area were chosen. The main objectives of this work are to (i) find out the suitability of the soil of the chosen area using HSQI with the view to check, the nutrients supply/excessive nutrients, etc., (ii) to offer suggestions based on the test result to improve the quality of the soils. The twelve parameters considered are available nitrogen (kg/ha), pH, water holding capacity (%), available phosphorus (kg/ha), texture, available potassium (kg/ha), organic matter (%), bacterial content (SPC/g), electrical conductance (mmho/cm), chloride (mg/L), total hardness (mg/L) and bulk density (g/cm^3) [5,6].

2. MATERIALS AND METHODS

2.1 Study Area and Soil Sampling Procedure

The samples were taken form fifteen places of Thanjavur and Tiruvarur distrtcts namely Ullikadai, Umbalapadi, Vijayamangai, Karuppur, Thensarukkai, Erumaipatti, Thattumalpadugai, Thaliyur, Srinivasapuram, Veerànchery, Papanasum, Eachangudi, Pasupathikoil and Perumalkoil (Fig. 1).

Fig. 1. Study map of sampling area

The field was divided into different homogenous units based on the visual observation and farmer's experience. The surface rubbish was removed at the sampling spot. Drove the auger to a plow depth of 15 cm and drew the soil sample. Collected at least 15 samples from each sampling unit and placed in a tray. Made a 'V' shaped cut to a depth of 15 cm in the sampling spot using a spade. Removed thick slices of soil from top to bottom of the exposed face of the 'V' shaped cut and placed in a clean container. Mixed the samples thoroughly and removed foreign materials like roots, stones, pebbles and gravels. Reduced the bulk, about one kilogram by quartering. Quartering was done by dividing thoroughly mixed sample into four equal parts. The two opposite quarters were discarded and the remaining two quarters were remixed and the process was repeated until the desired sample size was obtained. Collected samples were taken in a clean cloth bag and labeled them with information like name of the farmer, location of the farm, survey number, previous crop grown, present crop, crop to be grown in the next season, date of collection, and name of the sampler etc., [6].

2.2 Sample Processing and Storage

Assigned the sample number and entered it in the laboratory soil sample register. The collected samples were dried in shadow by spreading on a clean sheet of paper after breaking the large lumps, if present. Spread the soil on a paper or polythene sheet on a hard surface and powdered the sample by breaking the clods to its ultimate soil particle using a wooden mallet. Sieved the soil material through 2 mm sieve. Repeated powdering and sieving until only materials of >2 mm (no soil or clod) were left in the sieve. Collected the material passing through the sieve and stored in a polythene bag with proper labelling for laboratory analysis. One kg of the sample in each type was collected and quality was assessed according to HSQI table consisting of the twelve important parameters. The value of each test was determined using the methods given in (Table 3).

The twelve parameters selected in the present study for the formulation of HSQI are either directly or indirectly related to other parameters. To design the HSQI table, data were collected from scholars in this area with the following objectives. They were asked to; (i) arrange the selected twelve parameters in their order of importance, (ii) make scoring on a 10 -point scale with '0' indicating the lowest rating and '10' indicating the highest using the statistical 'Q' test (iii) assign weighting curve value (Q -Value) (Table 2) and (iv) draw the graph for each parameter according to the permissible limit and tolerance limits. The information like the test results, weighting factor and the 'Q' value were used to formulate the soil quality Index. In accordance with HSQI formulation, if the total HSQI value is above 90, then the soil sample is considered to be an excellent and is highly suitable for the cultivation with special reference to rice and sugarcane, if the total HSQI value ranges from 70 to 90, then the sample is good in quality for the cultivation of paddy and sugarcane. If the total HSQI value lies between 50 and 70, the soil quality is considered to be medium, and if it is below 50, then the sample is very bad from which no good yield can be expected (Table 2). Q values of all samples were calculated from Fig.2 to 12 for the respective parameters [6].

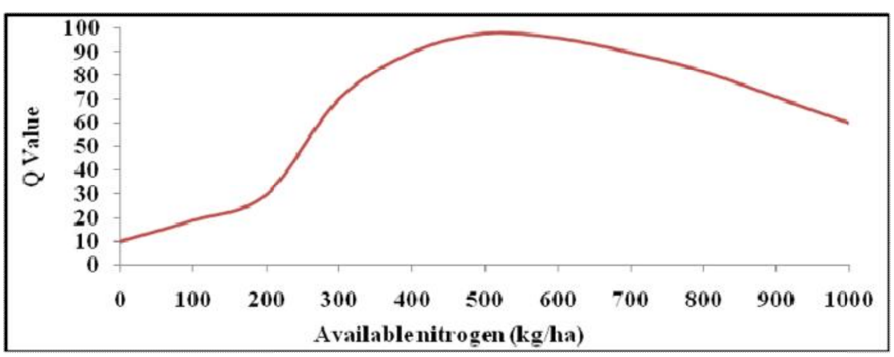

Fig. 2. Standard Q graph for available nitrogen

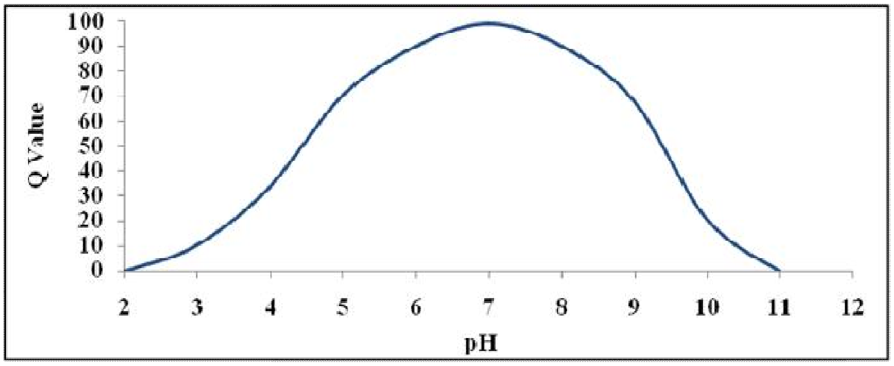

Fig. 3. Standard Q graph for pH

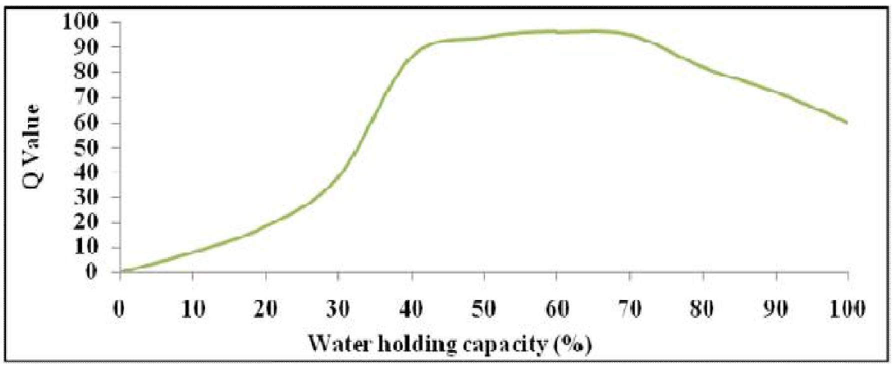

Fig. 4. Standard Q graph for water holding capacity

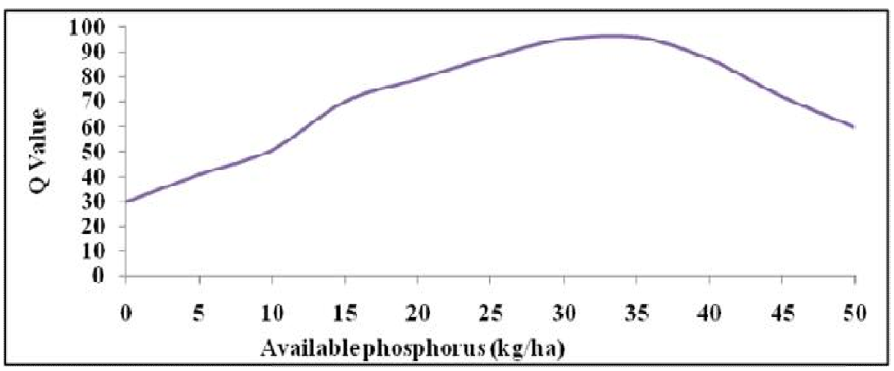

Fig. 5. Standard Q graph for available phosphorus

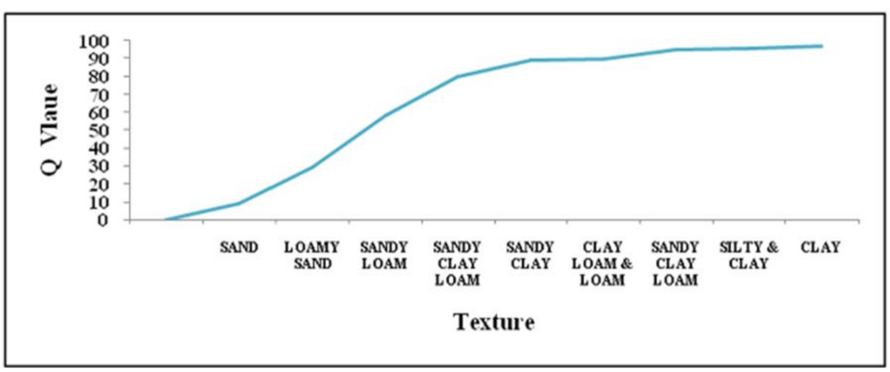

Fig. 6. Standard Q graph for texture

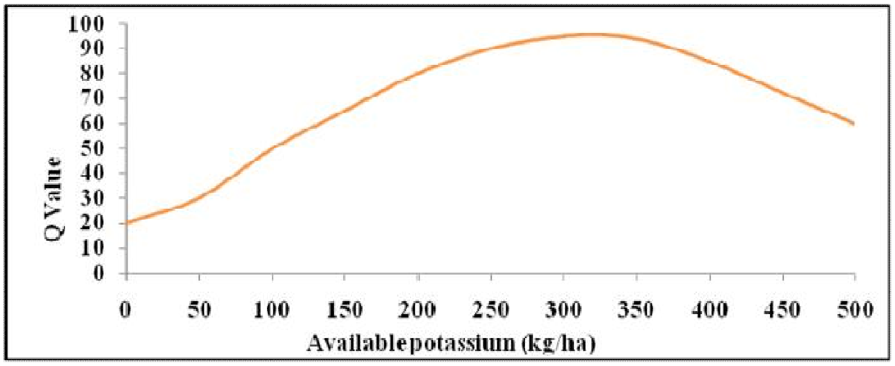

Fig. 7. Standard Q graph for available potassium

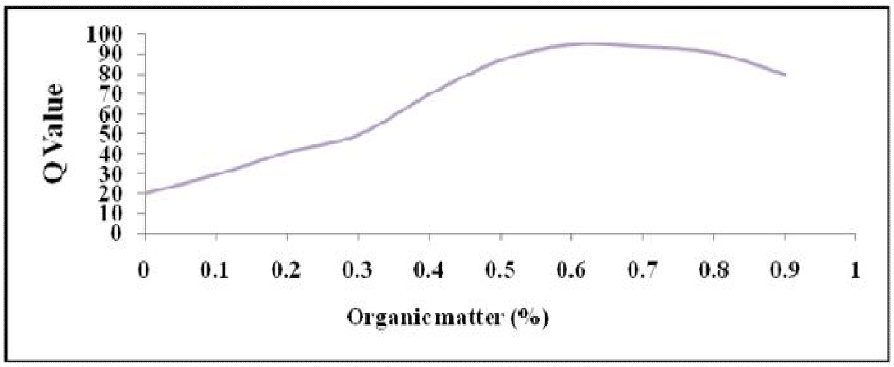

Fig. 8. Standard Q graph for organic matter

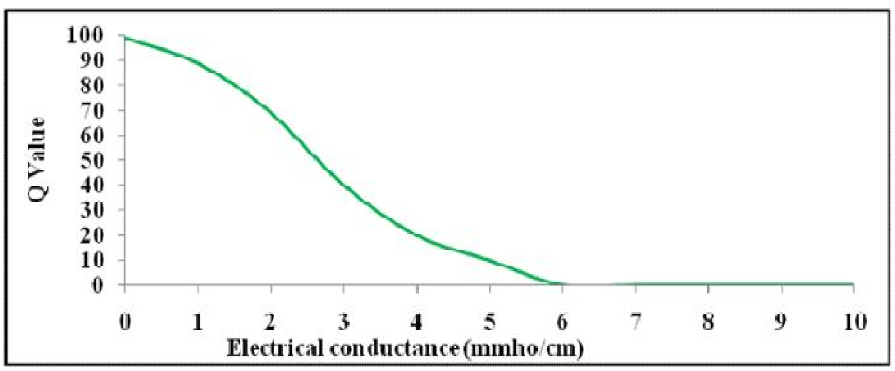

Fig. 9. Standard Q graph for electrical conductance

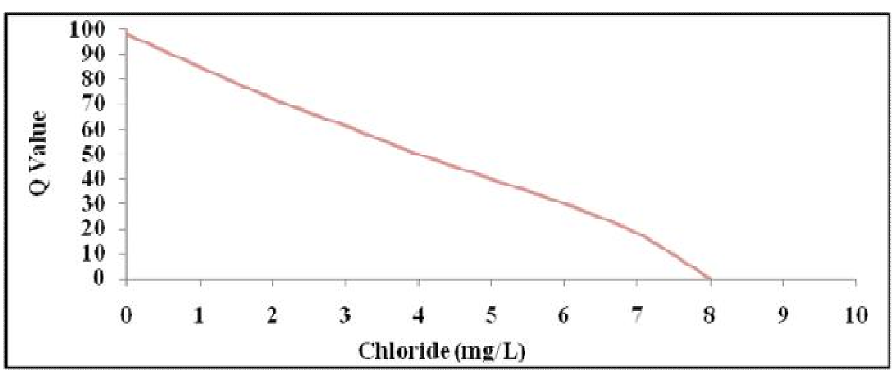

Fig. 10. Standard Q graph for chloride

Table 1. Heber soil quality index (HSQI)

Entry	Parameter	Weigthing factor
1	Available nitrogen (kg/ha)	0.095
2	pH	0.095
3	Water holding capacity (%)	0.093
4	Available phosphorus (kg/ha)	0.090
5	Texture	0.089
6	Available potassium (kg/ha)	0.087
7	Organic Matter (%)	0.084
8	Bacterial content (SPC/g)	0.082
9	Electrical conductance (mmho/cm)	0.076
10	Chloride (mg/L)	0.075
11	Total hardness (mg/L)	0.070
12	Bulk density (g/cm^3)	0.069

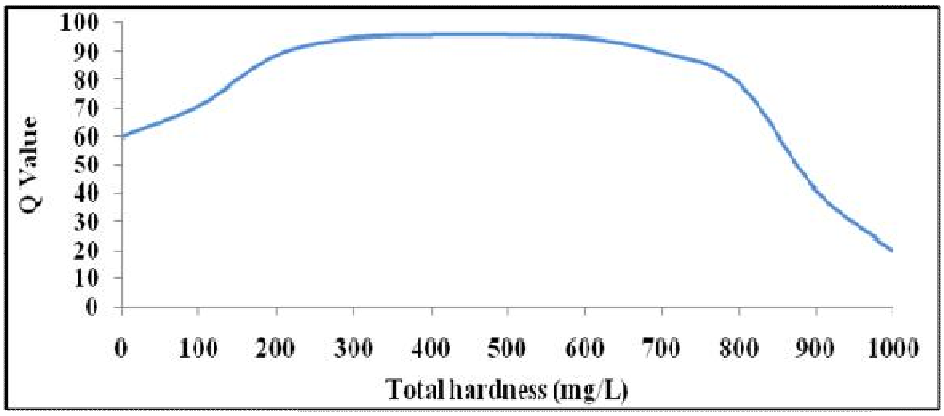

Fig. 11. Standard Q graph for total hardness

Table 2. Classification of soil quality on the basis of HSQI values for the cultivation of rice and sugarcane

Range	Quality of soil	Expected yield
>90	Excellent	Excellent yield is anticipated. The soil can contribute much more than the entire crop nutrient requirement.
71 – 90	Good	75 to 100% of the crop yield potential is expected without addition of the indicated nutrient. Yield increase to the added nutrient will be expected. A small portion of the nutrient requirement must come from fertilization.
50 – 70	Medium	50 to 74% of the crop yield potential is expected without addition of the indicated nutrient. Yield increase to the added nutrient is expected.
<50	Bad	Less than 50% of the crop yield is expected without the addition of the indicated nutrient.

3. RESULTS AND DISCUSSION

The analytical data for the samples are presented in the tables 6 – 10. The overall HSQI values of all samples ranged from 76.18 – 85.40 (Table 5), which reveals that the quality of soils studied in this investigation is good for the cultivation of rice and sugarcane.

Among the various soil samples analyzed, Sample 1 (Ullikadai) was found to have high total HSQI value, 85.40 (Table 6). This suggests that this sample is good for the cultivation of rice and sugarcane. Among the twelve parameters analyzed for this sample, the test results of the parameters such as available nitrogen (385 kg/ha), pH (8.1), water holding capacity (51.28

%), texture (silty clay loam) and available potassium (287.5 kg/ha) were found to be good in accordance with the optimum range required for the best cultivation of rice and sugarcane (Table 4). The HSQI values of available nitrogen, pH, water holding capacity, texture and available potassium were found to be extremely good with Q values of 8.55, 8.46, 9.02, 8.37, and 8.18 respectively. The parameters such as available phosphorus (47 kg/ha), organic matter (0.52%), electrical conductance (0.09 mmho/cm), chloride (1.5 mg/L) and bulk density (1.27 g/cm^3) contribute moderately to the quality of this soil sample with the HSQI values of 5.94, 7.56, 7.45, 6.00 and 6.49 respectively. Bacterial content and total hardness do not significantly contribute to the quality of this soil sample.

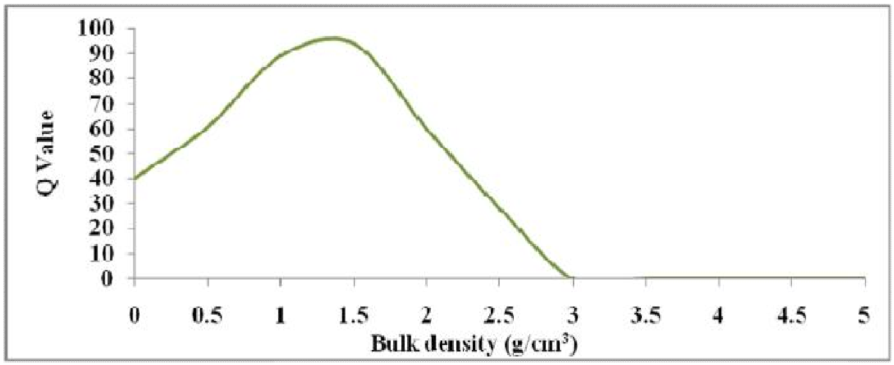

Fig. 12. Standard Q graph for bulk density

Table 3. Parameters and their methods of determination

Entry	Parameter	Method
1.	Available nitrogen (kg/ha)	Alkaline permanganate method [7].
2.	pH	Electrometric method [8]
3.	Water holding capacity (%)	Weight loss method [9]
4.	Available phosphorus (kg/ha)	Olsen's method [8,10]
5.	Texture	International pipette method [9]
6.	Available potassium (kg/ha)	Flame photometer method [11-13]
7.	Organic matter (%)	Walkley and black method [14]
8.	Bacterial content (SPC/g)	Standard plate count method [14]
9.	Electrical conductance (mmho/cm)	Digital conductometric method [8,9]
10.	Chloride (mg/L)	Tirtimetric method [8,15]
11.	Total hardness (mg/L)	Tirtimetric method [16]
12.	Bulk density (g/cm^3)	Clod method [17]

Table 4. Optimum range of the twelve parameters for better cultivation of rice and sugarcane

Entry	Parameter	Range
1.	Available nitrogen (kg/ha)	>560 [18,19,21]
2.	pH	4.5 – 8.0 [20,21]
3.	Water holding capacity (%)	40 – 55 [22,23,24,25]
4.	Available phosphorus (kg/ha)	> 25 [26]
5.	Texture	Clay and Clay loam [20,27]
6.	Available potassium (kg/ha)	>280 [28]
7.	Organic matter (%)	0.6 – 0.8 [30,31]
8.	Bacterial content (SPC/g)	10^8 – 10^9 [29]
9.	Electrical conductance (mmho/cm)	< 1 ([32,33]
10.	Chloride (mg/L)	< 4 [22]
11.	Total hardness (mg/L)	< 1.5 [35,36,37]
12.	Bulk density (g/cm^3)	1.23 – 1.5 [34]

The sample 10 (Veeranchery) was registered with the lowest total HSQI value, 76.18 (Table 9) which reveals that this sample of medium quality for the cultivation of rice and sugarcane. The parameters such as pH (7.7), water holding capacity (43.64%), texture (silty clay loam), available potassium (212.5 kg/ha), organic matter (0.81%) and electrical conductance (0.15 mmho/cm) were found to be good as per the optimum range required for the best cultivation (Table 4). The HSQI values of pH, water holding capacity, texture, available potassium, organic matter and electrical conductance were found to be extremely good with 9.12, 8.56, 8.37, 7.48, 7.56 and 7.45 respectively. The parameters such as available phosphorus (101.5 kg/ha), bacterial content (280000 SPC/g), total hardness (56 mg/L) and bulk density (1.34 g/cm^3) values contribute moderately to the quality of this soil sample with the HSQI values of 5.40, 4.92, 4.62 and 6.49 respectively. The test results of available nitrogen (175 kg/ha) and chloride (3.5 mg/L) were found to be extremely lower than optimum range values. This suggests that this soil sample suffers from the deficiency of available nitrogen, available potassium and chloride.

Table 5. Quality of each soil

Sample number	Sampling site	Total HSQI value	Quality of soil
1	Ullikadai	85.40	Good
2	Umbalapadi	77.66	Good
3	Vijayamangai	81.34	Good
4	Karuppur	79.93	Good
5	Thensarukkai	81.10	Good
6	Erumaipatti	77.32	Good
7	Thattumalpadugai	78.33	Good
8	Thaliyur	79.26	Good
9	Srinivasapuram	79.52	Good
10	Veeranchery	76.18	Good
11	Papanasum	81.25	Good
12	Eachangudi	78.83	Good
13	Pasupathikoil	78.51	Good
14	Perumalkoil	83.64	Good
15	Kudikadu	80.69	Good

Nitrogen is the most mobile essential plant nutrient, with numerous factors affecting transformation processes and distribution of nitrogen in the soil [38-40]. Availability of nitrogen in soil depends upon soil texture, soil pH and organic matter. Higher levels of nitrate are retained in clay soils than loamy soils, but sandy soils retain the lowest concentrations [41]. The risk of nitrate leaching is the highest in sandy soils. Leaching of clay soils is less prominent with nitrate being retained in the surface soil layers. Clay soils generally contain more organic matter and humus with a higher organic nitrogen reserve than sandy soils. This may be due to the high water holding capacity of clay type soils and faster plant growth rates, which increase the supply of organic matter to the soil. If the soil with a carbon content <2% have half the nitrogen reserve compared to soils with >10% carbon [42]. This confirms that the mineralization potential of soils increases with increasing organic matter content. The rate of nitrification increases with increasing pH. Lime applied to soil to increase the pH, stimulates the microbial population and also the enzymes involved in the nitrification process. In pasture soils where lime is surface applied, and very slow to increase the pH of subsurface soil layers, nitrification in the topsoil is substantially faster than in the subsoil. Loss of nitrogen as gaseous compounds from the soil takes place when nitrate is converted to NO, NO_2 and N_2 through the process of denitrification, especially under anaerobic conditions due to soil compaction and water logging [43]. All the tested samples have silty clay loam type which proves that samples have high water holding capacity and organic matter values. Ammonia gas (NH_3) may be lost from surface application of urea as urine (particularly from dairy cows) or fertilizer. Loss of nitrogen from volatilization can have a significant effect on mineral nitrogen budgets. According to the Indian soil culture, the optimum quantity of available nitrogen recommended by the agricultural scientists and soil experts for the effective cultivation of rice and sugarcane is >560 kg/ha (Table 4). Available nitrogen of the samples investigated in this study ranged from 105 – 385 kg/ha. This range suggests that all the soil samples taken in this investigation suffer from nitrogen deficiency.

Soil water pH is a measure of the soil acidity or alkalinity. pH plays a major role in the cultivation of any crops. Phosphate, a macronutrient, may also be limited in these high pH soils due to its precipitation in the soil solution. Lowering the pH of alkaline soils, or acidifying the soil, is an option [39]. Elemental sulfur can be added to the soil as it forms sulfuric acid when it reacts with water and oxygen in the presence of sulfur-oxidizing bacteria. Iron and aluminum compounds can be added to soil, as they cause the release of hydrogen when they react with water. Sulfuric acid may also be added directly [40]. Additions of appreciable amounts of organic matter will help acidify the soil as microbes decompose the material, releasing CO_2 which then forms carbonic acid. Organic acids are also released during humus decomposition. Peat and peat moss are highly acidic forms of organic matter, but can be costly. pH of all the soil samples ranged from 6.8 – 8.4, which infers that the quality of these soils is acidic to basic. The optimum range of pH recommended for the better yield of rice and sugarcane is 4.5 – 8.0 (Table 4). Soil sample 3 (Vijayamangai) (Table 6) registered a high pH (8.4) which indicates that this soil is basic but within the recommended limit and low pH (6.8) was recorded for sample 13 (Pasupathikoil) (Table 10). Other samples showed pH values the intermediate values. Therefore, as far as pH is concerned, almost all soil samples chosen for this study is good and better yield is expected from them.

Plants get most of their water from the soil. A soil's ability to hold water is called its water-holding capacity. Clay soils have high water-holding capacity, and sandy soils have low water-holding capacity. When a soil pore space is filled with water, the soil is saturated [43]. After a heavy rainfall or irrigation, a clay soil tends to remain saturated longer than a sandy soil. A loamy soil reaches its field capacity 2-3 days after a heavy rainfall or irrigation. At field capacity, the soil holds as much water as it can against the force of gravity. If no additional water is added for many days, the water will move in the soil from wetter to drier areas. Plant uptake causes removal of water, and capillary action causes water to rise up through the tiny tube-like openings of a soil (formed by a "string" of small pores in the soil) and evaporate from the surface [44]. Eventually, a soil may dry enough to reach its permanent wilting percentage, and the plant wilts and cannot recover. At this point, the available water (water that remains available to the plant) is gone, and the only water that remains is so tightly bound to soil particles that plants cannot access to it. When increases organic matter to soil, water holding capacity also increases. The water holding capacity of samples was determined to be in the range of 43.64 – 51.28 %. As per the recommendations of the soil experts, soils with water holding capacity in the range of 40 – 55% (Table 4) is good for the plantation of rice and sugarcane from which a better yield is anticipated. Sample 1 (Ullikadai) (Table 6) and sample 10 (Veeranchery) (Table 9) recorded high (51.28%) and low (43.64%) values of water holding capacity. Therefore, as far as this particular parameter is concerned all samples are good. All soil samples were reported as silty clay loam. Clay loam soil particles can hold more water and hence these samples have high water holding capacity values. The Organic matter of these samples 0.41% - 0.81% have high value, which is also responsible for high water holding capacity.

Phosphorus is an essential element for plant growth. It is a vital component of DNA and RNA, also the genetic memory unit of all living things [45-47]. Typically, in soils developed in temperate climates, the contribution of phosphorus by organic matter is relatively small and the main source of phosphorus for plants is the inorganic forms. The recommended value for the effective cultivation of rice and sugarcane is > 25 kg/ha (Table 4). Available phosphorus of the samples investigated in this study ranged from 39 – 173.25 kg/ha. Sample 3 (Vijayamangai) (Table 6) and sample 14 (Perumalkoil) (Table 10) recorded high (173.25 kg/ha) and low (39 kg/ha) values of available phosphorus. All the samples have an excess of available phosphorus content 39 – 173.25 kg/ha. pH of the samples ranged from 6.8 – 8.4, which shows that these samples are moderately acidic to alkaline nature.

Soil texture is an important soil characteristic feature which influences storm water infiltration rates. Numerous soil properties are influenced by texture, including, water holding capacity, organic matter content, cation exchange capacity (CEC) and pH buffering capacity [48-49]. Soil texture affects the soil's ability to retain water and nutrients. Generally speaking, soils with large amounts of clay or organic matter tend to hold water and nutrients more effectively than sandy soils. Sand does not hold nutrients very tightly, so as water drains through sandy soil, it tends to carry nutrients along with it. This process, known as leaching, carries nutrients out of the root zone and makes them unavailable to plants. Clay, on the other hand, has the ability to attract and hold nutrients in the soil and thus fewer nutrients are lost when water drains through clay soils. However, too much clay in the soil can cause other problems. For example, clay soils have a tendency to be waterlogged during wet weather and rock hard when they dry out. If a soil has too much sand or clay, the most cost-effective remedy is to add organic matter. Organic matter in the soil mimics the positive effects of clay (improved water and nutrient retention) without the disadvantages. Organic materials are the most effective when the soil is amended at least 30 percent by volume. The effect of adding organic material is not permanent because it decomposes with time. Coarse materials decompose more slowly and last longer in the soil [50]. Also, organic material should be composted before incorporating it into the soil because microbes feeding on uncomposted material can actually remove important nutrients from the soil. Soil texture of all the samples studied in the chosen area is reported as silty clay loam. As far as texture is concerned all the samples have high water holding capacity, organic matter and bulk density values.

The potassium is taken up by plants in the soil solution in the form of K^+ ion. The availability of is essential for photosynthesis and development of chlorophyll. It also improves vigour of plants to enable to withstand adverse climatic conditions, reduces lodging in cereal crops, regulates the stomata opening and closing and the movement of ions within the plants and hence it is called traffic policeman of the plant. Availability of potassium in the soil, depends upon soil texture, soil pH, cation exchange capacity and calcium and manganese content. Increases the soil texture, greater will be the fixation of potassium. Soils containing montmorilonite will have more potassium than kaolinite clay soils. A decrease in pH, reduces the potassium fixation as a result of competition of H_3O^+ for the inter layer exchange position. Liming of soil favours the potassium fixation. Increasing texture soils having higher CEC can hold more potassium exchange [51]. Potassium uptake has been reduced as the amount of Ca^{2+} and Mg^{2+} are increased or uptake of these two cations would be reduced as the available supply of potassium is increased. Deficiency of potassium generally affected in plant becomes stunted in growth with shortening of internodes, busy in appearance and also show reduced rates of photosynthesis [52]. The leave tips will appear dark brown in colour and blades will bluish green, chlorotic and necrotic are seen in rice and sugarcane (The recommended optimum value of available potassium for the better cultivation of rice and sugarcane is > 280 kg/ha (Table 4). The samples chosen in this study recorded the range of 125 – 687.5 kg/ha. The sample 4 (Karuppur) (Table 7) showed high values of available potassium (687.5 kg/ha), sample 8 (Thaliyur) (Table 8) recorded low value (125 kg/ha) of available potassium.

Organic matter is a built up in the soil of partly decayed plant and animal residues. Organic soils, such as peats, contain from 20% to as much as 95% organic matter. Mineral soils contain anywhere from a trace to 15% or 20% organic matter. Organic matter is used to increases the nutrient holding capacity of soil. It is a pool of nutrients for plants. It also chelates (binds) nutrients, preventing them from becoming permanently unavailable to plants. It is a food for soil organisms from bacteria to worms. These organisms hold on to nutrients and release them in forms available to plants. It improves water infiltration and decreases evaporation. It also increases water holding capacity in sandy soils. Fine-textured soils can hold much more organic matter than sandy soils for two reasons. First, clay particles form electrochemical bonds that hold organic compounds. Second, decomposition occurs faster in well-aerated sandy soils. A sandy loam rarely holds more than 2% organic matter. The optimum range of organic matter for the better cultivation of rice and sugarcane is 0.6 - 0.8% (Table 4). All the soil samples in this study were found to have organic matter in the range 0.41% - 0.81%. The sample 10 (Veeranchery) (Table 9) registered high organic matter (0.81%), sample 2 (Umbalapadi) (Table 6) showed the low content of organic matter is 0.41%. As far as soil texture is concerned all samples are silty clay loam type, which shows that these samples have high water holding capacity and bulk density values.

Soil bacteria live off organic material, thus they are chiefly found in the humus-rich top layer of approximately 25 centimetres. Healthy soil contains billions of bacteria; there are thousands of species. They carry out a great number of important processes that are essential to life. They break down dead organic matter to release nutrients, which thus once again become available to plants. Other bacteria clean the soil and contribute to good soil structure. Nitrogen-fixing bacteria fix nitrogen from the air and make it available to the plant. The organic matter in soil being the chief source of energy and food for most of the soil organisms, it has great influence on the microbial population. Organic matter influence directly or indirectly of the population and activity of soil microorganisms. It influences the structure and texture of soil and thereby activity of the microorganisms. All soil samples have in the range of bacterial content values 28 x 10^4 – 72 x 10^5SPC/g. The optimum range of bacterial content recommended is 10^8 – 10^9 in grams (Table 4). The sample 7 (Thattumalpadugai) (Table 8) registered high value of bacterial content (72 x 10^5 SPC/g) sample 10 (Veeranchery) (Table 9) showed low bacterial content value (28 x 10^4 SPC/g). Increase of organic matter is also responsible for bacterial content values.

Soil electrical conductivity is an indirect measurement that correlates very well with several soil physical and chemical properties. Since sands have low conductivity and clays have high conductivity, soil electrical conductivity correlates very strongly with particle size and soil texture. Soils prone to drought or excessive water will show variations in soil texture that can be delineated using soil electrical conductivity [53]. Since water-holding capacity is intimately linked to crop yields, there is enormous potential to use soil electrical conductivity measurements to delineate areas with different yield potential. Soil electrical conductivity also can delineate differences in organic matter content and cation exchange capacity [54]. Perhaps the greatest difficulty with a measurement as inclusive as soil electrical conductivity is to conclude what is causing the variation seen in soil electrical conductivity in any given area. The electrical conductance of the samples ranged from 0.04 – 0.30 mmho/cm. The optimum range of electrical conductance recommended is <1 mmho/cm (Table 4). The sample 3 (Vijayamangai) registered high value of electrical conductance (0.30 mmho/cm) (Table 6) and sample 4, 7, 8 and 14 (Karuppur, Thattumalpadugai, Thaliyur and Perumalkoil) low value of (0.04 mmho/cm) (Tables 7, 8 and 10).

Chloride is the most recent addition to the list of essential elements. Many people make the common mistake of confusing the plant nutrient chloride (Cl^-), with the toxic form chlorine (Cl). Chlorine is not the form that plants use. Chlorine exists either as a gas, or dissolved in water, such as bleach, and is not found in fertilizer. Chloride is important for exchange of gas, photosynthesis and safeguard against diseases in plants. When a plant's leaf pores, called stomata, open and close to allow the exchange of gases, the plant sees an increase in potassium. A subsequent increase in chloride balances out the positive charge of the potassium to prevent plant damage. The exchange of gases between the plant and the air around it is critical for photosynthesis; a deficiency of chloride inhibits photosynthesis, threatening plant health [55]. Too little chloride in plants can cause, wilting due to a restricted and highly branched root system, often with stubby tips, and leaf mottling and leaflet blade tip wilting with chlorosis has also been observed. Too much chloride in plants results in symptoms such as, leaf margins is scorched and abscission is excessive and size is reduced and may appear to be thickened. The Overall plant growth is reduced. Chloride accumulation is higher in older tissue than in newly matured leaves. In conifers, earlist symptom is a yellow mottling of the needles, followed by the death of the affected needles. The chloride content of the samples was found to be in the range of 1.2 – 3.5 mg/L. The recommended optimum range of chloride content is <4 mg/L (Table 4). The sample 10 (Veeranchery) showed high values (3.5 mg/L) (Table 9), the sample 2 (Umbalapadi) had low value of 1.2 mg/L (Table 6).

The total hardness of tested samples ranged from 28 – 56 mg/L. The recommended optimum range of total hardness is <1.5 mg/L (Table 4). The sample 10 (Veeranchery) showed high values (56 mg/L) (Table 9). The sample 2, 4 and 6 (Umbalapadi, Karuppur and Erumaipatti) (Table 1, 2 and 2) exhibited low value of total hardness (28 mg/L). Almost all the samples were found to have extreme hardness which is not good for the cultivation of rice and sugarcane.

Bulk density is defined as the mass of oven-dried soil per unit volume of soil. Soils with high bulk density have a smaller volume of pore spaces. Very high bulk density is undesirable for plant growth, since infiltration, aeration (supply of air to roots) and root development are likely to be below optimum. Bulk density values are < 1.0 in top soils high in organic matter, 1.0 to 1.4 for well-aggregated loamy soils, and 1.2 to 2.0 for sands and compacted subsoil horizons in clay soils [56]. For example, on the riverina soils, bulk densities range from 1.2 to 1.4 in well-structured clay soils, to 1.4 to 1.8 in the sandy loam soils. Soil layers with a high bulk density are often very hard when dry. The pale, bleached layer just under the surface in some sandy loam soils is an example of a soil horizon with a high bulk density. Compacted soil layers have a high bulk density. High bulk densities can restrict root development and plant growth. Bulk density values of the samples ranged from 1.12 – 1.38 mg/cm^3. The optimum range of bulk density values recommended for the efficient cultivation of sugarcane and rice is 1.23 – 1.50 mg/cm^3 (Table 4). The sample 2 (Umbalapadi) showed high values of bulk density (1.38 mg/cm^3) (Table 6). The sample 3 (Vijayamangai) registered as the low value of bulk density (1.12 mg/cm^3) (Table 1). Soil texture is reported as silty clay loam. This proves that all samples have high water holding capacity and bulk density.

Table 6. Heber soil quality index of Ullikadai, Umbalapadi and Vijayamangai

	Sampling site		Ullikadai				Umbalapadi				Vijayamangai			
	Sample number		1				2				3			
Entry	Parameter	Unit	HSQI											
			Test result	Q value	Weighting factor	Total	Test result	Q value	Weighting factor	Total	Test result	Q value	Weighting factor	Total
1.	Available nitrogen	kg/ha	385	90	0.095	8.55	280	65	0.095	6.18	280	65	0.095	6.18
2.	pH	-	8.1	89	0.095	8.46	8	90	0.095	8.55	8.4	85	0.095	8.08
3.	Water holding capacity	%	51.28	97	0.093	9.02	46.3	92	0.093	8.56	44.28	92	0.093	8.56
4.	Available phosphorus	kg/ha	47	66	0.090	5.94	138.75	60	0.090	5.40	173.25	60	0.090	5.40
5.	Texture	-	Silty clay loam	94	0.089	8.37	Silty clay loam	94	0.089	8.37	Silty clay loam	94	0.089	8.37
6.	Available potassium	kg/ha	287.5	94	0.087	8.18	550	60	0.087	5.22	325	95	0.087	8.27
7.	Organic matter	%	0.52	90	0.084	7.56	0.41	72	0.084	6.05	0.62	96	0.084	8.06
8.	Bacterial content	SPC/g	390000	60	0.082	4.92	700000	60	0.082	4.92	4500000	60	0.082	4.92
9.	Electrical conductance	mmho/cm	0.09	98	0.076	7.45	0.12	98	0.076	7.45	0.30	96	0.076	7.30
10.	Chloride	mg/L	1.5	80	0.075	6.00	1.2	82	0.075	6.15	2.3	70	0.075	5.25
11.	Total hardness	mg/L	32	64	0.070	4.48	28	62	0.070	4.34	44	66	0.070	4.62
12.	Bulk density	g/cm^3	1.27	94	0.069	6.49	1.38	94	0.069	6.49	1.12	92	0.069	6.35
	Total HSQI value					85.40				77.66				81.34

Table 7. Heber soil quality index of Karuppur, Thensarukkai and Erumaipatti

Sampling site			Karuppur				Thensarukkai				Erumaipatti			
Sample number			4				5				6			
Entry	Parameter	Unit	HSQI											
			Test result	Q value	Weighting factor	Total	Test result	Q value	Weighting factor	Total	Test Result	Q value	Weighting factor	Total
1.	Available nitrogen	kg/ha	280	65	0.095	6.18	245	54	0.095	5.13	197.5	30	0.095	2.85
2.	pH	-	7.8	96	0.095	9.12	7.3	99	0.095	9.41	7.7	96	0.095	9.12
3.	Water holding capacity	%	45.7	92	0.093	8.56	47.62	96	0.093	8.93	49.18	96	0.093	8.93
4.	Available phosphorus	kg/ha	78.25	60	0.090	5.40	125	60	0.090	5.40	86	60	0.090	5.40
5.	Texture	-	Silty clay loam	94	0.089	8.37	Silty clay loam	94	0.089	8.37	Silty clay loam	94	0.089	8.37
6.	Available potassium	kg/ha	687.5	60	0.087	5.22	437.5	78	0.087	6.79	150	64	0.087	5.57
7.	Organic matter	%	0.72	94	0.084	7.90	0.73	94	0.084	7.90	0.71	94	0.084	7.90
8.	Bacterial content	SPC/g	3600000	60	0.082	4.92	2900000	60	0.082	4.92	680000	60	0.082	4.92
9.	Electrical conductance	mmho/cm	0.04	98	0.076	7.45	0.05	98	0.076	7.45	0.05	98	0.076	7.45
10.	Chloride	mg/L	1.4	80	0.075	6.00	1.7	78	0.075	5.85	1.4	80	0.075	6.00
11.	Total hardness	mg/L	28	62	0.070	4.34	32	64	0.070	4.48	28	62	0.070	4.34
12.	Bulk density	g/cm^3	1.31	94	0.069	6.49	1.28	94	0.069	6.49	1.27	94	0.069	6.49
	Total HSQI value					79.93				81.10				77.32

Table 8. Heber soil quality index of Thattumalpadugai, Thaliyur and Srinivasapuram

Sampling site			Thattumalpadugai				Thaliyur				Srinivasapuram			
Sample number			7				8				9			
Entry	Parameter	Unit	HSQI											
			Test result	Q value	Weighting factor	Total	Test result	Q value	Weighting factor	Total	Test result	Q value	Weighting factor	Total
1.	Available nitrogen	kg/ha	210	36	0.095	3.42	280	65	0.095	6.18	280	65	0.095	6.18
2.	pH	-	7.8	96	0.095	9.12	7.9	92	0.095	8.74	7.4	98	0.095	9.31
3.	Water holding capacity	%	48.22	98	0.093	9.11	50.16	97	0.093	9.02	44.28	92	0.093	8.56
4.	Available phosphorus	kg/ha	47	66	0.090	5.94	70.25	60	0.090	5.40	78.25	60	0.090	5.40
5.	Texture	-	Silty clay loam	94	0.089	8.37	Silty clay loam	94	0.089	8.37	Silty clay loam	94	0.089	8.37
6.	Available potassium	kg/ha	125	60	0.087	5.22	125	60	0.087	5.22	550	60	0.087	5.22
7.	Organic matter	%	0.75	93	0.084	7.81	0.57	94	0.084	7.90	0.72	94	0.084	7.90
8.	Bacterial content	SPC/g	7200000	60	0.082	4.92	730000	60	0.082	4.92	2600000	60	0.082	4.92
9.	Electrical conductance	mmho/cm	0.04	98	0.076	7.45	0.04	98	0.076	7.45	0.12	98	0.076	7.45
10.	Chloride	mg/L	1.4	80	0.075	6.00	2.3	70	0.075	5.25	1.9	72	0.075	5.40
11.	Total hardness	mg/L	36	64	0.070	4.48	40	64	0.070	4.48	36	64	0.070	4.48
12.	Bulk density	g/cm^3	1.25	94	0.069	6.49	1.19	92	0.069	6.35	1.16	92	0.069	6.35
	Total HSQI value					78.33				79.26				79.52

Table 9. Heber soil quality index of veeranchery, papanasum and eachangudi

Sampling site			Veeranchery				Papanasum				Eachangudi			
Sample number			10				11				12			
Entry	Parameter	Unit	HSQI											
			Test result	Q value	Weighting factor	Total	Test result	Q value	Weighting factor	Total	Test Result	Q value	Weighting factor	Total
1.	Available nitrogen	kg/ha	175	26	0.095	2.47	245	54	0.095	5.13	175	26	0.095	2.47
2.	pH	-	7.7	96	0.095	9.12	7.7	96	0.095	9.12	80	90	0.095	8.55
3.	Water holding capacity	%	43.64	92	0.093	8.56	47.88	94	0.093	8.74	45.8	92	0.093	8.56
4.	Available phosphorus	kg/ha	101.5	60	0.090	5.40	78.25	60	0.090	5.40	138.75	60	0.090	5.40
5.	Texture	-	Silty clay loam	94	0.089	8.37	Silty clay loam	94	0.089	8.37	Silty clay loam	94	0.089	8.37
6.	Available potassium	kg/ha	212.5	86	0.087	7.48	250	90	0.087	7.83	362.5	93	0.087	8.09
7.	Organic matter	%	0.81	90	0.084	7.56	0.6	96	0.084	8.06	0.59	96	0.084	8.06
8.	Bacterial content	SPC/g	280000	60	0.082	4.92	2700000	60	0.082	4.92	7100000	60	0.082	4.92
9.	Electrical conductance	mmho/cm	0.15	98	0.076	7.45	0.07	98	0.076	7.45	0.05	98	0.076	7.45
10.	Chloride	mg/L	3.5	50	0.075	3.75	2.1	72	0.075	5.40	1.5	80	0.075	6.00
11.	Total hardness	mg/L	56	66	0.070	4.62	40	64	0.070	4.48	36	64	0.070	4.48
12.	Bulk density	g/cm^3	1.34	94	0.069	6.49	1.18	92	0.069	6.35	1.29	94	0.069	6.49
	Total HSQI value					76.18				81.25				78.83

Table 10. Heber soil quality index of Pasupathikoil, Perumalkoil and Kudikadu

	Sampling site		Pasupathikoil				Perumalkoil				Kudikadu			
	Sample number		13				14				15			
Entry	Parameter	Unit	HSQI											
			Test result	Q value	Weighting factor	Total	Test result	Q value	Weighting factor	Total	Test result	Q value	Weighting factor	Total
1.	Available nitrogen	kg/ha	105	20	0.095	1.90	280	65	0.095	6.18	210	38	0.095	3.61
2.	pH	-	6.8	99	0.095	9.41	8.1	89	0.095	8.46	7.9	95	0.095	9.03
3.	Water holding capacity	%	45.94	92	0.093	8.56	50.22	93	0.093	8.65	49.28	92	0.093	8.56
4.	Available phosphorus	kg/ha	109.5	60	0.090	5.40	39	90	0.090	8.10	47	66	0.090	5.94
5.	Texture	-	Silty clay loam	94	0.089	8.37	Silty clay loam	94	0.089	8.37	Silty clay loam	94	0.089	8.37
6.	Available potassium	kg/ha	225	86	0.087	7.48	200	80	0.087	6.96	300	95	0.087	8.27
7.	Organic matter	%	0.63	96	0.084	8.06	0.69	94	0.084	7.90	0.72	94	0.084	7.90
8.	Bacterial content	SPC/g	6300000	60	0.082	4.92	5800000	60	0.082	4.92	630000	60	0.082	4.92
9.	Electrical conductance	mmho/cm	0.05	98	0.076	7.45	0.04	98	0.076	7.45	0.05	98	0.076	7.45
10.	Chloride	mg/L	1.5	80	0.075	6.00	1.7	76	0.075	5.70	1.7	76	0.075	5.70
11.	Total hardness	mg/L	36	64	0.070	4.48	32	64	0.070	4.48	32	64	0.070	4.48
12.	Bulk density	g/cm^3	1.29	94	0.069	6.49	1.26	94	0.069	6.49	1.27	94	0.069	6.49
	Total HSQI value					78.51				83.64				80.69

4. CONCLUSIONS

The chief source of income for the farmers residing in Thanjavur and Thiruvarur district, India, depends on the cultivation of rice and sugarcane. Highly useful and newly formulated HSQI was exploited in this study to rate the soil samples collected from fifteen places of Thanjavur and Thiruvarur district as excellent, good or bad with special reference to rice and sugarcane cultivation. The total HSQI values of all the samples investigated in this study ranged from 76.18 – 85.40 which suggests that these soil samples of good quality. Soil quality index used to estimate the available nutrient status, reaction (acidic/alkaline) of a soil. It is also useful evaluate to the fertility status of soils of a country or a state or a district. It is well recognized as a sound scientific tool to assess the inherent power of the soil to supply plant nutrients. The benefits of these have been established through scientific research, extensive field demonstrations, and on the basis of actual fertilizer use by the farmers on soil test based fertilizer use recommendations. It also provides the necessary information needed to maintain the optimum fertility year after year. This soil quality index a time saving and economically convenient process.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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